Gabler Trisotti, Maria Fernanda (2025) *Effects of home-based resistance exercise programmes on muscle fitness, well-being, thoughts and perceptions of healthy adults.* PhD thesis.

https://theses.gla.ac.uk/85173/

Copyright and moral rights for this work are retained by the author

A copy can be downloaded for personal non-commercial research or study, without prior permission or charge

This work cannot be reproduced or quoted extensively from without first obtaining permission from the author

The content must not be changed in any way or sold commercially in any format or medium without the formal permission of the author

When referring to this work, full bibliographic details including the author, title, awarding institution and date of the thesis must be given

Enlighten: Theses
https://theses.gla.ac.uk/
research-enlighten@glasgow.ac.uk

Effects of home-based resistance exercise programmes on muscle fitness, well-being, thoughts and perceptions of healthy adults

Maria Fernanda Gabler Trisotti
MSc

Submitted in fulfilment of the requirements for the

Degree of Doctor of Philosophy

University of Glasgow

School of Cardiovascular and Medical Sciences

College of Medical, Veterinary & Life Sciences

University of Glasgow

July 2024

Abstract

Resistance or strength exercise produces several health benefits including an increase in muscle mass, muscle strength, improvements in body fat, metabolic rate, glycaemic control, blood pressure, blood lipid profile, flow-mediated dilatation and cardiorespiratory fitness. World and UK physical activity (PA) guidelines suggest performing at least two days a week muscle-strengthening activities involving major muscle groups. However, less than half of the UK and Scotland's adult population achieve the recommended guidelines. Different barriers towards strength exercise have been identified, such as lack of time, family constraints, not having the equipment, inadequate knowledge, and financial barriers, among others. Home-based resistance exercise programmes with a low time commitment that involve bodyweight exercises and resistance bands could be a solution to overcome the barriers and increase the number of people performing strength exercise. This thesis aimed to explore the effects of two home-based resistance exercise programmes on muscle strength, muscle endurance and thickness in healthy adults. Additionally, it aimed to explore participants' experiences, thoughts, tolerance and acceptability of the home-based resistance exercise programmes.

Firstly, twenty-six healthy adults (n=22 female, n=4 male) and underwent a 12-week intervention (ONE Study) (Chapter 2). Participants were randomised (1:1) to a control group (N=14, n=12 female, n=2 male) and a resistance exercise group (RE) (N=12, n=10 female, n=2 male). Participants in the CG were asked to keep their normal PA levels, while the RE group was asked to do a home-based resistance exercise programme of performing one minute of resistance exercise per day, for six days a week (one exercise per day with one day rest). Muscle strength, muscle endurance, body composition and anthropometry were measured at baseline, 4-week, 8-week and post-intervention. Muscle thickness was measured at baseline and post-intervention. No significant changes were found for muscle strength, muscle endurance, muscle thickness, anthropometry and fat mass. There was a significant Time*Group interaction in fat free mass (p=0.025), with a significant linear trend for the control group (p=0.009), experiencing a decrease in fat free mass of 1.11 kg between baseline and post-intervention. A subgroup of the RE group took part in qualitative semi-structured interviews (N=7). Thematic analysis and framework analysis were used. The

analysis generated 13 themes, including physical activity before the study, reasons for joining the study, instructions and learning, programme of daily life and planning, perceptions of the programme, self-monitoring, impact of the programme, motivators for physical activity, barriers and facilitators, health, suggestions for the programme, selling the programme and other. The main finding is that convenience, enjoyment, progression, a sense of achievement and receiving the benefits of the strength exercise were important for participants in order to do the exercise programme and continue to do it in the long term.

Secondly, seventy-five participants underwent 12-week online intervention (REFLEX Study) (Chapter 3). Participants were randomised (1:1) into a flexibility exercise group (N=36) and a RE group (N=39). Participants in the flexibility exercise group were asked to do at least one set of flexibility exercises per muscle group (six muscle groups in total) per week. Participants in the RE group were asked to do at least one set of resistance exercises per muscle group (six muscle groups in total) per week. All participants could choose to do up to three sets per muscle group. The intervention was delivered through a webapp. Muscle endurance (push-up test, half-squat test and plank test), flexibility (sit-and-reach test), well-being, self-esteem, vitality and energy, exercise motivation, adherence, volume and frequency of exercise were measured. No significant changes were found in muscle endurance and flexibility, well-being, self-esteem, vitality and energy and energy motivation outcomes. Only 57.9% of the RE group and 55.6% of the flexibility group completed 80% of the minimum amount of exercise prescribed. The RE group started the intervention with 7 sets per week (mean) but decreased to four sets by week 12. The flexibility group started the intervention by doing nine sets per week (mean) and also decreased to three sets by week 12. Many participants in both groups chose to do all of their exercises on one day per week. Finally, a subgroup of the REFLEX Study took part in qualitative interviews (RE group N=11;Flexibility group N=10). Similar results to the ONE Study were found in the REFLEX Study. Additionally, understanding instructions and being able to follow them emerged as essential for doing the exercises properly and self-monitoring. Participants also reported that competing priorities and external circumstances affect how they managed to fit the exercises into their everyday lives. Finally, personal and external accountability were major motivators to do the exercises during the programme.

This thesis showed that these two home-based resistance exercise programmes did not have a significant effect on muscle fitness, flexibility, anthropometry, fat mass, well-being, vitality and energy, self-esteem and exercise motivation regulation. However, they did have a significant effect on fat free mass. Finally, it showed that convenience, enjoyment, a sense of achievement, experiencing the effects of strength exercise, progression and variety of exercises are important to start doing resistance exercises and continuing to do them

Table of Contents

List of Tables

List of Figures

Acknowledgements

Firstly, I would like to thank ANID Chile for granting me a scholarship to be able to do a PhD at the University of Glasgow. I would also like to thank my supervisors Prof Jason Gill, Prof Stuart Gray and Prof Cindy Gray, for guiding and advising me through these past four and a half years. Thank you for supporting me during my maternity leave and for encouraging me to finish my PhD.

I want to give a special thanks to Megan McLoone, Ayan Merchant, Phil McBride, Marisa Nishio and Anthony Muchai for helping me collect data during my research projects, especially while I was away on maternity leave. Without you I would not have been able to finish my PhD.

I also want to thank Fanny Pertermann, Rosie Brown, Lyn Ferguson and Ayan Merchant for your friendship and support during these years. My PhD journey was much more happier and fun with you all.

I want to thank my family in Chile for supporting me during this time. Thank you for encouraging me to keep working hard and for always being at the other side of the line when I need you. I want to especially thank my mum, for encouraging me to study abroad, without that I would not be where I am now.

I want to thank Prof Marcelo Cano and Prof Allan White from the University of Chile. Thank you for your encouragement, advice, the good times in the lab and all the support and help that you gave to apply for scholarships and to study abroad.

I want to thank my wonderful husband, Robert. Thank you for your support and love these past four years, you have been an absolute star. Thank you for helping me record the exercise videos. I want to thank my beautiful daughter, Mia. Thank you, for coming to me and for being your mummy. Even though this time has been hard, it has been the time that I have been most happy. Finally, I want to thank God for being my strength and my refuge.

Author's Declaration

I declare that, except where explicit reference is made to the contribution of others, this dissertation is the result of my own work. The contents of this thesis have not been submitted for any other degree at the University of Glasgow or any other institution.

María Fernanda Gabler Trisotti

July 2024

Abbreviations

1-RM	One maximal repetition
5-RM	Five maximal repetition
ACSM	American College of Sport Medicine
ASIS	Anterior superior iliac spine
BMI	Body mass index
BREQ-2	Adapted Behavioural Regulations in Exercise Questionnaire
COVID	Coronavirus disease
CVD	Cardiovascular disease
DM2	Type 2 diabetes mellitus
DXA	Dual-energy x-ray absorptiometry
EQ-VAS	EQ Visual Analogue Scale
FLEX	Flexibility
IDVL	Individual difference level version
IPAQ	International physical activity questionnaire
IPAQ-SF	International physical activity questionnaire (Short Form)
ME	Muscle endurance
MT	Muscle thickness

PA	Physical activity
PAR-Q+	Physical activity readiness questionnaire
RCT	Randomised controlled trial
RE	Resistance exercise
REPS	Repetitions
ROM	Range of Motion
SD	Standard deviation
SEM	Standard error of the mean
SLV	State-level version
TC	Thigh circumference
VL	Vastus lateralis
WC	Waist Circumference
WEMWBS	Warwick-Edinburgh Mental Wellbeing Scale
WHO	World Health Organization

General definitions

This section consists of general definitions of specific terms found in this thesis. This consists in:

Physical activity: is defined as "any bodily movement produced by skeletal muscles that requires energy expenditure", involving movements during leisure time, transporting from one place to another including commuting (Caspersen et al., 1985, WHO, 2022b).

Physical inactivity: is defined as not doing enough physical activity and therefore not meeting the current physical activity guidelines (WHO, 2022b).

Sedentary behaviour: is the behaviour while being awake with an energy expenditure of 1.5 Metabolic Equivalent of Task (MET) or lower, for example sitting, lying, reclining, driving a car, or watching television (WHO, 2022b).

Physical fitness: "A set of attributes that can be measured with specific tests" (Caspersen et al., 1985). The health-related and skill-related components of physical fitness can be seen in Table 1.

Table 1. Physical fitness components.

	Component	Definition
Health related physical fitness components	Cardiorespiratory endurance	The ability of the respiratory and circulatory systems to provide oxygen during constant physical activity.
	Body Composition	Relative amounts of bone, fat, muscle and other vital body parts.
	Muscular Strength	Ability of the muscle to produce force.
	Muscular endurance	Ability of the muscle to keep performing without fatigue.
	Flexibility	The range of motion (ROM) in a particular joint.
Skill related physical fitness components	Agility	Ability to change the position of the entire body quickly, with accuracy and speed.
	Coordination	Ability to use senses and body parts to perform movements accurately and smoothly.
	Balance	Control equilibrium during movement or static.
	Power	Ability to perform work.

	Reaction time	The time between a stimulus and the reaction to it.
	Speed	Ability to perform a movement in a short period of time.

Adapted from (Caspersen et al., 1985).

Exercise: A type of PA that is planned, repetitive, has a structure, and has the objective to maintain or improve one or more components of physical fitness (Caspersen et al., 1985). The components of physical fitness are related to how well a person performs physical activity (McArdle et al., 2015). Additionally, there are different categories of exercise, such as aerobic exercise, resistance/strength exercise, flexibility exercise and balance exercise.

Body composition: It is the study of the components and relative proportions of the body and the clinical values of these, such as fat mass and fat-free mass. Different methods are used to assess body composition, such as magnetic resonance imaging (MRI), computed tomography (CT), dual energy x-ray absorptiometry (DXA), hydrostatic (underwater) weighing, plethysmography, anthropometry (skinfold measurements and circumference measurements) and bioelectrical impedance analysis (BIA) (ACSM, 2016).

Cardiovascular fitness (CRF): is the ability to perform dynamic exercise, of moderate to vigorous intensity with large muscles for long periods of time. This depends on the coordination of the musculoskeletal, muscular and cardiovascular systems (ACSM, 2016).

Muscle fitness: is composed of muscle strength muscle endurance and power. Muscle strength is defined by the ACSM as the force that can be generated by a muscle group or a specific muscle. Muscle endurance is the ability of the specific muscle or muscle group to perform a repeated contraction over a period of time (ACSM, 2016).

Flexibility fitness: It is defined as the ability to be able to move a joint through its complete range of movement (ROM). It depends on muscle viscosity, distensibility of the joint capsule, ligaments, tendons and an appropriate warm-up (ACSM, 2016).

Concentric action: "Muscle shortening during force application" (McArdle et al., 2015).

Eccentric action: "Muscle lengthening when there is force application" (McArdle et al., 2015).

Isokinetic action: "Muscle action performed with a constant angular limb velocity" (McArdle et al., 2015).

Isometric action: "Muscle action with no noticeable change in the muscle length" (McArdle et al., 2015) .

Repetition: "One complete exercise movement, usually consisting of a concentric and an eccentric action or a complete isometric muscle action" (McArdle et al., 2015).

Set: "Preestablished number of repetitions performed" (McArdle et al., 2015).

Training volume: "Total work performed in a single training session" (McArdle et al., 2015).

Chapter 1 Introduction

1.1 The role of physical activity in health and disease

1.1.1 Physical activity guidelines, historical studies and epidemiological studies.

Research on the relationship between health and physical activity starts more or less in the second half of the 20th century. The American College Sports Medicine (ACSM) starts by providing a specific exercise recommendation, which undergoes several revisions in the later years. The 1990 ACSM revision started to consider physical activity for performance and health. Then in 1995 the ACSM recommended people to do 30 minutes or more of moderate-intensity physical activity each day to reduce non-communicable diseases (Blair et al., 2004). Later on, in the early 2000s the guidelines started to recommend 150-300 min/week of moderate-intensity or vigorous intensity, respectively, of aerobic physical activity to reduce non-communicable disease and improve quality of life (Troiano et al., 2020). The benefits of aerobic exercise have been well described in the literature, by improving metabolic health (Sigal et al., 2014), lower all cause mortality, coronary heart disease and cardiovascular disease events (Kodama, 2009), with in others. It has been later shown that doing resistance exercise alongside aerobic exercise provides a greater benefit, such as lower all cause mortality and lower cardiovascular mortality (Saeidifard et al., 2019), lower percentage of body fat, increase of lean mass and body mass index (Sigal et al., 2014) and glucose control (Church et al., 2010). Later muscle strengthening activities were included in the physical activity guidelines for the first time, and it was recommended to do at least 2 sessions a week (Strain et al., 2016). This is how the physical activity guidelines have changed throughout time leading to the current physical activity guidelines.

The final revision of the physical activity guidelines happened between 2018 and 2020 (Troiano et al., 2020). The current World Health Organisation (WHO) physical activity guidelines state that adults (18-64 years old) should do at least 150-300 minutes of moderate-intensity or 75 minutes of vigorous aerobic physical activity per week, do muscle-strengthening activities two days a week or more and to reduce sedentary time. In addition, adults should increase the

amount of physical activity to gain more health benefits and all adults should aim to do more than the recommended levels to help reduce the negative effects of sedentary behaviour (WHO, 2022b). The British physical activity guidelines state that adults (19-64 years old) should do at least 150 minutes of moderate-intensity or 75 of vigorous-intensity aerobic physical activity, do strengthening activities using all major muscle groups at least two days a week, spread the exercise over 4 to 5 days a week and to reduce sedentary time and breaking long periods of not moving (NHS, 2021). These guidelines are not specific and lack detail (especially regarding the prescription of resistance exercise) because they are meant for the general public,. The prescription of aerobic exercise is simple and easy, while the prescription of resistance exercise is more challenging due to its nature. However, the ACSM guidelines are more specific, they recommend doing moderate intensity aerobic exercise at least five days a week or vigorous intensity at least three days a week. Additionally, it recommends training each major muscle group two or three days a week with at least 48 hrs in between sessions, between 2-4 sets and 8-12 repetitions per set with 2-3 min rest intervals for improving muscular fitness (ACSM, 2016).

The last WHO Physical Activity report highlighted that 27.5% of adults do not meet the current physical activity guidelines, with big differences between sexes, countries, age groups and regions (WHO, 2022b). These differences can be seen in Figure 1. It shows that the regions of the Americas and Eastern Mediterranean have the highest prevalence of adults not meeting the WHO physical activity guidelines.

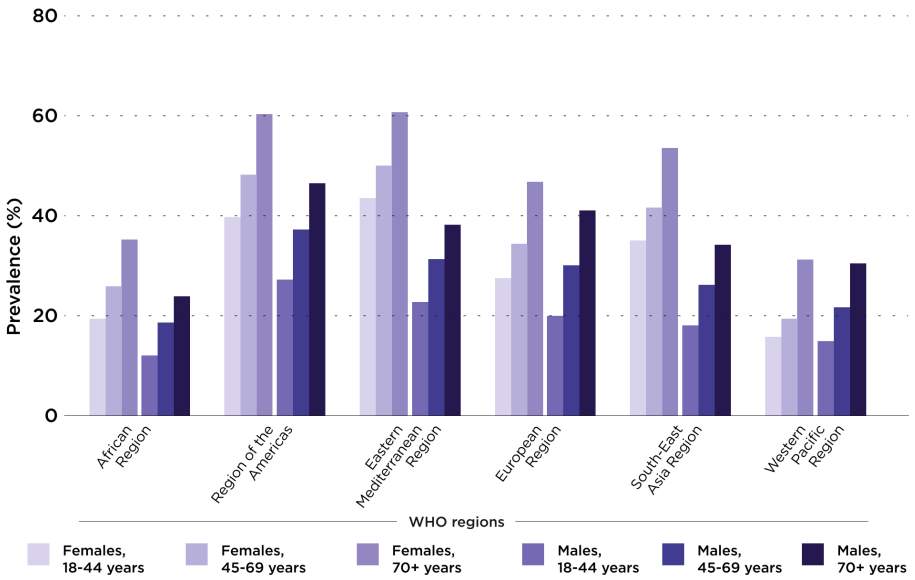


Figure 1. Prevalence of adults aged 18+ years not meeting WHO physical activity guidelines, by WHO region, 2010-2016. From "Global status report on Physical Activity 2022" (WHO, 2022b).

In 2021 64% of adults (16 years old or over) met the aerobic physical activity guidelines: 70% of men and 59% of women (Figure 2) (NHS Digital, 2023). Additionally, 32% of adults met the guideline for muscle-strengthening activities: 36% of men and 29% of women. If we consider the compliance to aerobic and muscle-strengthening activities together, only 30% of adults meet both guidelines: 34% of men and 27% of women (NHS Digital, 2023) (Figure 3).

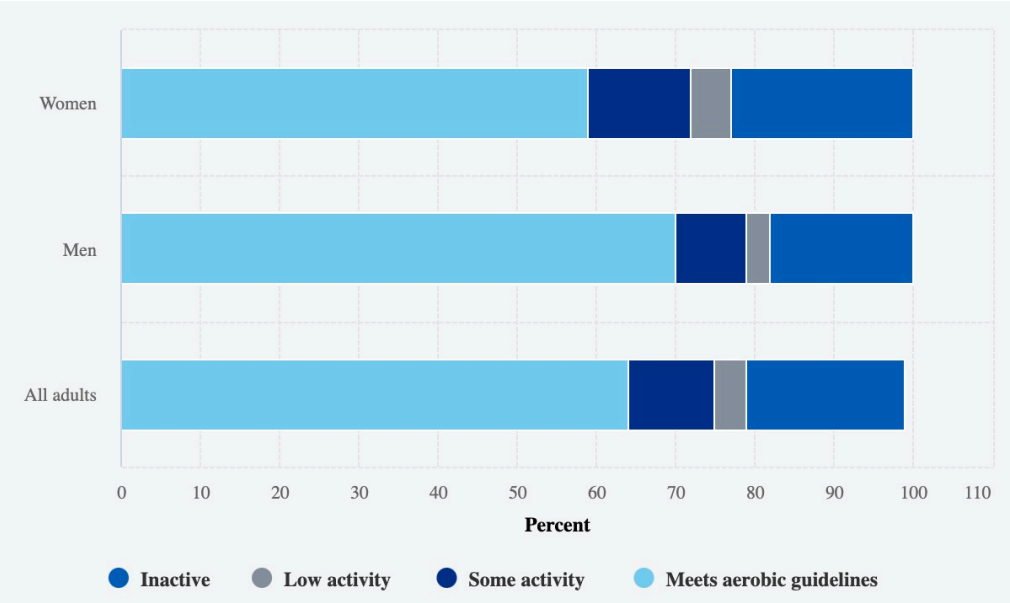


Figure 2. Summary of activity levels, by sex for aerobic activity. From "Health Survey for England, 2021 part 2" (NHS Digital, 2023).

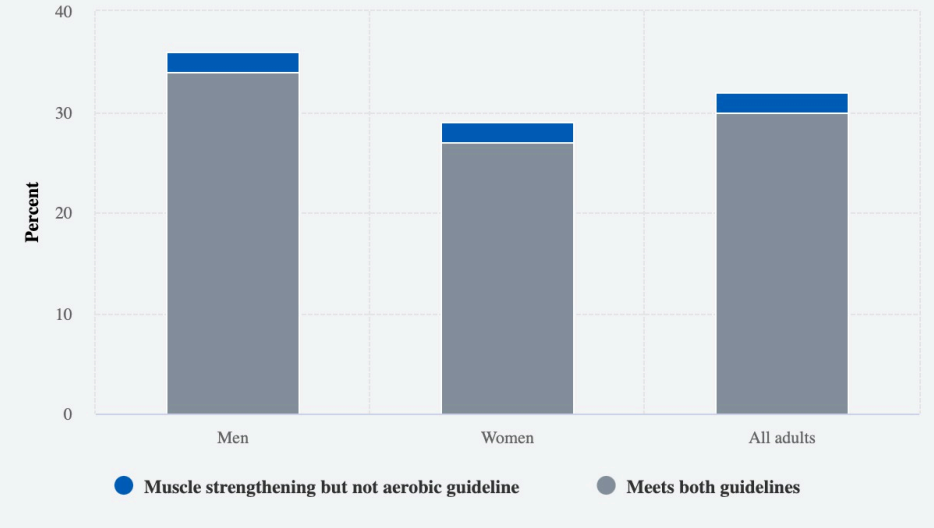


Figure 3. Proportion meeting aerobic and muscle strengthening guidelines, by sex. From "Health Survey for England, 2021 part 2" (NHS Digital, 2023).

In Scotland, 69% of adults (16 years old or over) met guidelines for moderate or vigorous physical activity (MVPA), with 73% of men and 65% of women (Birtwistle et al., 2021). Adherence over the years has been slightly improving, and it can be seen in Figure 4.

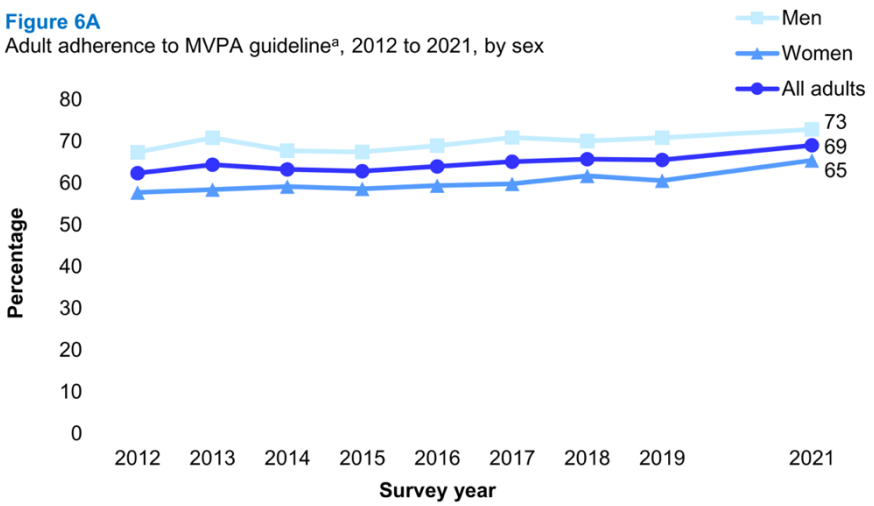


Figure 4. Adult Adherence to MVPA guideline, 2012 to 2021, by sex. From "The Scottish health survey 2021: A national statistics publication of Scotland" (Birtwistle et al., 2021)

In addition, 35% of adults complied with the MVPA and strengthening activities guidelines, with 38% of men and 32% of women in 2021. The proportion of people meeting both guidelines decreased as age increased (Figure 5) (Birtwistle et al., 2021).

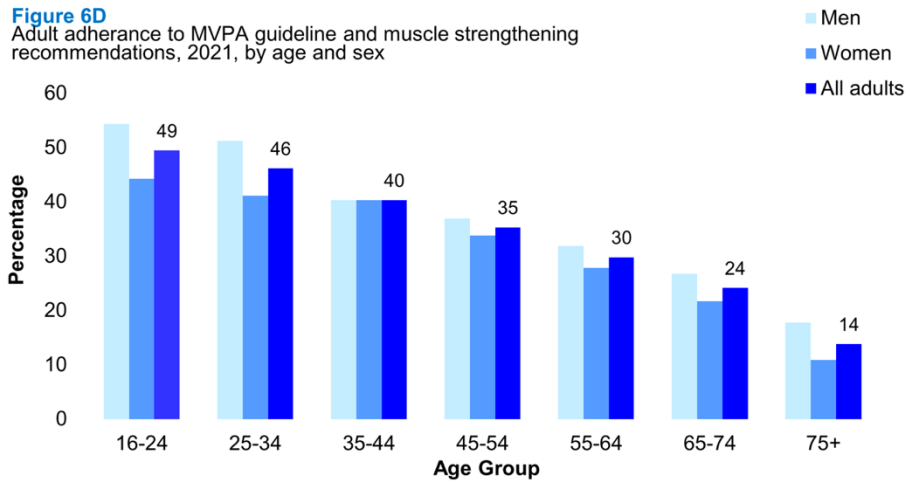


Figure 5. Adult Adherence to MVPA and muscle strengthening recommendations, 2021, by age and sex. From "The Scottish health survey 2021: A national statistics publication of Scotland" (Birtwistle et al., 2021).

Overall, we can say that across the general population people tend to do less resistance exercise. Also, women do less physical activity than men, for aerobic and resistance exercise, and older people do less physical activity (aerobic and resistance exercise) than younger people.

1.1.2 The benefits of physical activity

A recent study showed that between 2018 and 2020, 7.2% of all-cause and 7.6% of cardiovascular disease deaths were attributable to physical inactivity. Additionally, 1.6% of cases of hypertension and 8.1% of cases of dementia were attributable to physical inactivity. It showed a higher "semiadjusted population attributable risk (PAR_{semi})" for all-cause mortality for higher-income countries (9.3 (7.2 to 11.6)) (PAR_{semi} (95% CI)) compared to middle-income (6.8 (5.0 to 8.7)) and low-income (4.3 (3.3 to 5.5)) countries. Even though the relative burden of physical inactivity is higher in high-income countries, there is a higher absolute burden in middle-income countries due to having larger population numbers (Katzmarzyk et al., 2022).

A meta-analysis by Ekelund et al. (2016) used a harmonised approach to compare mortality between people with different levels of physical activity and different levels of sitting time. It showed that there is a dose-response relationship between sitting time combined with low levels of physical activity and all-cause mortality risk. People in the lowest quartile of physical activity (<2.5 MET

h/week) and with the highest sitting time (>8 h/day) had 59% higher mortality during follow-up than the reference group (most active quartile (35.5 MET h/week) and with the lowest sitting time (<4 h/day)). Additionally, people in the most active quartile, but with the highest sitting time had significantly lower mortality risk (HR 1.04, 95% CI 0.99–1.10) than the least active with the lowest sitting time (HR 1.27, 1.22–1.30) ($p<0.0001$). Finally, in the most active group, there was no significant relationship between sitting time and mortality rates. The author suggested that the increased mortality risk associated with sedentary time was eliminated by high levels of moderate physical activity levels (between 60-75 min per day) (Ekelund et al., 2016).

The WHO states that the economic burden of physical inactivity is large. It estimates that globally between 2020-2030 around US$27 billion annually will be expended in treatments of preventable non-communicable diseases if there is no change to the prevalence of physical inactivity. The largest cost will be among high-income countries, accounting 70% of expenditure on treatments due to physical inactivity (WHO, 2022b).

Therefore, it is most important to find new ways to increase the number of people doing physical activity and to do the minimum amount of physical activity recommended by the physical activity guidelines.

1.2 Resistance exercise and training

The American College of Sports Medicine (ACSM) defines resistance or strength exercise as an exercise that improves muscular fitness (strength, endurance and power), such as machines with stacked weights or pneumatic resistance, free weights, resistance bands (ACSM, 2016), isometric exercises, isokinetic exercises, plyometric exercises and body weight exercises (McArdle et al., 2015). Additionally, resistance exercises can be multi-joint (e.g., push-ups, leg press and deadlifts), single-joint (e.g., triceps extension, quadriceps extension and calf raise) or core exercises (e.g., plank and bridges). They should target agonist and antagonist muscle groups to avoid imbalances, and perform with the correct technique and form, which involves moving through the full range of motion (ROM) of the joint, performing the repetitions deliberately in a controlled manner and using an appropriate breathing technique (ACSM, 2016).

1.2.1 Acute responses to resistance exercise

The main acute response to acute exercise performance is done by the neuroendocrine system (Kraemer and Ratamess, 2005). The main hormones involved in the response to acute resistance exercise are explained below:

a) Testosterone

A review by Kraemer et al. (2005) has found that testosterone levels influenced by acute resistance exercise. Testosterone levels generally acutely increase in men, while in women it has been shown to stay the same or have an elevation after resistance exercise. In young women, it has been seen an acute increase, while in middle-aged and elderly women there has been no change. Additionally, the review found that the magnitude of change is influenced by the nutritional intake, the individual's absolute level of muscular strength, muscle mass involved, intensity, volume and training experience. Large muscle mass exercises , higher volumes (number of sets) and higher intensity (higher loads) produce higher levels of testosterone, while carbohydrate/protein supplementation tends to limit testosterone response (Kraemer and Ratamess, 2005).

b) Growth hormone (GH) super family

The most common molecule of the GH family is the 22kD molecule which has been the most studied in relation to resistance exercise. Resistance exercise has been shown to increase in men and women human GH through 30 minutes post-exercise. The magnitude of the increase depends on training status, intensity, volume, rest intervals, exercise selection, muscle mass recruited and muscle actions. Higher volume, moderate to high intensity, short intervals and large muscle mass produce a higher GH hormone response. Additionally, in older people have a limited acute GH response. Finally, it has been seen that exercise specificity (concentric vs excentric) may affect acute GH levels (Kraemer and Ratamess, 2005)

c) Cortisol

It has been shown that resistance exercise produces an acute response of cortisol and adrenocorticotropic hormone (ACTH, stimulates release of cortisol), similarly in men and women. Resistance exercise programmes that are metabolically demanding, with high volume, moderate to high intensity and short rest intervals, produce higher cortisol and lactate levels (Kraemer and Ratamess, 2005).

d) Insulin-like Growth Factors (IGFs)

IGFs are polypeptide hormones produced by the liver, that are structurally related to insulin and mediate several actions of GH. They stimulate hypertrophy due to increasing protein synthesis. It is not clear the acute response of IGFs to resistance exercise. Some studies have shown an increase during and after resistance exercise, while most studies have shown no change (Kraemer and Ratamess, 2005).

e) Catecholamines

It has been shown an increase in plasma levels of norepinephrine, epinephrine and dopamine due to acute resistance exercise. The magnitude of this increase may be dependent on volume, rest intervals, amount of muscle stimulated and muscle contraction (Kraemer and Ratamess, 2005)

1.2.2 Responses to resistance exercise training

Previous research has demonstrated that resistance exercise impacts body composition (Bacchi et al., 2012, Strasser et al., 2012, Phillips and Winett, 2013, Sigal et al., 2014, Wewege et al., 2022), metabolism, blood pressure (Kraemer et al., 2002, Ashton et al., 2020), muscle mass, muscle strength and muscle endurance (McLeod et al., 2023). More details of the effects of resistance exercise are explained below:

a) Anthropometry and body composition

Overall the literature shows that resistance exercise has a positive impact in body composition (Bacchi et al., 2012, Phillips and Winett, 2013, Wewege et al.,

2022, Lopez et al., 2022). A randomized control trial in type 2 diabetic adults, showed a significant reduction in body mass, total body fat, trunk fat and waist circumference in a resistance exercise group after a 4-month intervention (Bacchi et al., 2012). Resistance exercise increases muscle mass in the young and elderly and reduces body fat mass and visceral fat mass (Phillips and Winett, 2013). A recent systematic review and meta-analysis by Wewege et al. (2022) including 58 studies, showed that resistance exercise (mean length of 20.5 weeks (6-104 weeks); mean frequency of 2.7 sessions per week (1-4 per week); mean number of exercises per session 8.1 (4-15 per session); mean 2.6 sets per session (1-5 sets per session)) produces a significant reduction of 1.4% body fat percentage (95% CI − 1.78 to − 1.14, $p < 0.0001$), with changes being significantly larger in non-scan (hydro-densitometry, whole-body air plethysmography) than scan (DXA, MRI, CT) subgroups (between-subgroup difference = 1.4% [95% CI 2.0–0.8], $p < 0.0001$). Additionally, it showed that resistance training significantly reduces body fat mass by 0.55kg (95% CI − 0.75 to − 0.34, $p < 0.0001$). Similarly to percentage of body fat, the non-scan subgroup had significantly bigger reductions in body fat mass compared to the scan subgroup (between subgroup difference = 1.15 kg [95% CI 0.29–2.0], $p = 0.009$). Resistance exercise significantly reduced visceral fat by a standardised mean difference of −0.49 (95% CI −0.87 to −0.11, $p = 0.011$) (Wewege et al., 2022). Another systematic review and meta-analysis by Lopez et al (2022) in overweight and obese people across the lifespan found that resistance exercise (14.6 ± 11.0 weeks (4 to 96 weeks), frequency 1 to 5 sessions per week, volume of 20 to 165 sets per week, an intensity from 20-97% 1-RM) significantly reduced body fat percentage (N=89 studies, ES=-2.2%, 95%CI: -2.4to -2%), whole-body fat mass (N=52 studies, ES = -1.6 kg, 95% CI: -1.9 to -1.3 kg), visceral adipose tissue (N=13 studies, ES = -0.4 SMD, 95% CI: -0.5 to -0.2) and subcutaneous adipose tissue (N=9, ES = -0.4 SMD, 95% CI: -0.5 to -0.2), body mass (N=93 studies, ES = -1.6 kg, 95% CI: -1.9 to -1.3 kg) and BMI (N=74 studies, ES = -0.6 $kg*m^2$, 95% CI: -0.7 to -0.5 $kg*m^2$) (Lopez et al., 2022).

b) Blood pressure effect

For blood pressure, there is also a mix of results of the effects of resistance exercise. Some studies show no improvements in blood pressure (Sigal et al.,

2007), while others have shown improvements in systolic and diastolic blood pressure (Bacchi et al., 2012, Ashton et al., 2020, Phillips and Winett, 2013).

A study in type 2 diabetic adults showed that a 22-week resistance exercise programme (3 sessions per week, 2-3 sets per session per exercise, 7 exercises on weight machines, 7-9 reps) was not significantly different from the control group (p=0.71) (Sigal et al., 2007). A review from Phillips & Winett et al. (2013) reported that the reductions in systolic blood pressure with resistance exercise are similar to the ones obtained with aerobic exercise, and also similar in magnitude to the reductions induced pharmacology (Phillips and Winett, 2013). A most recent systematic review and meta-analysis by Ashton et al. (2020) looked at the short-term (≤ 6 weeks), medium-term (7-23 weeks) and long-term (≥ 24 weeks) of resistance exercise on cardiometabolic health. It included 173 trials with 6169 participants (N control = 2840; N RE = 3329), using mainly weight machines and supervised. It found that medium-term resistance exercise reduced systolic blood pressure (−4.02 (95% CI −5.92 to −2.11) mm Hg, p<0.0001 and diastolic blood pressure (−1.73 (−2.88 to −0.57) mm Hg, p=0.003 and versus control. Additionally, long-term resistance exercise reduced systolic blood pressure by −5.08 (−10.04 to −0.13) mm Hg, p=0.04; and diastolic blood pressure by −4.93 (−8.58 to −1.28) mm Hg, p=0.008 (Ashton et al., 2020).

c) Metabolism

Glycaemic control

It has been shown that resistance exercise improves glycaemic control (Kraemer et al., 2002, Ashton et al., 2020), in particular HbA_{1c} (Sigal et al., 2007, Bacchi et al., 2012, Lee et al., 2017), insulin sensitivity (Kraemer et al., 2002, Bacchi et al., 2012, Di Meo et al., 2017a), fasted insulin and fasted glucose (Ashton et al., 2020). Resistance exercise also increases GLUT4 protein concentration in the skeletal muscle and stimulates the synthesis of glycogen (Di Meo et al., 2017a).

Lipid profile

There is mixed evidence for the effect of resistance exercise on lipid profile. Improvements in triglycerides (TG) and HDL cholesterol levels have been

demonstrated in some studies (Bacchi et al., 2012). A study in type 2 diabetics showed that a 4-month resistance exercise programme (3 sessions per week, 60 min supervised sessions, weight machine and free weight exercises, nine exercises, 30-50% 1-RM to 70-80% 1-RM load) did not statistically differ from the aerobic exercise group, but were significantly different compared to baseline for triglycerides, total cholesterol, and HDL cholesterol (Bacchi et al., 2012). Others have failed to show and significant changes in TG, HDL cholesterol, LDL cholesterol and total cholesterol (TC) (Sigal et al., 2007, Ashton et al., 2020). The systematic review and meta-analysis by Ashton et al (2020) (mentioned in the section above) showed no significant effects of short-term, medium term and long term of resistance exercise for triglycerides, HDL cholesterol, LDL cholesterol and total cholesterol (Ashton et al., 2020).

d) Mortality and non-communicable disease risk

A recent systematic review and meta-analysis looked at the risk of mortality and non-communicable diseases (NCDs), such as cardiovascular disease (CVD) and cancer, and muscle-strengthening activities in adults. It included 16 studies in the analysis, with a maximum follow-up of 25.2 years, including men and women from 18 to 97.8 years old. The results showed that muscle-strengthening activities were significantly associated with a 15% lower risk of all-cause mortality (RR 0.85; 95% CI 0.79 to 0.93; $p<0.001$), with a non-linear association and the lowest relative risk (RR) at 40 min per week (RR 0.83; 95% CI 0.79 to 0.86). Additionally, muscle-strengthening exercises were significantly associated with 17% lower CVD risk (RR 0.83; 95% CI 0.73 to 0.93; $p=0.002$), and had a non-linear association for CDV risk, with the lowest risk found at 60 min per week (RR 0.82; 95% CI 0.76 to 0.90). Finally, it found that muscle-strengthening activities were significantly associated with a 12% lower risk of total cancer (RR 0.88; 95% CI 0.80 to 0.97; $p=0.008$), with a non-linear association and the lowest risk observed at 30 min per week (RR 0.91; 95% CI 0.85 to 0.97 (Momma et al., 2022).

a) Muscle mass, strength and endurance

Physiology

Resistance or strength exercise increases muscle size, primarily by increasing the size of the muscle fibres (muscle cells), a process called hypertrophy. This happens due to a net positive myofibrillar protein balance. The principal pathway for muscle hypertrophy is the insulin-like growth factor 1 (IGF-1)/ phosphatidylinositol-3-kinase (PI3K)/protein kinase B (PKB) also called Akt (Di Meo et al., 2017b). When IGF-1 binds to its receptor an intracellular signal is generated, which leads to autophosphorylation and generation of docking site for PI3K, which is activated. After this, PI3K uses phosphoinositide-4,5-biphosphate (PIP2) to generate phosphoinositide-3,4,5-triphosphate (PIP3). PIP3 then is a docking site for phosphoinositide-dependent kinase 1 (PDK1) and Akt. Akt is phosphorylated by PDK1 and is activated. Then Akt phosphorylates the factors of the FoxO family inhibiting protein degradation. Akt also indirectly stimulates protein synthesis via the mammalian target of rapamycin (mTOR) signalling (Schiaffino and Mammucari, 2011). The mTOR is formed by two multiprotein complexes, mTOR complex 1 (mTORC1) and mTOR complex 2 (mTORC2) (Toschi et al., 2009). The mTORC1 phosphorylates S6 kinase (S6K), which creates signals for protein synthesis (Schiaffino and Mammucari, 2011). A simplified version of this process can be seen in Figure 6.

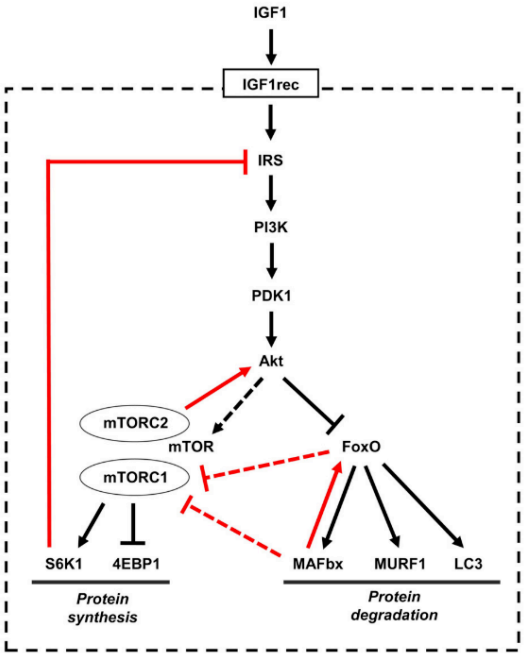


Figure 6. Insulin-like growth factor 1 (IGF-1)-Akt pathway controls muscle growth via the mammalian target of rapamycin (mTOR) and FoxO. From (Schiaffino and Mammucari, 2011).

Volume of exercise

The volume of resistance exercise is most commonly expressed as the number of sets or the number of repetitions, but it can also be expressed as volume load (sets x repetitions x load) (Nunes et al., 2021) and it has been considered as the variable that is the most easily modified (Figueiredo et al., 2018). Overall, it has been shown that volume has an effect on muscle hypertrophy favouring a higher amount of sets (McLeod et al., 2023). A study comparing the effects of one set, three sets and five sets found that one set did not have significant changes in muscle thickness, while three sets and five sets did significantly change muscle thickness after the intervention and were significantly different to one set and the control group (Radaelli et al., 2015). Another study, comparing one, three and five sets, found that five sets had a significant increase in muscle thickness compared to one set, but it did not find any differences between three and five sets (Schoenfeld et al., 2018). Finally, a systematic review and meta-analysis by Schoenfeld et al. found that there was a significant effect of weekly sets (continuous variable) on muscle size with an increase in percentage gain by 0.37% for each additional set. Additionally, it found that higher volume (9 sets or more x muscle group x week) produced a significant effect on muscle size compared to lower volume (less than 9 sets x muscle group x week) within each study (Schoenfeld et al., 2017b).

Volume is known to influence muscle strength gains (Ralston et al., 2017, McLeod et al., 2023). A meta-analysis found that high weekly set (10 sets or more) had a significantly greater effect on strength gains compared to low weekly set (five sets or less) in combined isolation and multi-joined exercises (mean effect size (ES) 0.18; 95% CI 0.06–0.30; p = 0.003). The same analysis comparing low weekly sets (five sets or less) and medium weekly sets (between five and nine sets), found that there was a slightly higher gain in muscle strength with medium weekly sets compared to low weekly sets (ES 0.15; 95% CI 0.01–0.30; p = 0.04). Additionally, when effects on 1-RM was analysed it was found that high weekly sets had a slightly greater effect with high weekly sets compared to low weekly sets (ES 0.14; 95% CI -0.01 to 0.29; p = 0.06) (Ralston et al., 2017). Another review found similar results (McLeod et al., 2023).

A randomised controlled trial found that after a 6-month intervention, one set per week of resistance exercise did not produce significant changes in muscle endurance for bench press, while three and five sets per week did significantly increased muscle endurance compared with one set, and compared to the control group. It also found that five sets per week had a significantly greater increase in muscle endurance for bench press compared to three sets per week. On the other hand, all exercise groups (one set, three sets and five sets) significantly increased muscle endurance for leg press compared with the control group. Five sets had a significantly greater effect on muscle endurance for leg press (Radaelli et al., 2015).

Frequency of exercise

There are mixed results about the effect of frequency of resistance training per week in the literature. Two studies comparing 3 times per week versus 1 time per week (volume equated) found a similar increase in muscle mass with no significant differences between groups (Thomas and Burns, 2016, Neves et al., 2022). Other studies have different results. A study by Gentil et al. found that one time a week produced a significant increase of 3% in muscle thickness, while two times a week did not produce any significant changes (Gentil et al., 2018). Another study found that three times a week produced a significant increase in muscle thickness, while six times a week did not and any significant changes with both groups having the same volume per week (Saric et al., 2018).

A systematic review by Schoenfeld et al. (2016) analysed seven studies with 200 subjects and found a significant effect of frequency in muscle hypertrophy. The results showed that when the volume is equated, higher frequencies (mean ES 0.49 ± 0.08 (95 % CI)) have a significantly greater effect on muscle hypertrophy compared to lower frequencies (mean ES 0.30 ± 0.07 (95 % CI 0.12–0.47)) ($P = 0.002$) (Schoenfeld et al., 2016). However, a review by Grgic et al. (2019) including 21 studies (2472; 1772 females and 700 males), found that resistance training frequency does not have an effect on muscle mass gain when volume is equated and that muscle hypertrophy is more influenced by volume than frequency (Grgic et al., 2019). The difference in the findings can be due to the number of studies included and the number of participants in each analysis.

A systematic review and meta-analysis found that there was a significant effect of frequency on muscle strength gains (1-RM, multi-joint and single joint exercises, isometric and isokinetic strength), with the ESS (ES ± standard error of the mean) gradually increasing with each extra training day per week: one day 0.74 ± 0.13, 0.48–1.01 95% CI; two days 0.82 ± 0.13, 0.55–1.09 95% CI; three days 0.93 ± 0.13, 0.65–1.21 95% CI; four days and more 1.08 ± 0.16, 0.74–1.42 95% CI; p = 0.003). However, when the volume was equated there was no significant effect of training frequency on strength (p = 0.421) (Grgic et al., 2018a). Another systematic review and meta-analysis found that there was a slightly bigger effect with high frequency compared to low frequency in strength gain, but it was not significant (ES difference 0.07;p = 0.25). Similarly to the previous meta-analysis, it also found no significant effect of frequency when the volume of exercise was equated (p = 0.78) (Ralston et al., 2018).

Another study comparing the effect of frequency in muscle endurance, found that three days a week and 6 days a week with equated volume did not have significant effects on lower-body and upper-body muscle endurance (Saric et al., 2018).

Load of the exercise

Several studies have shown that load does not affect muscle hypertrophy (Fisher et al., 2013, Schoenfeld et al., 2015b, Schoenfeld et al., 2017a, Schoenfeld et al., 2021, McLeod et al., 2023). Fisher et al. (2013) showed that there is no difference between low and high load when the training is performed to failure (Fisher et al., 2013). Similar results were found in a systematic review and meta-analysis, concluding that the effect of heavy and light loads can be similar when the exercise is performed with a high level of effort (Schoenfeld et al., 2017a). Additionally, another more recent review by the same author found similar muscle growth with loads of 30% 1-RM or more independent of age and training status (Schoenfeld et al., 2021). Finally, a review by McLeod et al. also concluded that the hypertrophy effect was independent of resistance training load (McLeod et al., 2023).

Overall, there is plenty of evidence in the literature that higher loads have a greater effect on muscle strength compared to lower loads (Schoenfeld et al.,

2017a, Schoenfeld et al., 2021, Carvalho et al., 2022, McLeod et al., 2023). A systematic review and meta-analysis found that there was a significant difference between low (60% 1-RM or less) and high loads (over 60% 1-RM), with high load having greater mean ES and percentage gain (difference = -0.37 ± 0.10; CI -0.59 to –0.16; p = 0.003). Additionally, it did not find any significant differences between high and low load for isometric and isokinetic strength (Schoenfeld et al., 2017a). Another more recent systematic review and meta-analysis by Carvalho et al. (2022) compared the effect of very low load (less than 30% 1-RM), low load (between 30-59% 1-RM), moderate load (between 60-79% 1-RM) and high load (80% 1-RM or more) with matched volume load on 1-RM. It found that high loads were favoured versus low loads (p = 0.006; ES:1.03; 95% CI: 0.37, 1.69), and high load had a higher effect on muscle strength (1-RM test) than moderate loads (p = 0.012; ES:0.60; 95% CI: 0.17, 1.03), and moderate load versus low load (p = 0.048; ES: 0.83; 95% CI: 0.01, 1.65). There were no differences between low load and very low load (Carvalho et al., 2022).

Finally, a review by Schoenfeld et al. (2021) showed that the evidence regarding the effect of load on muscle endurance is weak and the effects are not clear (Schoenfeld et al., 2021).

Failure

Momentary muscular failure is the inability to perform the concentric phase of an exercise repetition with a full ROM without losing form (Refalo et al., 2023). A study found that performing exercise to failure in untrained participants was not necessary for maximal increases of hypertrophy in high intensity resistance exercise, but it was essential for low intensity resistance exercise (Nóbrega and Libardi, 2016). On the other hand, a systematic review and meta-analysis by Grgic et al. (2022) showed that there was no significant difference for hypertrophy between failure and non-failure training (p = 0.152; ES = 0.22, 95%CI: -0.11 to 0.55), suggesting that both produce similar increases in muscle size. Additionally, a subgroup analysis for trained subjects training to failure demonstrated a significant effect on muscle hypertrophy while non-failure training did not (Grgic et al., 2022). Another systematic review and meta-analysis found no significant difference between performing exercise to momentary failure and non-failure (0.12 (0.13, 0.37) (ES (95% CI), p = 0.343).

Momentary muscular failure resistance training had an ES= 0.41(0.27, 0.55) (ES (95% CI) and p = <0.001, while non-failure had an ES=0.37 (0.15, 0.58) (ES (95% CI) and p = 0.001(Refalo et al., 2023).

A current opinion suggests that high-intensity resistance training to failure was not necessary to maximise strength gains, while low-intensity resistance training to failure was essential for strength gains (Nóbrega and Libardi, 2016). A recent systematic review and meta-analysis found no significant differences between training to failure and non-failure in the analysis that included all the studies. However, in the sub-group analysis with not equated volume studies there was a significant difference favouring non-failure (p = 0.025; ES = -0.32,y 95%CI: -0.57 to -0.07), while in the subgroup analysis with equated volume studies, there were no significant differences between failure and non-failure training (Grgic et al., 2022).

Repetition duration

There is currently no evidence that repetition duration has any effect on muscle hypertrophy (Fisher et al., 2013, Schoenfeld et al., 2015a, McLeod et al., 2023). The systematic review and meta-analysis found no significant differences in muscle hypertrophy between fast/heavy (6-12 reps, repetition duration 0.5-4s; ES 0.67 ± 0.19 (95 % CI 0.22–1.13)), fast/light (20-30 reps), repetition duration 0.5-4s; ES 0.79 ± 0.37 (95 % CI 0.095–1.67)), medium (6-12 reps, repetition duration 4-8s; ES 0.27 ± 0.20 (95 % CI -0.22 to 0.75)) or slow (6-12 reps, repetition duration 8s or more; ES 0.29 ± 0.27 (95 % CI -0.34 to 0.92)) (Hochberg-adjusted P value = 0.94). Additionally, it did not find any significant differences in the effect of repetition duration in the analysis for direct hypertrophic measurements, fast/heavy (ES 0.42 ± 0.17 (95 % CI -0.10 to 0.95) and medium (ES 0.37 ± 0.17 (95 % CI -0.16 to 0.90), (P = 0.73) (Schoenfeld et al., 2015a).

Rest intervals

Rest has been defined as the time between sets and exercises for recovery. The main focus of the literature is the inter-set rest interval since this affects fatigue, muscle recovery, training goal and duration (Grgic et al., 2017). A short inter-set rest interval length is 60 seconds or less, and a long inter-set interval

length is more than 60 seconds (Grgic et al., 2017). A systematic review included 6 studies, with 115 individuals (97 men, 18 women), mean duration of the study 8.3 weeks, training frequency between 2-3 days per week, free weight, machine-based, multi-joint and single join exercises looked at the effects of short versus long inter-set intervals on hypertrophy. Due to the small number of studies, it was only able to perform a robust variance regression analysis, finding a non-significant effect favouring long inter-set rest intervals. The review suggested that long inter-set rest intervals may be used for increasing muscle hypertrophy because they allow a higher training volume load. However, it claims that these results should be considered with caution due to the low number of studies (Grgic et al., 2017). In conclusion, the effect of inter-set rest intervals on muscle hypertrophy is unclear.

A systematic review looking at the effect of rest interval duration on muscle strength found that in trained subjects even though different durations could produce strength gains, having rest intervals of at least 2 minutes was needed to maximize strength gains. Furthermore, in untrained individuals rest intervals of short (less than 60 seconds) to moderate (between 60-120 seconds) were needed to obtain muscle strength gains (Grgic et al., 2018b).

Variation

Variation is the systematic change of one or more training variables (e.g. load, volume, exercise) throughout the exercise programme. The selected variation can be deployed during the same session or session by session through the programme, and it can be used to stimulate different sections of one muscle group, or just one muscle. It has been found that for hypertrophy it is better to have a planned variation to target different sections of one muscle group and to consider biomechanics and anatomy (Kassiano et al., 2022).

Similarly to hypertrophy, evidence suggests that exercise variation can influence muscle strength gains in a negative or positive way (Kassiano et al., 2022). It has been suggested that for muscle strength, specificity should be considered and that the exercise desired for maximal strength gains should be the one with higher priority and be rotated regularly in the resistance exercise programme (Kassiano et al., 2022).

Periodisation

Periodisation is when the training variables are manipulated in a planned way during a period of time to increase exercise adaptations and avoid overtraining syndrome (Lorenz and Morrison, 2015). The variables are manipulated in cyclical fashion to enhance fitness levels (Evans, 2019). A plan consists of a mesocycle (around one year), mesocycles (around a month) and a microcycle (around a week), and it depends on the goals and completions of the athlete (Evans, 2019).

There are several types of periodisation. Some of those are linear, undulating and block periodisation. Linear periodisation is when volume and load are changed across the mesocycles (3-4 months period). Each mesocycle focuses on one training parameter (e.g. strength, speed, power) and the advancement occurs when the previous phase is successfully completed (Lorenz and Morrison, 2015).

The undulating periodisation is when the volume and load change more frequently (every 2 weeks, weekly or daily) allowing longer periods of recovery for the neuromuscular system. With this periodisation, several training parameters can be worked on at the same time (Lorenz and Morrison, 2015). Finally, block periodisation has phases of 2-6 weeks with a high volume of specialised exercises for each phase. Firstly, the accumulation phase (2-6 weeks) consists of general exercises of 50-70% 1-RM. Secondly, the transmutation phase consists of more specific exercises of 75-90% 1-RM. Thirdly, the realization phase consists of more specific exercises with 90% or more of 1-RM (Lorenz and Morrison, 2015).

A recent systematic review and meta-analysis looked at the effect of periodisation on hypertrophy. It found 10 studies comparing non-periodised and periodized resistance training. The analysis showed no effect on hypertrophy favouring non-periodised or periodized regimes (ES 0.13, 95% CI [-0.10, 0.36]; Z = 1.10 (P = 0.27)) with equated volume. Additionally, it found 11 studies comparing linear periodisation and undular periodisation. The analysis found no effect favouring linear periodisation or undular periodisation (ES 0.05, 95% CI [-0.20, 0.29]; Z = 0.36 (P = 0.72)). These results suggest that periodisation does

not have effects on muscle hypertrophy when the volume is equated (Moesgaard et al., 2022).

It has been shown that periodized training has a significant effect on muscle strength (1-RM) compared to non-periodised training (ES 0.31, 95% CI (0.04, 0.57); Z = 2.28 (P = 0.02)), with no difference between training status. Additionally, it was reported that there was a significant effect favouring undulating periodisation on 1-RM (ES 0.31, 95% CI (0.02, 0.61); Z = 2.06 (P = 0.04)), compared to linear periodisation. There was also a moderate effect in trained participants favouring undulation periodisation (ES 0.61, 95% CI (0.00, 1.22); Z = 1.97 (P = 0.05)) compared to linear periodisation, while in untrained participants there was no difference between linear or undulating periodisation (Moesgaard et al., 2022).

Summary

In summary, it has been found that a higher volume of resistance exercise produces greater hypertrophy effects on muscle mass and muscle strength. The effects of frequency in muscle mass are unclear, while higher frequencies have been found to produce higher gains in muscle strength, but there are no differences when the volume is equated. Load has been found to not have an effect on muscle mass, while higher loads have a greater effect on muscle strength compared to lower loads. Periodisation (equated volume) has been found to not have an effect on muscle mass, while it does have a significant effect in muscle strength compared to no periodisation. Additionally, undulating periodisation produces higher effects on muscle strength compared to linear periodisation on trained individuals. However, no differences were found in non-trained individuals. The variation of resistance exercise is beneficial to hypertrophy and strength when it is applied to target different sections of the muscle group. Rest intervals effects on muscle mass are unclear, while rest intervals of minimum two minute are necessary for trained individuals for maximal strength gains, while rest intervals of 60-120 seconds are needed for non-trained individuals. Finally, resistance exercise to momentary failure produces similar muscle gains compared to non-failure.

1.2.3 Home-based resistance exercise training

There is a small amount of evidence on home-based resistance programmes in the literature. Many of the studies, trials and reviews involve older adults with or without medical conditions (Tsekoura et al., 2018, Kis et al., 2019, Perkin et al., 2019, Vitale et al., 2020, Chaabene et al., 2021, Mañas et al., 2021, Fyfe et al., 2022a, Zhang et al., 2022). Some studies have been done in adults with medical conditions such as type 2 diabetes (Payne et al., 2008, Plotnikoff et al., 2010, Al Ozairi et al., 2023) or cancer (Lund et al., 2019, Gorzelitz et al., 2023), and just a few on healthy adults (Kikuchi et al., 2022, Kikuchi et al., 2023). The effects of home-based resistance exercise programmes on different outcomes are explored below:

a) Metabolism

A study compared in adults a supervised online low-load home-based resistance exercise programme with an 8-week supervised in-person low-load resistance exercise programme consisting of two sessions per week, with each session lasting one hour, with nine exercises (leg raise, squat, rear raise, shoulder press, rowing, dips, lunge and single leg lift) and doing as many repetitions as possible. It found that both groups decreased HbA1c, and no significant differences between groups were found. Additionally, it found that there were no significant changes in lipid profile parameters (TG, LDL, TC, HDL) and IGF-1. However, these results need to be considered with caution since the study did not have a control group (Kikuchi et al., 2022). Similarly, a randomised control trial by Al Ozairi et al. in type 2 diabetic adults, found a six-month home-based resistance exercise programme did not have a significant effect on TC, HDL and LDL. In contrast the study by Kikuchi et al., this study did not find any changes in HbA1c (Al Ozairi et al., 2023).

b) Body composition and muscle mass

A few studies have looked at BMI, fat free mass, whole body fat, percentage of body fat, lean leg mass, cross-sectional area, calf circumference, skeletal muscle mass index and others (Tsekoura et al., 2018, Perkin et al., 2019, Al Ozairi et al., 2023, Vitale et al., 2020). Most did not find any effects of home-based resistance exercise programmes on body composition parameters, such as

BMI, fat-free mass (Tsekoura et al., 2018, Perkin et al., 2019, Al Ozairi et al., 2023), whole body fat (Al Ozairi et al., 2023), percentage of body fat, lean leg mass (Perkin et al., 2019). However, Al Ozairi et al. found a significant reduction in liver fat (Al Ozairi et al., 2023) in type 2 diabetic adults after a 6-month home-based resistance training intervention consisting of three sessions per week, progressing from 1 set per session to three sets per session, doing 15-20 repetitions, doing seven exercises (squat, push up, calf raise, seated row, lunge, lateral raise and plank). On the other hand, Vitale et al. found different results. The randomised controlled trial was conducted in adults during the COVID-19 lockdown in older adults. It compared a 6-month home-based resistance exercise intervention to continuing usual lifestyle. The intervention consisted of 24 weeks, four sessions per week, with each session lasting 55 minutes, nine exercises (squat on hair, leg adduction, leg abduction, calf raise, monopodial balance standing, side raise, bices curl and triceps curl), between 3-4 sets and 12-15 reps. The study found that the exercise group had a significant increase in total fat mass. This was explained due to having the intervention during the COVID-19 lockdown in Italy (Vitale et al., 2020).

More studies have demonstrated that home-based resistance programmes have a significant effect on muscle mass. Vitale et al. and Kikuchi et al. found a significant increase in thigh cross-sectional area (CSA) (Vitale et al., 2020, Kikuchi et al., 2022). Additionally, other studies have found a significant increase in calf circumference, skeletal muscle mass index (Tsekoura et al., 2018), arm and leg free fat mass (Al Ozairi et al., 2023). However, a couple of studies did not find a significant effect on thigh CSA (Perkin et al., 2019, Al Ozairi et al., 2023) and calf CSA (Perkin et al., 2019). Finally, a systematic review and meta-analysis found three studies with no effects on BMI, muscle mass and free fat mass, but it was not able to perform any analysis due to the heterogeneity of the results (Mañas et al., 2021).

c) Muscle strength

Several studies have shown that home-based resistance exercise does not have an effect on grip strength (Al Ozairi et al., 2023, Kikuchi et al., 2022, Vitale et al., 2020, Tsekoura et al., 2018). A study done in elderly with sarcopenia found that a 12-weeks home-based resistance exercise programme (two sessions per

week, 60 min session, 1-sets, 8-12 reps, free weights and ankle cuff weights) did not produce any significant changes in grip strength compared to the control group (Tsekoura et al., 2018). Another study done in older individuals found that a 24-week home-based resistance exercise programme (four sessions per week, 55 minutes sessions, nine different exercises for lower and upper muscle groups, 3-5 sets, 12-15 reps, 60-90 seconds rest intervals) did not produce any significant changes in the exercise group pre vs post, and comparing it with the control group (Vitale et al., 2020). Additionally, a study was done in adults looking at the effects of an 8-week low intensity online home-based resistance exercise programme (2 sessions per week, 60 minutes sessions, nine exercises, as many reps as possible and supervised online sessions). It found that there were no significant changes pre vs post in the exercise group, and comparing it with the control group (Kikuchi et al., 2022). A study done in type-2 diabetics adults showed that a 6-month home-based resistance exercise programme (three sessions per week, seven exercises for all major muscle groups, 1-3 sets, 5-20 reps, volitional muscular failure) did not produce significant changes in grip strength (Al Ozairi et al., 2023). Additionally, similar results were found by a systematic review and meta-analysis by Mañas et al (2020). It looked at the effects of unsupervised home-based resistance exercise in community dwelling older adults. It looked at 21 studies, 4,053 participants, age range of 68-84 years old, 2-7 sessions per week, 30-60 min sessions, 12-52 weeks. It found that there was no significant effect on grip strength (Hedges' g = −0.00; 95%CI = −0.17, 0.16, p=0.932) (Mañas et al., 2021).

However, several studies have shown that home-based resistance exercise significantly increases muscle strength (Tsekoura et al., 2018, Kis et al., 2019, Chaabene et al., 2021, Kikuchi et al., 2022, Kikuchi et al., 2023, Al Ozairi et al., 2023). Tsekoura et al. found a significant increase in isokinetic knee strength after a 12-week home-based programme (N=18) compared to a control group (N=18) in independent older adults (male and female) with presarcopenia, sarcopenia and severe sarcopenia. The home-based group performed 100 min of walking per week, with two sessions per week of resistance exercises, each 60 minutes long, 1-2 sets and 8-12 reps (Tsekoura et al., 2018). Similarly, Kikuchi et al. (2022), that was detailed in the previous section, found a significant increase in knee extensor strength after an 8-week online home-based resistance training

programme (Kikuchi et al., 2022). Two studies found a significant increase in the number of push-ups completed after the intervention (Al Ozairi et al., 2023, Kikuchi et al., 2023). Two meta-analyses found that home-based resistance programmes have a significant effect on lower-body muscle strength in older adults (Hedges' g = 0.33; 95%CI = 0.11, 0.56; p = 0.004 (Mañas et al., 2021) (Mean Difference, 0.6 Kg; 95% CI, 0.16–1.04; I2, 0%; p for heterogeneity = 0.4) (Kis et al., 2019). Another systematic review showed that home-based programmes produced a significant moderate increase in muscle strength (Standardised Mean Difference = 0.30 [0.12 to 0.48]; p < 0.01) (Chaabene et al., 2021).

However, just a few studies have shown no significant effects on muscle strength. A couple of studies did not find a significant effect on thigh extensors (Vitale et al., 2020, Kikuchi et al., 2023) and flexors strength (Vitale et al., 2020). A meta-analysis (12 studies, 1160 participants) looking at the effects of minimally supervised home-based resistance exercise in older adults, found that there were no significant effects on upper body strength (Kis et al., 2019). These differences could be due to having different types of populations, different levels of supervision, and different volumes and intensities of exercise.

d) Physical function

In the literature, there is evidence that home-based strength exercise improves physical function in elderly (Tsekoura et al., 2018, Kis et al., 2019, Perkin et al., 2019, Mañas et al., 2021, Fyfe et al., 2022a, Zhang et al., 2022). This improvements have been found in the "timed up and go test" (TUG) (Tsekoura et al., 2018, Kis et al., 2019, Zhang et al., 2022), "sit to stand test" (Perkin et al., 2019, Mañas et al., 2021), 5 times sit-to-stand (5-STS) (Fyfe et al., 2022a, Zhang et al., 2022) and the 30-second STS test (Fyfe et al., 2022a).

However, Al Ozairi et al. did not find any changes on the short physical performance battery (SPPB) (Al Ozairi et al., 2023). Similarly, the systematic review and meta-analysis by Mañas et al. found no significant effects on the SPPB and TUG (Mañas et al., 2021).

e) Quality of Life and well-being

One study found that after a 12-week resistance exercise programme, there was a significant improvement in quality of life measured with the health-related quality of life questionnaire (HRQOL) in the home-based resistance exercise group (Zhang et al., 2022). Similarly, another study found significant improvements in the Sarcopenia Quality of Life (SarQol_GR) questionnaire in the home-based group after a 12-week home-based programme (N=18) compared to a control group (N=18) in independent older adults (male and female) with presarcopenia, sarcopenia and severe sarcopenia. The home-based group perfomed 100 min of walking per week, with two sessions per week of resistance exercises, each 60 minutes long, 1-2 sets and 8-12 reps (Tsekoura et al., 2018). However, a systematic review and meta-analysis found that unsupervised home-based resistance exercise programmes did not have a significant effect on the European Quality of Life-5 Dimensions (EQ-5D) questionnaire, nor on the mental and physical components of the 12-item Short Form Health Survey (SF-12) (Mañas et al., 2021).

Another study by Kikuchi et al. found no significant changes in the Well-Being Index (WHO-5) and the Kessler Psychological Distress Scale (K6) but found significant improvements in the Center for Epidemiologic Studies-Depression Scale (CES-D) in the online home-based resistance exercise group (Kikuchi et al., 2023) (Kikuchi *et al.*, 2023).

f) Summary

In summary, the evidence shows that home-based resistance exercise programmes do not affect glycaemic control, lipid profile, body composition and grip strength. There is plenty of evidence showing that home-based resistance exercise programmes improve muscle strength. Finally, the effects of home-based resistance exercise programmes on physical function, quality of life and muscle mass are still unclear.

A type of home-based resistance exercise are exercises with resistance bands. The evidence regarding these will be explained in the next section.

1.2.4 Resistance bands training

Resistance exercise bands are considered to be inexpensive, portable and versatile (Iversen et al., 2017). A crossover study comparing muscle activation in conventional resistance training (barbells, free-weights and machines) versus resistance exercise bands found that conventional exercises produced significantly higher levels of activation compared with band exercises in all exercises. However, there were marginal differences in muscle activation during in lateral pull-down, unilateral row and deadlift exercises, but not in squat exercises. The differences in muscle activation were found when the bands were slack during the exercise, disappearing when the band was tense again (Iversen et al., 2017). This shows that bands could be a good alternative for upper body exercises and some lower body exercises, but not the squat exercise.

A systematic review and meta-analysis by Martins et al. included 11 studies and looked at the effect of resistance band training on muscle strength in elderly participants. The analysis included 834 older adults between 60 and 79 years old. It found that resistance band training had a significant effect on muscle strength in healthy elderly (Standardized mean difference (SMD) 1.30 (95% CI: 0.90, 1.71) (Martins et al., 2013). Another systematic review and meta-analysis including seven studies found that there was no superiority between conventional resistance training (weight machines or free weights) and resistance band training (tubes and Therabands) on strength gain in upper-limb (SMD = –0.11; 95% CI = −0.40, 0.19; p = 0.48) and lower-limb (SMD = 0.09; 95% CI = −0.18, 0.35; p = 0.52) in adults. It concluded that resistance band exercise produces similar strength gains to conventional strength training (Lopes et al., 2019). Another meta-analysis looked at the effect of resistance band training in type 2 diabetics. It included seven studies with band resistance programmes between 12-16 weeks, with 3-10 sessions per week, each session lasting between 30-60 minutes, having between 7-12 exercises, doing between 2-3 sets and between 8-20 repetitions. It found that the resistance band training produced a significant increase in lower extremities strength in the resistance exercise groups compared to the control group (weighted main difference (WMD) = 21.90 kg; P < 0.0001), but not upper extremities (WMD = 2.27 kg; P = 0.13) or handgrip (WMD = 1.98 kg; P = 0.46) strength (McGinley et al., 2014). Overall, the evidence shows that resistance band training is a suitable alternative to increase muscle

strengthening guidelines compliance, by targeting some of the resistance training barriers which are explained in detail in the next section.

1.3 Perceptual responses to resistance exercise

A study done in type 2 diabetic adults, found that enjoyment fitness improvement and a sense of well-being were frequently expressed by participants performing resistance exercise and combined exercise (Tulloch et al., 2013). Another study done on older adults, looked at the feasibility of an online home-based resistance exercise training programme. Participants expressed joy towards exercise, liked the convenience of the programme (easy to follow, clear instructions and at home), the instructions and having progression (Vikberg et al., 2022).

Additionally, it has been shown several motivators to perform resistance exercise. A study in older adults found that to feel fit, good physically and mentally are the main motivators in older adults that do not currently participate in resistance exercise (Burton et al., 2017). Another study in type 2 diabetics showed that social support from family was the main facilitator for resistance exercise. Other facilitators found in this study were the possibility of obtaining health benefits, a general sense of well-being and a sense of achievement (Tulloch et al., 2013). A systematic review and meta-analysis by Vasudevan & Ford et al (2022) regarding women and resistance exercise, found that social support of the group training and the support from family, friends, family and significant others were strong motivators. In addition, body image and improving physique, a sense of obligation, experiencing mental health benefits, having an increase in knowledge and understanding of resistance exercise, financial initiative and having supervision were motivators to perform resistance exercise (Vasudevan and Ford, 2022).

On the other hand, people have identified several barriers to resistance exercise. Some studies have reported the lack of time (Trost et al., 2002, Hurley et al., 2018, Vasudevan and Ford, 2022), the effort involved (Trost et al., 2002, Hurley et al., 2018), lack of purpose, pain due to injury, negative experiences of prescriptive exercise, apathy (Hancox et al., 2019), illness and work commitment (Tulloch et al., 2013) as barriers to resistance exercise.

Furthermore, some qualitative studies involving women have reported other barriers such as worrying about looking ‘manly’ or ‘bulking up (Dworkin, 2003, Vasudevan and Ford, 2022)’, excessive tiredness, not being comfortable in crowded gyms, being uncomfortable around men or doing resistance exercise alone, looking weak (Peters et al., 2019), risk of injury, social stigma, lack of support, gender-based barriers, inadequate knowledge, boredom, unavailability of equipment in the community or home, financial barriers (purchasing equipment or gym membership), lack of supervision, and family constraints (Vasudevan and Ford, 2022).

Finally, a study in older adults with long-term conditions, frailty and deterioration in health, has shown that there was a general lack on awareness and understanding of resistance exercise. Most of the participants had never heard of it and its benefits (Hurst et al., 2023).

1.4 Rationale

The physical activity guidelines have included resistance exercise because doing resistance exercise alongside aerobic exercise gives you more benefits. However, the main problem is that around two thirds of the adult population do not perform resistance exercise. This could be for several reasons, such as the lack of time, the financial cost, not being aware that they should do it or its benefits, family constraints, unavailability of the equipment in the community, with in others. It is essential to increase the amount of people doing muscle-strengthening activities to obtain population health benefits by addressing this barriers.

The ACSM guidelines give a clear prescription for resistance exercise, however they are more adequate for athletes and not for the general public. It is important to find a low dose of resistance exercise that can produce a meaningful effect and benefit, that that is not intimidating with the main goal to get people to start performing resistance exercise. It has been previously explained int his chapter that even though higher volume of resistance exercise is better, one set per week stills provides with a benefit if it is performed to fatigue.

New resistance exercise programmes that have a low time commitment, a low cost and not intimidating are needed. Home-based resistance exercise programmes, including body weight exercises and resistance bands, could be a solution to these issues. There is plenty of evidence of home-based resistance exercise programmes in older adults, but there is limited evidence in adults. Therefore, this PhD aims to address these gaps in the literature by the aims and objectives in the section below.

1.5 Thesis aims and specific objectives

The aims of this thesis are the following:

- To understand the effects of low-dose home-based resistance exercise on muscle strength, muscle endurance, muscle mass and body composition in healthy adults who do not engage in resistance exercise.

- To understand the effects of low-dose home-based resistance exercise on well-being, self-esteem, energy and vitality, and exercise motivation regulation in healthy adults who do not engage in resistance exercise.

- To determine the acceptability and feasibility low-dose home-based resistance programmes exercise in healthy adults who do not engage in resistance exercise.

The objectives of this thesis are:

- Determine the effects of low-dose home-based resistance exercise programmes on muscle strength, endurance and thickness.

- Determine the effect of low-dose home-based resistance exercise programmes on body composition.

- Determine the effect of low-dose home-based resistance exercise on well-being, self-esteem, energy and vitality, and exercise motivation regulation.

- To understand the adherence, volume and frequency during the low-dose home-based resistance exercise programmes.

- To explore participants' perceptions, feelings, thoughts, enjoyment, tolerance and acceptability of low-dose home-based resistance exercise programmes.

- Develop and optimise a Theory of Change for lowp-dose home-based resistance exercise.

Chapter 2 ONE Study: Effect of one minute of resistance exercise per day on muscular strength

COVID 19 Statement:

The ONE study received ethical approval on the 27th May 2019. Recruitment and data collection started in June 2019. Due to the COVID-19 pandemic, recruitment was paused in March 2020 with a total of 27 participants, from which 7 participants from the intervention group took part in qualitative interviews. The laboratories opened again in Summer-Autumn 2021 just about I was going to leave for maternity leave, leaving not enough time for data collection. Once I returned in September 2022, there was not enough time (1 year and 4 months left) to complete the sample required, therefore, the ONE study was considered as a pilot study for the REFLEX study (Chapter 3 and 4).

2.1 Introduction

Resistance or strength training programmes result in a variety of health benefits, including significant increases in muscle size and strength (Saric et al., 2018), reduction of body fat, increased metabolic rate, improvement of insulin sensitivity, blood glucose tolerance, blood lipid profiles (Kraemer et al., 2002, Ashton et al., 2020), improvement of resting blood pressure, flow-mediated dilatation and cardiopulmonary fitness in adults (Ashton et al., 2020). Due to these positive effects on health, resistance exercise was included in the Global physical activity guidelines during in 2010 (WHO, 2010).

The WHO and the UK physical activity guidelines recommend performing muscle-strengthening activities involving major muscle groups on two days a week or more (WHO, 2022a, Department of and Social, 2019). Data from several studies has suggested that only 10%-30% of adults comply with this guideline, and almost twice as many adults in the US report no muscle strengthening activities compared to no aerobic activities (Bennie et al., 2020). In 2021 in Scotland, only 35% of adults met the MVPA and muscle-strengthening guidelines – 38% of men and 32% of women (Birtwistle et al., 2021).

Participation in muscle-strengthening exercise is low and it is not clear why is that. The literature shows that people have several barriers to resistance exercise such as being ill or having work commitments (Tulloch et al., 2013), lacking time (Trost et al., 2002, Hurley et al., 2018, Vasudevan and Ford, 2022), feeling apathetic towards it, feeling pain due to an injury, not having a purpose, having a negative experience with prescribed exercise (Hancox et al., 2019) and the effort needed (Trost et al., 2002, Hurley et al., 2018). Additionally, women have expressed barriers such as not wanting to look manly (Dworkin, 2003, Vasudevan and Ford, 2022), being too tired, feeling uncomfortable in gyms with many people and around men, a long time needed, looking weak (Peters et al., 2019), not having enough support, supervision or knowledge, feeling bored, not having the equipment needed at home or in the community, worrying about getting an injury, gender based barriers, family restraints and financial barriers (purchasing equipment or gym membership) (Vasudevan and Ford, 2022). Finding different approaches that consider these barriers is important to increase adherence to muscle-strengthening activities guidelines.

“Exercise snacks” are defined as several short bouts (around 20 seconds) of vigorous exercise that can be done during the day with several hours of rest in between. It has been mentioned that resistance exercise might be feasible for “exercise snacks” due to the fact that it can be performed with minimal equipment or bodyweight in a non-gym setting unsupervised with a time-based prescription (Fyfe et al., 2022a), which would make it easier to incorporate during the day on a regular basis and may be a more convenient way to undertake resistance exercise for some people. A pilot study by Perkin et al. looked at the effect of a 28-day home-based exercise-snacking resistance exercise programme on older adults (65-80 years old). The programme involved two bouts of “exercise snacking” per day, each consisting of five bodyweight exercises (sit-to-stand, seated knee extensions, standing knee bends, march on the spot and standing calf raises). Each exercise was performed for one minute and participants needed to do as many repetitions as possible. The study showed high adherence (98%), and a significant increase in the exercise snacking group for the 60-second sit-to-stand test (functional measure) (29 (8) to 38 (13) (repetitions)), while the control group did not significantly change (29 (14) to 29 (13)(repetitions)). However, the authors did not find any differences in leg strength, leg power and lean muscle mass; although it is relevant to mention that the study was underpowered and the intervention only lasted four weeks (Perkin et al., 2019). More studies that are powered and with longer interventions are needed to determine the effects the effects of exercise snacking with resistance exercise. Also, it would be relevant to explore the effects of exercise snacking in younger adults.

A systemic review and meta-analysis looked at the effect of resistance training frequency on muscle hypertrophy. It found a significant effect of training frequency on hypertrophy (p=0.002), with higher frequency (0.49 ± 0.08 (95 % CI 0.29–0.69)) associated with a greater effect size than lower frequency (0.30 ± 0.07 (95 % CI 0.12–0.47)) on a volume equated basis (same volume per week) (Schoenfeld et al., 2016).

A later systematic review meta-analysis also found that resistance exercise frequency had a significant effect on muscular strength, with higher frequencies resulting in higher gains, with one session a week (0.74 ± 0.13; 0.48–1.01), two sessions (0.82 ± 0.13; 0.55–1.09), three sessions (0.93 ± 0.13; 0.65–1.21) or four

sessions (1.08 ± 0.16; 0.74–1.42) (mean ± standard error of the mean; confidence interval). However, once volume was equated, there was no significant effect, meaning that the frequency effect was driven by the exercise volume and not frequency in itself (Grgic et al., 2018a). Additionally, it has been found that three sessions per week, each with a single set per muscle group, are sufficient to induce substantial muscular strength changes (chest press 22% increase and leg press 16% increase) when the exercise is performed to failure (Ismail et al., 2019).

As mentioned above, the guidelines recommend doing muscle-strengthening activities at least two days a week, but they do not give specific prescription details, such as volume per week (set per week), repetitions, etc. Even though higher frequencies (not volume-equated) are associated with higher muscle strength gains, one session a week still produces a relevant effect. This is relevant to consider since lack of time is a common barrier (Trost et al., 2002, Hurley et al., 2018, Vasudevan and Ford, 2022). A low dose programme could be a way to over come this. People have also mentioned financial barriers (Vasudevan and Ford, 2022) and being uncomfortable in a gym (Peters et al., 2019). In this case, home-based resistance exercise programmes could be the answer. Additionally resistance bands are a feasible alternative for training at home, because of their versatility, portability, low price and low space requirements (Iversen et al., 2017). Several studies have revealed elastic resistance band training and conventional resistance training provide similar increases in muscle activation when relative loadings are matched (Andersen et al., 2010, Aboodarda et al., 2013, Aboodarda et al., 2011) and that training with resistance bands has a similar increase in strength as conventional resistance training (Lopes et al., 2019). However, the majority of these studies are on elderly people or patients.

2.2 Study Aims

The primary aim of this study was to determine the effects of one-minute-per-day home-based resistance exercise training on muscular strength. The secondary aims were to determine the effects of one-minute-per-day home-based resistance exercise training on body composition, muscle thickness and

endurance, and to determine participants' perceptions, feelings, thoughts, enjoyment, tolerance and acceptability of the resistance exercise programme

2.3 Methods

2.3.1 Participants characteristics

Inclusion and exclusion characteristics

The inclusion criteria for this study were: male or female, aged between 18-65 years old and undertaking ≤ 60 min a week of vigorous-intensity aerobic physical activity (Ainsworth et al., 2011). Exclusion criteria included diabetes, uncontrolled hypertension (blood pressure > 150/90 on medication), history of cardiovascular disease, participating in ≥ 60 min of vigorous-intensity physical activity (Ainsworth et al., 2011) and other significant illnesses that would prevent the participant from undertaking physical activity.

Study sample

A total of 27 participants were screened for the study. Only one participant was excluded and 26 participants underwent baseline measurements and were randomly allocated to the RE group (N=12) and control group (N=14). 17 participants underwent the 4-week assessment, 20 underwent the 8-week assessment and 19 participants had post-intervention measurements. More details of recruitment and retention are shown in Figure 7.

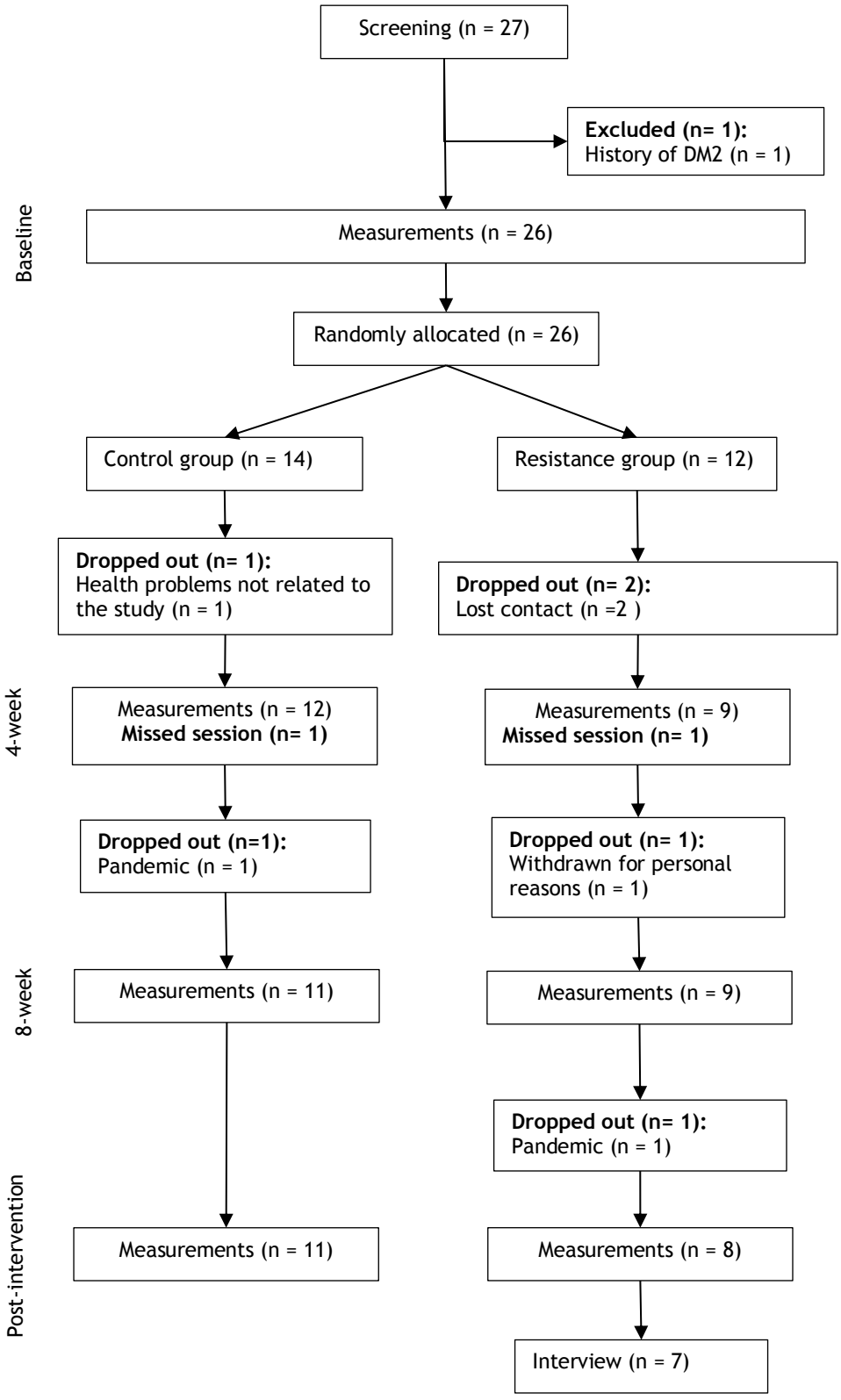


Figure 7. ONE Study flow diagram. Abbreviation: DM2: Type 2 diabetes mellitus.

A subsample of the intervention group (N=7) was recruited with purposive sampling (selection of participants that have a particular characteristic needed) to include a range of views of men, women, younger and older.

2.3.2 Ethics

The ONE Study was approved by the MVLS College Ethics Committee (200180137) (Appendix A; Appendix B) and underwent one amendment (Appendix C). It is registered in clinicaltrials.gov (NCT03981250).

Participants had at least two days to read the participant information documents (Appendix D; Appendix E). After that, they attended an online video call to answer any questions and gave recorded informed consent. Participants could withdraw at any time from the study without consequence or reason. Data obtained was anonymised and was not passed outside the research team. In case of exclusion, participant data was destroyed, while in case of withdrawal, participant data was retained.

2.3.3 Overview of the study

Participants first attended a screening session with a researcher to determine their eligibility for the study. Those who were eligible underwent baseline measurements in which anthropometric measures, body composition, muscle strength, muscle endurance, and muscle thickness were measured. After baseline measurements, participants were randomised to the resistance exercise (RE) group or a control group. The RE group underwent a 12-week home-based resistance exercise programme while the control group was asked to keep their usual lifestyle. Participants in the RE group underwent a familiarization session with the researcher to receive their resistance bands and receive training in performing the exercises and being shown how to complete the exercise diary. All participants attended two more measuring sessions during their 4th week and 8th week to measure the same outcomes. Finally, participants had a 12-week measurement within 48 hours of finishing the programme to measure the same outcomes. A subsample of the RE group took part in interviews within one month after the 12-week measurements. Figure 8 provides an overview of the study protocol.

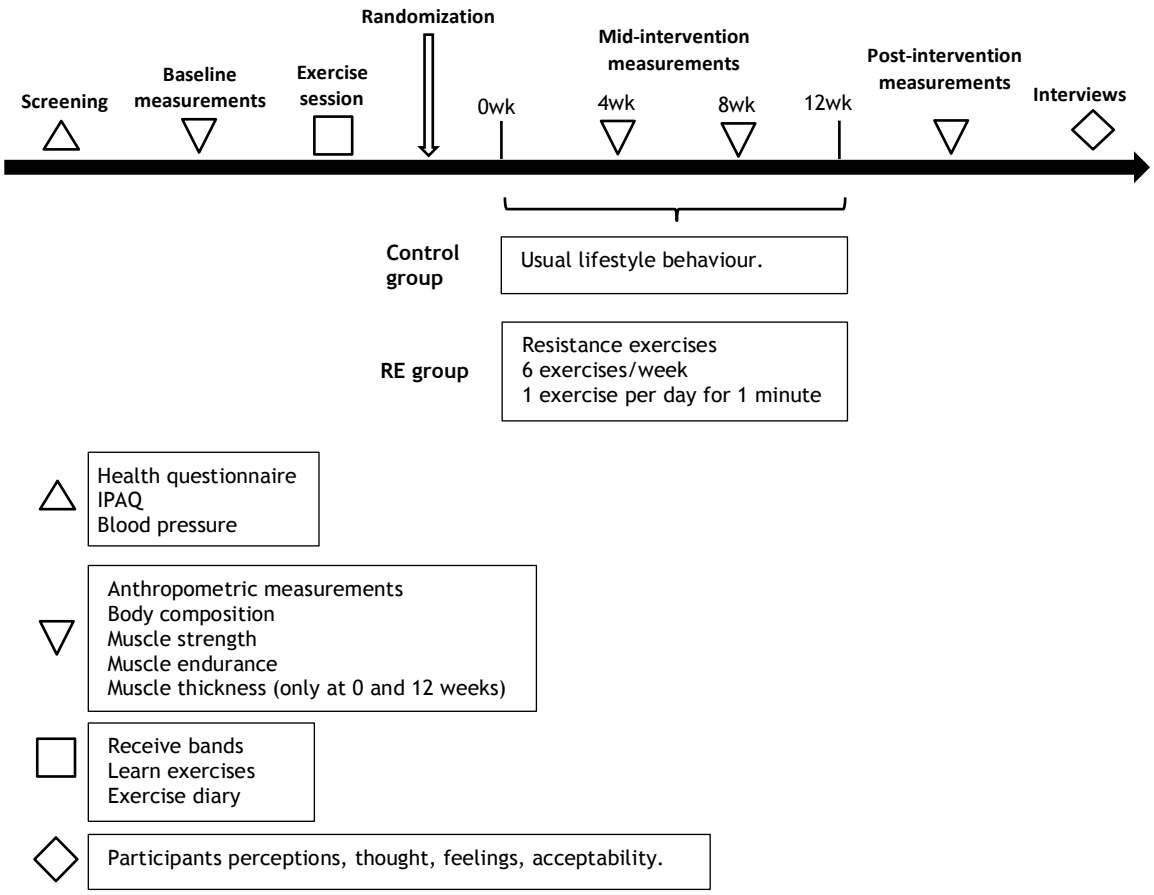


Figure 8. Study protocol overview. IPAQ: International Physical Activity Questionnaire; RE: Resistance exercise group.

2.3.4 Screening Procedures

a) Health questionnaire

All participants undertook a health questionnaire (Appendix F) to determine their health history.

b) International Physical Activity Questionnaire (IPAQ)

All participants completed the International Physical Activity Questionnaire (IPAQ) (Appendix G).

c) Resting blood pressure measurement

Each participant lay supine on a clinical bed for 10 minutes. They were then asked to uncover their left arm and rest their arm on the bed with their palm

facing upwards. The blood pressure meter (Boso-Medicus) was used to measure blood pressure to determine if they were suitable for the study.

2.3.5 Anthropometric measurements

a) Height

Height was measured with the participants standing on a stadiometer (SECA 220, Hamburg, Germany) with no shoes. Participants' feet and heels were together, touching the back of the stadiometer. Their head was aligned with the Frankfort plane and they were asked to hold a deep breath at the moment of the measurement. Height was measured by the distance from the floor to the vertex of the head (highest point of the skull) to the nearest 0.1 cm. Height was measured at four time-points during the study, at baseline (0 weeks), at 4-weeks, at 8-weeks and post-intervention (12-weeks).

b) Body Mass

Body mass was measured with participants standing and wearing minimal clothing and no shoes using an electronic scale (SECA 877, Hamburg Germany) after a void bladder. Participants were asked to stand with their arms at their side until the weight was stable. This process was repeated twice, and the average was taken. Weight was measured to the nearest 0.05 kg. Weight was measured at four time-points during the study, at baseline (0 weeks), 4-weeks, 8-weeks and post-intervention (12-weeks).

c) Body Mass Index

Body Mass Index (BMI) was calculated with the following equation:

$$BMI = \frac{Weight\ (kg)}{Height(m)^2}$$

d) Waist circumference

Waist circumference (WC) was measured with a flexible, inelastic anthropometric tape (SECA 201, Hamburg Germany). Participants were measured in a relaxed standing position, directly on their skin and with their arms crossed

on their chest. WC was measured at the end of the expiration phase at the narrowest point between the last rib and the iliac crest to the nearest 0.1 cm. Three measurements were taken, and the average used. WC was measured at four time-points during the study, at baseline (0 weeks), 4-weeks, 8-weeks and post-intervention (12-weeks).

2.3.6 Body composition

Body composition was assessed with Bioelectrical Impedance Analysis (BIA) of two points (leg-to-leg) (Tanita TBF-300, 50Khz, 90mA, Tokyo, Japan). The coefficient variation within-day impedance measurements for this method has been reported to be 0.9 ± 0.5% (mean ± SD) and the between-day was reported to be 2.1 ± 1.0% (mean ± SD) in adults (Nuñez et al., 1997). Participants were standing and barefoot after a void bladder. Percentage fat mass (% fat mass), fat mass (kg) and free fat mass (kg) were estimated. Participants were asked to not perform any physical activity 8 hours prior to the measurement, drink 500 millimetres of water the night before and again 2 hrs before the assessment, and not to consume any solid food for at least 2 hrs. Body composition was measured at four time-points during the study, at baseline (0 weeks), 4-weeks, 8-weeks and post-intervention (12-weeks).

2.3.1 Muscle strength

Muscle strength can be measured with several methods. Measurements can be static and dynamic. Static measurements involve dynamometers and tensiometers. On the other hand, dynamic measurements involve dynamic muscular contractions that can be concentric or eccentric changing the length of the muscle during it. They can be repetition maximum and isokinetic (ACSM, 2018). Some of these methods will be explained below:

a) Grip Strength

Grip strength is measured with a handgrip dynamometer. Different protocols have been created for grip strength measurement (National Institute for Health, 2016, Sousa-Santos and Amaral, 2017, ACSM, 2018). Grip strength gives a measurement of muscle function and physical capability and it is particularly relevant in the aging population. It measures isometric strength and allows to

identify muscle weakness in the upper limb ad reflects the strength of the lower limbs. There are several protocols for measuring grip strength such as the Southampton University and American Society of Hand Therapists protocols (Vaishya et al., 2024). The Southampton University protocol is the ones used in this study. Participants' cylindric grip strength was measured with a handheld dynamometer (Jamar J00105, Lafayette, IN, USA) (Figure 9). Participants were asked to sit in a chair with back support, with their forearms on armrests and their feet flat on the floor. Their wrists were just over the end of the chair arm and their thumbs were facing upwards. The dynamometer handle was set to the second slot for most participants. For those with very large hands, the dynamometer was set to the third slot. Participants were asked to hold the dynamometer with their thumb around one side and their fingers around the other side. The thumb and the fingers were visible on the same side of the dynamometer (Figure 10).

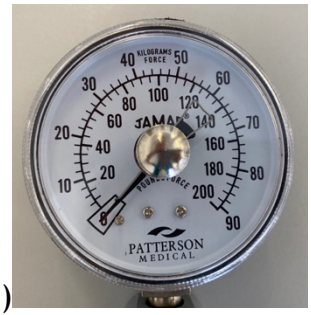
(A)  (B) 

Figure 9. JAMAR dynamometer (A) and dial (B)

Figure 10. Grip strength dynamometer holding position.

Once the participants were in the correct position, the examiner lightly supported the apparatus and rotated the red needle in the dynamometer dial to zero. The participants were asked to squeeze the handle for three seconds, and were given encouragement to do it as hard as they were able. After the three seconds, they were told to stop, and the strength was recorded in kilogram units

(kg) as indicated by the red peak needle. This was repeated three times for each hand, alternating sides (Roberts et al., 2011) . The average of the highest value recorded for both hands was used or the analysis. Grip strength was measured at four time-points during the study, baseline (0 weeks), 4-weeks, 8-weeks and post-intervention (12-weeks).

b) One Maximal Repetition

Repetition maximum is defined to be the highest resistance that a person can move in a full range of motion (ROM) with a good posture and it is used for testing muscle strength (ACSM, 2016, ACSM, 2018). One maximal repetition is considered the “gold standard” for muscle strength assessment, but there are more protocols using several repetitions. It can be done with free weights or machines. The measurement of strength will depend on the muscle group assessed (ACSM, 2018). The 1-RM test has a lot of advantages, such as eccentric actions are couples with concentric actions, reflecting the most used resistance exercises and daily life, allows multi-joint exercises and cost-effective. It also uses the same exercises that are used in the sessions and it is considered safe across multiple populations (Grgic et al., 2020). It has also bene shown that it has a very good test-retest reliability despite the previous resistance training experience, age, sex, with or without familiarisation session, single or multi-joint exercises, upper or lower muscle groups (Grgic et al., 2020).

One maximal repetition (1-RM) was measured at four time-points during the study, at baseline (0 weeks), 4-weeks, 8-weeks and post-intervention (12-weeks). To target major muscle groups in the body bench press, leg press and lateral pull down were chosen. They were measured in the following order: bench press, leg press and lateral pull down.

Firstly, the participants were shown the correct technique for each exercise and familiarized themselves with the equipment and the exercise at the beginning of the baseline measurement session. Once they were ready, they were asked to perform a warm-up of submaximal repetitions of the exercise that was being tested. An initial weight was selected, between 50-70% of the perceived capacity of each subject. Resistance (weights) was added gradually by 5-10% for upper body exercises and 10-20% for lower body exercises. Participants were

asked to perform one repetition for each weight until they were not able to complete the repetition with a complete range of motion (ROM) and speed of motion. Participants were given resting periods of 3-5 minutes between trials (ACSM, 2016). One maximal repetition has been found to have a high interclass correlation coefficient (>0.99). and high correlation (r>0.9) in untrained middle-aged individuals (Levinger et al., 2009).

Bench Press

Participants were asked to lie on a bench press (BodyCraft, MA5049B, Liverpool, United Kingdom) facing upwards with the bar in line with their shoulders. They were asked to grab the bar slightly wider than their shoulders, push it and adjust their wrists to a neutral position so that the bar felt comfortable. Participants were asked to bend their arms to at least 90 degrees of elbow flexion and push the bar up again (ACSM, 2016). The correct technique is shown in Figure 11.

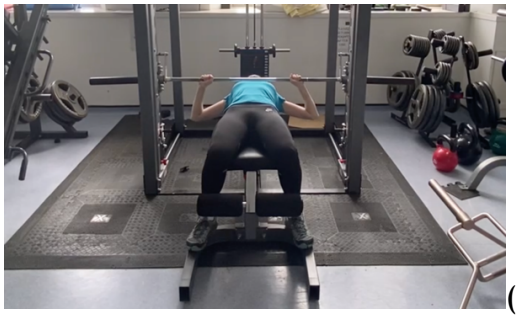

(a)

(b)

Figure 11. Bench Press exercise. Extension position (a) and flexion position (b).

Leg Press

For the leg press, a Body Max CF800 Leg Press/Hack Squat machine (Glasgow, United Kingdom) was used. Participants were seated at 45 degrees facing upwards with their feet flat on the platform surface. The seat and the platform positions were adjusted so the participants were comfortable seated. They were asked to place their feet on the platform slightly wider than their hips, as if they were performing a squat. After that, they were instructed to push the platform keeping their leg moving in line with their feet until their legs were straight and then to bring the platform back in a controlled way (ACSM, 2016). Participants were asked to not move their knees to the middle while doing the exercise, but

to always keep them straight in line with their feet. Below are some images for the correct technique for leg press (Figure 12).


(a)


(b)

Figure 12. Leg Press exercise. Extension position (a) and squat position (b).

Lateral Pull Down

Participants were asked to sit on a lateral pull down machine (BodyCraft, MA5049B, Liverpool, United Kingdom) facing the weights, and to grab the handle with both hands. The handle vertical position was adjusted for each participants height and arm length, so they could reach the handle comfortably, but not too close so that they could not do the complete ROM. Once the participants were in the right position, they were asked to pull the handle to their chest, with their elbows pointing to their waist, and then move the handle back to the top in a controlled way (ACSM, 2016) (Figure 13).


(1a)


(1b)


(2a)


(2b)

Figure 13. Lateral Pull Down exercise. Extended position front (1a), and back (1b); lateral pull down position front (2a) and back (2b).

2.3.2 Muscle Endurance

Muscle endurance can be measured in different ways, by performing a specific amount of contraction in a specific time period, or a maximal amount of contractions or by holding a contraction for a period of time. They can also be divided into static and dynamic. A static assessment consists in holding a submaximal contraction in a static position for a period of time. A dynamic test consists of using weight machines, free weights and callisthenic exercises (body weight and minimal equipment) (ACSM, 2018).

Participants performed a muscle endurance test for the bench press, leg press and lateral pull down exercises after the 1-RM test. The load used for this test was 50% of the 1-RM previously measured for each exercise at all measurement time points. Participants were asked to perform as many repetitions as they were able until the point of fatigue (they were not able to do more with the complete ROM) (ACSM, 2016). The maximum number of repetitions was recorded. Muscle endurance was measured at four time-points during the study, at baseline (0 weeks), 4 weeks, 8 weeks and post-intervention (12-weeks).

2.3.3 Muscle Thickness

Muscle thickness (MT) was measured in vastus lateralis (VL) muscle located in the thigh using an ultrasound device (Telemed LS128 CEXT-1Z, Vilnius, Lithuania). Participants were asked to rest in a supine position with their knees fully extended and without any hip rotation (neutral anatomical position) on a clinical bed. To locate VL muscle, the thigh was measured with the anterior superior iliac spine (ASIS) and the superior border of the patella as the references points. At 50% of the thigh length, the thigh circumference (TC) was measured. A mark was made from middle of the thigh to the outward (lateral) side with 10% of the TC measurement to determine the area where the probe was going to be placed (Figure 14).

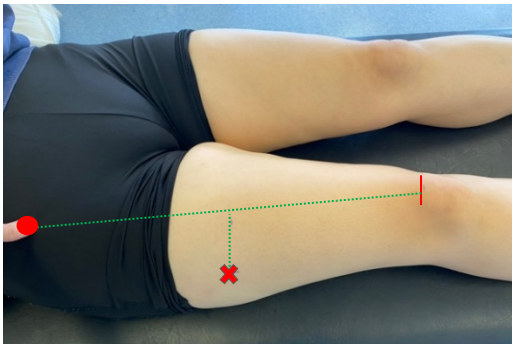


Figure 14. Ultrasound transducer position (X).

The probe was positioned on the thigh longitudinally and with the least pressure possible, and it was aligned until the ultrasound image showed the two aponeuroses clearly (Franchi et al., 2018). Both legs were assessed. Three images were taken and the VL thickness was measured in mm, and an average was used. Muscle thickness was measured at baseline (0-week) and 12-weeks.

2.3.4 Randomization and blinding

After baseline measurements, all participants were randomised 1:1 to the RE intervention group or the control group, using the closed envelope technique (Torgerson and Roberts, 1999).

Due to the nature of the exercise intervention blinding of the participants was not possible. In addition, the researcher in charge of measurements was not blinded for group allocation due to being in charge of all measurements sessions.

2.3.5 Intervention

a) Control group

The control group was asked not to change their physical activity behaviour during the study period.

b) Resistance group

The RE group was asked to engage in a home-based resistance exercise intervention for 12 weeks. Participants were asked to do one set of one exercise per day, for six days a week. The exercises were unsupervised and they could choose where to perform them (home, workplace, etc). Additionally, the participants were free to perform each exercise whenever they wanted during

the day, as long as they completed one exercise per day for six days a week. They performed six exercises (press-ups, squats, squat jumps, plank, upright row, seated row) for one minute, aiming for the maximum number of repetitions. A resistance band was used for the upright row and seated row exercises. Participants were asked to fill out a daily exercise diary (Appendix H), recording the number of repetitions performed or the time (in seconds) performed for the plank exercise.

Participants in the RE group attended a familiarisation session after their baseline measurements and before starting the exercise programme. Here, the exercise programme was explained, and the exercises were demonstrated by the researcher and practised by the participants (with feedback provided). An appropriate resistance band was selected for each participant (the thickest band they could achieve at least 2 repetitions with the correct technique for each exercise). Finally, the exercise diary was given (printed version) and instructions were given on how to complete it.

During the 4-week and 8-week measurements, participants were asked to bring their exercise diaries to check their progress and discuss their exercise programme. The researcher also changed the band if participants had plateaued in the number of repetitions performed.

2.3.6 Qualitative Interviews

Qualitative interviews were chosen to understand participants' thoughts, experiences and opinions of the exercise programme, barriers, facilitators and the ways in which they incorporated the exercises into their daily routine, because of the depth of the information they can gather. Seven RE participants took part in in-depth semi-structured interviews (duration of 35:31 $\pm$ 4:35 (mm : ss) (mean $\pm$ SD)) within a month after the end of the intervention period in their homes or online (via Zoom, due to the Government restrictions during the COVID-19 pandemic). The interviews were undertaken as part of a College of Social Sciences Strategic Research Fund Award by another researcher (Marisa Nishio (MN)) and supervised by Prof Cindy Gray (CG).

A topic guide was developed by MN, CG and MFGT to explore views, thoughts, opinions and experiences of the participants (**Appendix I**). The topic guide was developed by MN, CG and MFGT. There was an initial meeting to discuss the main topics and questions, followed by a second meeting after an interview to determine if there was anything that needed to be added or removed to the topic guide. A summarized version of the topic guide can be seen below in Table 2.

Table 2. Topic Guide Questions (summarized version).

Participation in the study	What did you think of the exercises you were asked to do? Talk me through how you did the exercises – prompt which did you do each day? Did this change over the period of the study? What helped you to do the exercises? What got in the way of your doing them?
Impact of the programme	What changes have you noticed in yourself as a result of doing the programme?
Improving the programme	We know this was not the perfect version of the programme – what changes would you suggest we should make for next time?

2.3.7 Data analysis

a) Sample size and power calculation

A previous investigation has reported an 8.7 kg increase for muscle strength for 5RM bench press after a 6-month resistance exercise training of 1 set per session 3 times a week (Radaelli et al., 2015). With a 9.9 kg SD for 5RM bench-press post-intervention (Radaelli et al., 2015), power of 80% and an alpha of 0.05, groups of 22 participants were needed. Considering 20% of drop out during the study, we planned to recruit 27 participants per group, with a total of 54 participants.

b) Statistical analysis

The primary outcomes were the change in 1-RM for bench press, leg press and lateral pull down between baseline to 12-weeks. Secondary outcomes were the change in 1-RM for bench press, leg press and lateral pull down from 0 to 4 weeks, from 4 to 8 weeks and from 8-12 weeks; and changes in grip strength, muscle endurance in bench press, leg press and lateral pull down, on weight, WC, fat mass and free fat mass over the 12 weeks.

For the final sample size in the analysis, participants with only baseline measurements were excluded. Participants with up to 4-week or 8-week data were included, and the last value was carried forward to 12-weeks. Participants with missing data for the 4-week or 8-week assessment had the value interpolated, using the average of the baseline and 8-week values, and 4-week and post-intervention values, respectively. The final sample size was 23 participants (19 female, 4 male). From the 23 participants, 10 were allocated to the RE group (8 female, 2 male) and 13 to the control group (11 female, 2 male).

Stata 18® was used for the statistical analysis. Normality tests were not used due to the sample being below 30 participants. Differences between groups in these measures were assessed by 2-way ANOVA (group x time) with repeated measures on the time factor. A $p<0.05$ was used to determine any statistical difference. A post-hoc analysis for trend was done if there was any significance found. The data is presented as mean $\pm$ SD or mean $\pm$ SEM depending on the variable. Sphericity was tested with Mauchly's test.

2.3.8 Qualitative analysis

This thesis started with a post-positivist ontology, looking at the validity and reliability of the experimental research by using lab-based methods to test hypotheses (Moon et al., 2021, Moon and Blackman, 2014). However, this thesis epistemology has shifted to also value the subjectivity (Moon and Blackman, 2014).

Qualitative interview data were transcribed by an external company approved by the University of Glasgow (1st Class Transcription Services). Anonymised transcripts were analysed by MN, supported by CG to ensure analytic rigour, using an adapted Framework approach (Ritchie *et al.*, 2003) to determine participants' perceptions, feelings, thoughts, enjoyment, tolerance and acceptability of the resistance exercise programme. We used an adapted Framework analysis because it is an appropriate method due that all researchers are trained in it and are familiar with it. This method allows transparency among the researchers and facilitates team work in every stage of the analysis.

NVivo 12 ® software was used. Initially, researchers MN, CG and MFGT read three transcripts separately and then, in a meeting, agreed on the codes. Thirteen codes exploring participants' experience, thoughts and acceptability of the flexibility and resistance exercise programmes were found. A codebook was developed for the thematic analysis by MN, MFGT and CG (**Appendix J**). The list of codes can be seen below in Table 3.

Table 3. Codes for thematic analysis ONE Study.

Codes	
• Physical activity before the study	• Motivators for physical activity
• Reasons for joining the study	• Barriers and facilitators
• Instruction and learning	• Health
• Programme of daily life and planning	• Suggestions for the programme
• Perceptions of the programme	• Selling the programme
• Self-monitoring	• Other
• Impact of the programme	

The process of analysis was deductive in order to focus on the aim to determine participants' perceptions, feelings, thoughts, enjoyment, tolerance and acceptability of the resistance exercise programme.

Then MN proceeded to code all interviews according to the codebook. After that MN proceeded to develop a Theory of Change for the resistance exercise programme with an inductive process. This was reviewed between all researchers (MN, CG and MFGT) and is presented in the results section in a diagramme. A Theory of Change is an evaluation that allows the evaluator to understand what is being implemented and the reasons behind it, by making connections between the intervention and the outcomes (Cobb et al., 2003). Developing a theory of change helps a team to reach an agreement on the assumptions and then be incorporated into an explicit product (diagramme) (Anderson, 2005) to guide planning, implementation and evaluation (Reinholz and Andrews, 2020). The project constantly considers and revises the theory of change (Reinholz and Andrews, 2020). Firstly, it is necessary to recognize the context in which the change will occur. After that, the team undergoes a process of backward mapping focusing on the long term outcomes that they want to achieve. This long term outcome will be accomplished after a medium term and short term outcomes are achieved. Finally, the team defines the assumptions and the linkages between all the elements. A theory of change is

normally showed in a visual representation in a diagramme (Reinholz and Andrews, 2020).

Additionally, the codes “Perceptions of the programme” and “Suggestions for the programme” were carefully read by MFGT in order to develop the second phase of the thesis (Chapter 3: REFLEX Study).

2.4 Results

2.4.1 Descriptive outcomes

Baseline descriptive outcomes for the entire sample, the control group and RE group are presented in Table 4 and training descriptive outcomes can be seen in Table 5. There were no significant differences at baseline between groups for age, body mass and BMI.

Table 4. Baseline descriptive outcomes ONE Study.

	Overall (N=23)		Control group (N=13)		RE group (N=10)	
	Mean ± SD	Min - Max	Mean ± SD	Min - Max	Mean ± SD	Min - Max
Age (years)	40.04 ± 14.09	19 - 65	42.69 ± 12.66	23 - 60	36.60 ± 15.74	19 - 65
Body Mass (kg)	70.90 ± 15.28	49.95 – 106.00	69.70± 16.24	49.95 – 106.00	72.45± 14.63	56.55 – 95.25
BMI (kg/m^2)	25.33 ± 5.59	17.60 – 41.60	25.60 ± 6.26	19.30 – 41.60	24.99 ± 4.89	17.60 – 33.10

Abbreviations: RE (resistance exercise), SD (standard deviation), BMI (Body Mass Index).

Table 5. Training descriptive outcomes ONE Study.

	RE group (N=8)
Volume (Mean ± SD)	
Total number of sessions completed	69 ± 5.3
Percentage of sessions completed (%)	92.3 ± 10.9
Exercises completed (Mean ± SD)	
Squat	11.9 ± 0.4
Seated Row	11.0 ± 2.8
Upright Row	11.9 ± 0.4
Plank	11.5 ± 1.1
Push-ups	11.4 ± 1.4
Squat Jump	11.5 ± 0.8

Abbreviations: RE (resistance exercise), SD (Standard deviation).

2.4.2 Anthropometric outcomes

The values for body mass, BMI and WC for all time points can be seen in Table 6. There were no significant differences over time or any significant group*time interactions ($p>0.05$), and therefore the post-hoc analysis for trends was not used. Post-hoc analysis for trend was not used due to the lack of significance differences between groups over time. Sphericity assumption was met.

2.4.3 Body composition outcomes

The values for fat mass and fat free mass for all time points can be seen in Table 7. Significant groups*time interactions were found for fat free mass. Post-hoc analysis for trend showed a significant linear trend for the control group ($p=0.009$). The control group experienced a decrease in fat free mass (1.11 kg) between baseline and post-intervention. There were no significant differences over time for fat free mass and fat mass, or any significant groups*time interactions for fat mass ($p>0.05$). Post-hoc analysis for trend was not used due to the lack of significance differences between groups over time. Sphericity assumption was met.

Table 6. Anthropometric outcomes during the study programme.

	0-weeks (mean ± SEM)	4-weeks (mean ± SEM)	8-weeks (mean ± SEM)	12-weeks (mean ± SEM)	Time *p*-value	Group*Time *p*-value
Body Mass (kg)						
Control group	69.70 ± 4.50	69.47 ± 4.55	69.54 ± 4.53	69.62 ± 4.55	0.639	0.668
RE group	72.45 ± 4.63	72.50 ± 4.39	72.67 ± 4.43	72.96 ± 4.41		
BMI (kg/m^2)						
Control group	25.59 ± 1.74	25.502 ± 1.76	25.54 ± 1.76	25.57 ± 1.77	0.617	0.655
RE group	24.98 ± 1.55	25.01 ± 1.47	25.07 ± 1.49	25.18 ± 1.51		
Waist circumference (cm)						
Control group	82.06 ± 3.90	81.59 ± 3.99	81.52 ± 3.67	81.62 ± 3.79	0.583	0.925
RE group	81.30 ± 3.12	81.31 ± 2.94	80.79 ± 2.96	80.93 ± 3.12		

Control group N=13, RE group N=10. *p-value < 0.05, statistical significance. Post-hoc analysis was not used due to not finding any significance in ANOVA analysis.

Table 7. Body composition during the study programme.

	0-weeks (mean ± SEM)	4-weeks (mean ± SEM)	8-weeks (mean ± SEM)	12-weeks (mean ± SEM)	Time *p*-value	Group*Time *p*-value
Fat Mass (kg)						
Control group	21.99 ± 3.43	21.89 ± 3.48	22.15 ± 3.55	22.96 ± 3.47	0.565	0.264
RE group	22.85 ± 3.68	22.49 ± 3.63	22.42 ± 3.62	22.42 ± 3.56		
Fat Free Mass (kg)						
Control group ⊥	47.24 ± 1.91	47.08 ± 1.91	46.87 ± 1.87	46.14 ± 1.67	0.894	0.025*
RE group	49.20 ± 3.37	49.53 ± 3.36	49.69 ± 3.34	50.01 ± 3.31		

Control group N=13, RE group N=10. *p-value < 0.05, statistical significance. (⊥) Post-hoc analysis for trend p<0.05.

2.4.4 Muscle strength

a) Grip strength

The values for grip strength for each time point can be seen in Table 8. There was an overall significant effect of time for grip strength (p=0.002), but there was no significant difference between groups through time (group*time interaction). Post-hoc analysis for trend was not used due to the lack of significance differences between groups over time. Sphericity assumption was met.

b) One maximal repetition

The values for 1-RM bench press, 1-RM leg press,1-RM lateral pull down and 1-RM total sum for each time point can be seen Table 8. There was an overall significant effect of time for 1-RM leg press (p=0.012) and 1-RM total sum (p=0.002), but there were no significant differences between groups over time (group*time interactions). Additionally, there were no overall significant effects of time or any significant differences between groups over time (group*time interactions) for 1-RM bench press and 1-RM lateral pull down. Post-hoc analysis for trend was not used due to the lack of significance differences between groups over time. Sphericity assumption was met.

2.4.5 Muscle endurance

The values for muscle endurance bench press, leg press, lateral pull down and total sum for each time point can be seen in Table 9. There was a significant overall effect of time for muscle endurance in leg press, lateral pull down and total sum, however, there were no significant differences between groups over time (group*time interactions). Additionally, there were no significant overall effect of time or any significant differences between groups over time for muscle endurance in bench press. Post-hoc analysis for trend was not used due to the lack of significance differences between groups over time. Sphericity assumption was met.

Table 8. Muscle strength outcomes during the study programme.

	0-weeks (mean ± SEM)	4-weeks (mean ± SEM)	8-weeks (mean ± SEM)	12-weeks (mean ± SEM)	Time *p*-value	Group*Time *p*-value
Grip Strength (kg)						
Control group	28.63 ± 1.61	29.90 ± 1.58	29.07 ± 1.74	31.86 ± 1.95	0.002*	0.073
RE group	30.93 ± 4.10	32.23 ± 3.60	32.33 ± 3.83	32.15 ± 3.70		
1-RM Bench Press (kg)						
Control group	35.82 ± 3.04	35.79 ± 2.60	35.44 ± 2.35	36.35± 2.48	0.065	0.119
RE group	34.20 ± 4.53	37.48 ± 5.24	38.20 ± 5.74	39.65 ± 6.13		
1-RM Leg Press (kg)						
Control group	142.54 ± 8.09	134.20 ± 9.04	147.25 ± 7.41	156.40 ± 10.0	0.012*	0.425
RE group	150.00 ± 16.1	158.00 ± 16.30	163.80 ± 16.50	166.00 ± 15.30		
1-RM Lat Pull down (kg)						
Control group	28.08 ± 1.82	29.33 ± 1.62	29.99 ± 1.73	33.43 ± 3.44	0.139	0.625
RE group	31.90 ± 3.29	32.18 ± 2.82	32.46 ± 2.73	33.37 ± 3.00		
1-RM Total Sum (kg)						
Control group	206.40 ± 11.20	199.30 ± 12.00	212.68 ± 9.83	226.20 ± 12.60	0.002*	0.432
RE group	216.10 ± 22.00	227.70 ± 23.50	234.40 ± 23.60	239.00 ± 23.10		

Control group N=13, RE group N=10. Abbreviations: 1-RM (One maximal repetition), 1-RM = the sum of 1-RM bench press, 1-RM leg press and 1-RM lat pull down. *p-value < 0.05, statistical significance. Post-hoc for trend not used due to the lack of significant group*time interactions.

Table 9. Muscle endurance outcomes during the study programme.

	0-weeks (mean ± SEM)	4-weeks (mean ± SEM)	8-weeks (mean ± SEM)	12-weeks (mean ± SEM)	Time *p*-value	Group*Time *p*-value
ME Bench Press (reps)						
Control group	18.79 ± 2.26	18.73 ± 2.19	19.08 ± 1.74	18.92 ± 1.53	0.112	0.094
RE group	22.30 ± 3.06	25.35 ± 3.37	21.50 ± 2.53	27.60 ± 4.60		
ME Leg Press (reps)						
Control group	43.07 ± 6.09	44.97 ± 3.61	54.77 ± 4.88	57.00 ± 5.57	0.001*	0.776
RE group	39.90 ± 6.32	47.45 ± 7.98	53.30 ± 8.63	63.10 ± 14.60		
ME Lat Pull down (reps)						
Control group	40.63 ± 3.15	41.07 ± 4.34	41.85 ± 3.13	44.31 ± 3.34	0.039*	0.417
RE group	40.00 ± 4.05	38.70 ± 3.70	42.10 ± 4.43	52.10 ± 8.60		
ME Total Sum (reps)						
Control group	102.49 ± 8.08	104.77 ± 4.65	115.69 ± 6.59	120.23 ± 6.58	0.0001*	0.322
RE group	102.20 ± 10.60	111.50 ± 11.20	116.90 ± 12.80	142.80 ± 22.00		

Control group N=13, RE group N=10. Abbreviations: ME (Muscle Endurance). *p-value < 0.05, statistical significance.

2.4.6 Muscle thickness

There were no significant differences between groups between baseline and 12-week measurements for muscle thickness (Control 0.09 ± 0.22, RE 0.40 ± 0.30 (mm); p = 0.420). The means and SEM for muscle thickness for baseline and post-intervention can be seen in Figure 15.

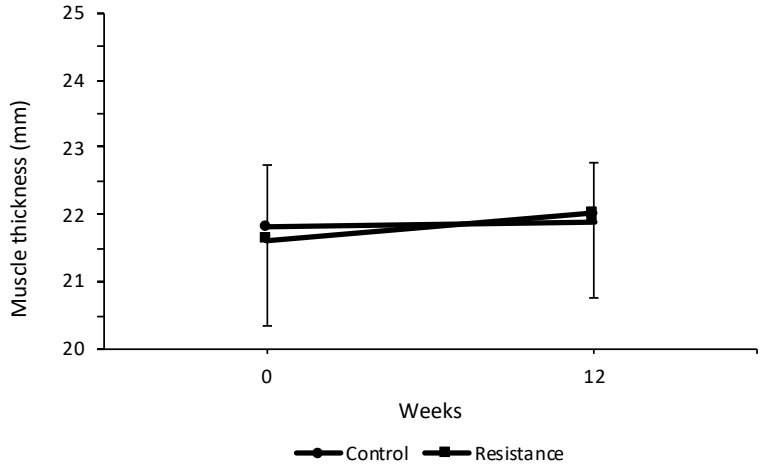


Figure 15. Muscle thickness before and after the programme, mean (SEM).

2.4.7 Adverse events

Two adverse events were reported during the ONE Study programme. One participant reported mildly injuring her shoulder outside of the exercise programme between the 4-week and 8-week measurement sessions, which stopped her from doing the 8-week upper limb measurements and the completion of upper limb exercises between 4-week and 8 week. The participant was able to take her measurements for the 12-week session. The other participant expressed pain in her right hip while performing the 1-RM leg press measurement during the 8-week visit. Measurements for the lower limb were immediately stopped and the participant was encouraged to seek medical advice. After a medical visit, the participant reported being diagnosed with osteoarthritis in her right hip. The participants did not perform the lower limb exercises (squats) for the rest of the programme and the 12-week lower limb measurements were not taken. No other adverse events were reported.

2.4.8 Qualitative results

Thirteen codes exploring participants' experience of the intervention were identified (Table 3). Seven themes were found such as convenience, enjoyment, sense of achievement, the benefit of the exercise, participants' highlights of the intervention and suggestions for the programme. Quotes have been extracted to illustrate each theme. Participants' characteristics are presented as RE group, gender, and age range to ensure anonymity.

a) Convenience

Most of the participants thought that the programme was convenient because it was not necessary to change clothes, the exercises were easy to do and it only required a small time commitment, which made it easier for them to fit it into their daily retunes.

> "I would say it's really easy to do, really easy to take part, so there's not really any excuse to not do it, because if you're going to get benefits from it, we have 24 hours in one day and this is only a minute, so it's a gift really." (RE group, female, over 45 years old)

One participant said that as a result of the exercise being convenient because of being quick to do, she felt a sense of achievement which motivated her to do the exercises because the exercise was quick to do.

> "So I guess this, by making it so short, and it felt like I was kind of achieving something very small but making progress, I guess, and even though it was so short and… Yeah, so I think being so precise and…I think that was quite motivating actually." (RE group, male, between 25-45 years old)

b) Enjoyment

Participants expressed enjoyment as a result of the programme. This sense of enjoyment was due to the resistance bands and how they made them feel a higher physical challenge and progression. One participant expressed that the challenge of the squats (bodymass exercise) made them feel a sense of achievement because they could feel the immediate effect on their muscles.

> "I loved the bands, I liked the resistance bands…I don't know that my numbers improved a lot. I know that she changed the bands part way

through to make them more resistant but I just enjoyed that." (RE group, female, over 45 years old)

"I just enjoyed doing the squats because it made me…you could feel the burn from the muscle just doing one minute of squats and I felt that I achieved something. I felt I was using the muscle, I felt the muscle burn. So I knew it was working." (RE group, female, over 45 years old)

c) Sense of achievement

Some participants observed in themselves a sense of achievement. This feeling of achieving something was driven by their improvement in muscle strength and being able to complete exercise sessions that were convenient for their short time commitment. Furthermore, the exercise diary allowed the participants to self-monitor their performance during the exercise programme which gave them this achievement feeling when looking at their improvement.

"Having something just to record what I was doing was…it made a lot of difference, whereas if I was just doing the exercises and not writing it down at all, for a start I wouldn't see any progress. Like when I looked at the diary at the end, I saw that for the most part the reps that I was able to do did go up, like week by week and I wouldn't have had that kind of sense of like progress and achievement if I didn't have the diary." (RE group, female, younger than 25 years old)

d) Benefits of the exercise

Participants experienced different health benefits as a result of participating in the exercise programme. An improvement in performance reflected in their measurement sessions improved some participants' mood.

"I really liked when I went for my check-ups that I could see improvement, even though I felt like I actually hadn't improved much in the strength of my lifts and press-ups had improved, so that was really satisfying to see, I was really pleased with that, it definitely improved my mood at that time. Yeah, I think I was satisfying, yeah." (RE group, female, younger than 25 years old)

Also, the improvement in muscle strength and feeling happier led some participants to feel better and be pleased. Finally, the programme led participants to have energy and an improved sleep quality.

> "I felt better, much better because it had been a while and I was definitely happier and I felt much stronger too. So that was really nice to just have that intensity and kind of see the changes that came in through that, so that was really nice." (RE group, female, between 25-45 years old)

e) Theory of Change resistance exercise

All the previous results can be reflected in a theory of change diagramme developed for home-based resistance exercise programme (Figure 16). It shows how the aspects of the intervention helped the participants to do their exercise, improve their muscle strength and endurance, and keep exercising and maintain the improvements obtained as a long-term goal. The outcomes of the Theory of Change are defined below:

- **"Home" environment:** Participants' descriptions of the environment in which the programme PA had been conducted.

- **Familiarity:** Participants' descriptions of having previous experience or being familiar with the programme's exercises.

- **Confidence:** Participants' descriptions of their thoughts regarding how well they were doing the programme's exercises.

- **Competence:** Participants' subjective fact of how well they performed the programme.

- **Enjoyment:** Participants' thoughts and opinions about having a good time with the programme in some way or other or liking something from the programme.

- **Convenience:** Participants' thoughts about the simplicity and easiness of the programme— requiring no gear or preparation, involving no complex physical movements, time commitment, etc.

- **Optimal challenge:** Participants' subjective sense of having a manageable set of exercises as the programme.

- **Physical Capability:** Participants' physical capacity to engage in the programme.

- **Achievement:** The sense of accomplishment gained from performing the exercise programme as described by participants.

- **Progression:** Participants' subjective opinions, feelings and ideas regarding their improvement of doing programme PA.

- **Physical and mental benefit of exercising:** Participants' mentioning of physical and/or mental benefits they experienced due to participating in the in the programme.

- **Autonomy:** The fact that the participants could decide which exercise to do and when to perform it.

- **Fitting in the exercise daily routine:** Participant's experience of making the programme part of their daily routine.

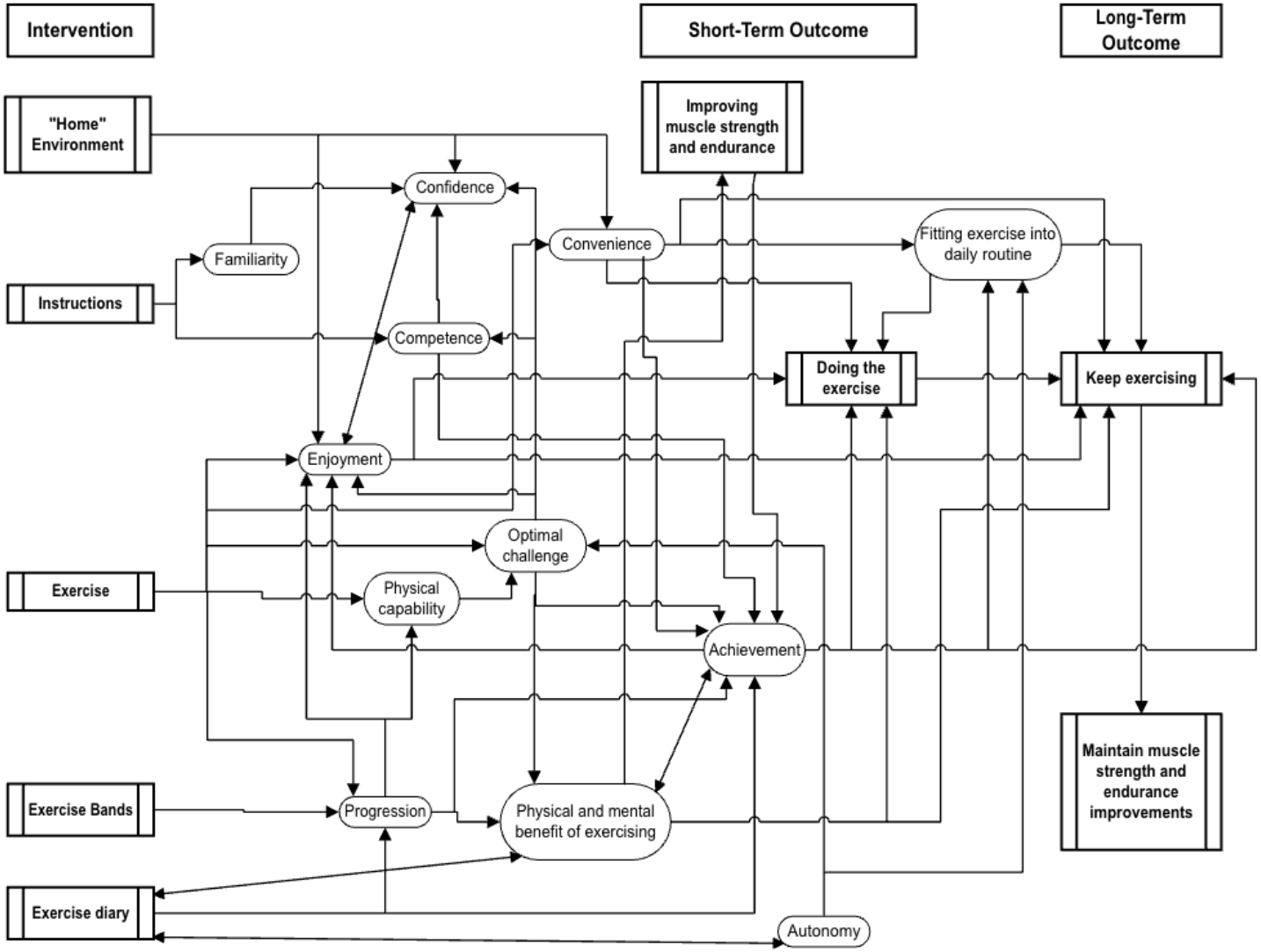


Figure 16: Theory of change ONE Study.

f) Participant's highlights of the programme and suggestions for the programme

A participant reported that the exercise programme was accessible for people who do not go or cannot afford to go to the gym.

> "…you can just do things from home, like only your hands and feet, basically, instead of using heavy machinery and equipment and numbers they do at the gym. So accessibility, it's kind of an accessible programme versus not everyone goes to the gym or can afford to go to a gym. It's like a socioeconomic aspect as well." (RE group, female, between 25-45 years old)

Additionally, participants reported liking that the exercise programme had one day of rest.

> "I: So the exercise was six days a week, right?
>
> P: Yes.
>
> I: So what did you think about this schedule?
>
> P: It was fine, it was fine. I took a Sunday off and did the exercises every day other than a Sunday." (RE group, female, over 45 years old)

Also, it was reported that having progression with different exercise bands (different thicknesses) was a good thing about the programme.

> "I: How many times did you change the band?
>
> P: Once, so I had, I think the thinnest one and then I think when we came to change the band, I think we did miss one in the middle out maybe and it went onto the orange band… It was definitely more difficult after the band changed. I saw a notable difference like in the numbers. It took quite a dip when the band changed which at first I was like, oh, that's…I was kind of getting a bit worried about it thinking like, should I still be doing…but like eventually I was like, you know what, it's a different weight, it was bound to go down a bit. So after I got over that, it was like it was good to have like a new challenge because the older band, it got to a point where it wasn't that difficult to be doing the exercises with it. So I had to change it and have like a challenge in it to be like you could feel your muscles working when you were using that one. It was quite nice." (RE group, female, younger than 25 years old)

On the other hand, participants reported several suggestions for the exercise programme. One suggestion was having more variety in the exercises.

> "…maybe having a bit of variation would have been nice… Like do some more, some different kind of exercises as well, maybe do side planks as well or something like that" (RE group, female, between 25-45 years old)

Some participants suggested having more difficult exercises, thicker resistance bands and a higher volume of exercise.

> "When it comes to squats and the resistance band ones, I think they could probably be made more difficult or even with the resistance band we could maybe start on a higher band because the first one like especially when you were doing the upright roll, like it's not even doubled over so there's not a lot of resistance. I think we could probably cope with like a higher one." (RE group, female, younger than 25 years old)

> "I did feel that I had kind of plateaued. So I feel like maybe if they would be incremental, so I guess starting with one minute and building up to three or five… But I think, yeah, as a matter of increasing either the number of reps or the time, whichever one is highest" (RE group, female, between 25-45 years old)

Finally, one participant expressed that he would have liked to choose how to fit the exercise into his everyday life instead of having a routine set up from the beginning.

> "I quite liked the concept of a rest day, I guess. But I guess on the flip side I know a little bit about building habits and things; and they do say that doing something every single day is better for building in that habit. I think I would have preferred it to have had a fixed day of the week, and just go, right, I'm going to do it every day apart from that day, and then stick to a routine; but I'm not the best at routines, and it ended up being pretty much that I was just trying to do it every day, and if I forgot then I'd go, okay, that's fine, that's the day off. So it was just a little bit of a catch-up day. But that probably wasn't helpful at actually me sticking to it. So yeah, it may…I don't know, I'm not sure exactly, but it may have been better for me just to have had been aiming to do it every day, but just I guess knowing that maybe once every now and then I might forget, but just to just skip it. But then that would maybe have ended up with one day a week anyway, or maybe less." (RE group, male, between 25-45 years old)

2.5 Discussion

There were no significant differences in muscle strength between the RE group and the control group after a 12-week home-based resistance exercise programme. Additionally, there were no significant between-group differences for muscle endurance.

There is mixed evidence regarding the effect of a home-based resistance exercise programme on muscle strength. A pilot single group before-and-after study by Kikuchi et al (2023) found that an online low-load eight-week resistance training (twice a week, 2-3 sets, 5-10 reps) programme in adults (N=39) significantly increased the number of push-ups performed, vertical jump height and the chair stand test. On the other hand, it did not find any differences in muscle voluntary contraction for the knee extensors (Kikuchi et al., 2023). Additionally, an RCT showed that a home-based resistance programme did significantly improve the number of completed push-ups in the intervention group compared to the control group, while finding no differences between groups in grip strength. This programme consisted of 32-weeks with 3 sessions per week, with each session of between 1 to 3 sets per week, each set to voluntary muscular failure (Al Ozairi et al., 2023). Both studies measured the number of push-ups while the ONE Study measured 1-RM, so they need to be considered with caution due to havi8ng different outcome measures and different protocols. Thirdly, another RCT found that a 6-month resistance exercise programme with 3 sessions per week and one set per session in young healthy men significantly increased the 5RM compared to the control group (Radaelli et al., 2015). The length of these programmes (8 weeks, 32 weeks and 6 months respectively) are different and the volume that was prescribed per week in both programmes is higher than the ONE study, which could explain the differences with our results.

A pilot study in elderly adults between 65-80 years old, looked at the effects of a home-based resistance exercise snacking programme on anthropometry, body composition, muscle function and size. Participants were asked to perform two bouts (one in the morning and another in the evening) of one minute for 5 exercises a day for 28 days. The muscle function results are similar to the ONE study results, though muscle function was measured with a leg dynamometer,

while our study measured muscle strength with 1RM and muscle endurance as the number of repetitions achieved with 50% 1RM (Perkin et al., 2019).

While the ONE study did not show any statistically significant differences in the strength outcomes, a recent meta-analysis of the effects of home-based resistance exercise in older adults including 17 studies and a sample of 1477 participants showed that the single-mode strength training analysis showed significant small effects on muscle strength (standardised mean differences = 0.30 ([0.12 to 0.48); $p < 0.01$) (Chaabene et al., 2021).

The ONE study did not find significant differences between groups for muscle thickness. Perkin et al. (2019) did not find significant differences in thigh muscle cross-sectional area, but it did have a large size effect of 0.96. These findings could mean even though the study was underpowered, there is a potential efficacy of resistance exercise snacking to improve leg power and muscle size (Perkin et al., 2019). While the ONE study also did not find any significant differences in muscle thickness, Perkin et al found a large size effect. This could be due to the differences in measurements, muscle thickness of the vastus lateralis with ultrasound compared to tomography to measure thigh cross-sectional area, and to differences in the samples, adults compared to elderly. The differences in the sample are relevant, since the elderly experience larger effects, due to having lower baselines than younger adults. Additionally, the ONE study only asked participants to perform one minute of RE a day for six days (6 minutes per week) instead of two bouts of one minute for five exercise per day (70 min per week). These results indicate that the volume of this kind of exercises needed to produce an increase in muscle mass and muscle strength in healthy adults is more than the one in the ONE study.

There were no significant differences between groups for any of the anthropometric outcomes. On the other hand, the ONE study found a significant increase in Fat Free Mass in the resistance exercise group, compared to the control group. Different results have been found by Olzairi et al. (2023) where a home-based resistance exercise increased lean mass in arms and legs of type 2 diabetic adults, but not whole-body fat-free mass (Al Ozairi et al., 2023), which is the opposite of the present study. In addition, Perkin et al. (2019) did not find any differences for DXA measured body fat and total lean mass between the

exercise snacking group and the control group after a 28-day home-based resistance exercise programme (Perkin et al., 2019). Free Fat Mass in the One study was measured with bioimpedance, while in the other studies, it was measured with an iDXA and DXA, which could explain the differences in the results. A previous study comparing BIA and DXA measurements in body composition outcomes has found that there was a small bias in patients, especially the ones with BMI 16-18. It suggested that at a population level both methods are interchangeable, however, they lack concordance at the individual level, irrespective of BMI (Achamrah et al., 2018).

Even though there were no significant changes in muscle strength and endurance, ONE study participants reported perceived improvements in their performance and muscle strength due to the programme during their qualitative interviews. This could indicate that the changes that the participants experienced were not enough to show significance, which could also be explained by the study being underpowered. Additionally, participants reported improvements in energy and sleep quality, but these have not been measured as part of the battery of tests used in this study.

Similar qualitative results to the ONE Study have been found in the literature. A study by Vikberg et al. (2022) looked at the feasibility of a 10-week online home-based resistance exercise programme in older adults (3 times a week, 45/min per session). It showed that having a programme that was easy to follow, clear instructions and having the flexibility of the environment and the timing of the exercise were all important for the participants. Additionally, participants described the exercise progression as good and they did not find the training time consuming. Finally, the participants also reported improvements in muscle strength and feeling joyful and satisfied with themselves for completing the training (Vikberg et al., 2022).

Another study on young women reported a feeling of achievement and skill acquisition in the resistance exercise group that was reflected by them enjoying the challenge of the resistance exercises and the progression of weights (Lambert et al., 2020). Finally, another study by Fyfe et al. (2022) looked at the feasibility and acceptability of a remotely delivered, home-based resistance exercise “snacking” programme. It showed that having brief and frequent

exercise sessions allowed the integration of the programme into the participants' daily routines. This programme needed minimal equipment which improved the feasibility of the programme (Fyfe *et al.*, 2022), which was similar to the ONE study qualitative results and is reflected in the theory of change.

Similarly to the ONE Study, some studies have found that participants expressed enjoyment, a sense of wellbeing (Tulloch et al., 2013) and that the programme was convenient (Vikberg et al., 2022). Additionally, it has been found a sense of achievement, a sense of wellbeing, (Tulloch et al., 2013) having the physical and mental benefits of the exercise are motivators and facilitators to perform resistance exercise (Vasudevan and Ford, 2022, Burton et al., 2017).

This study has limitations. Firstly, it was significantly underpowered due to pausing recruitment during the COVID-19 pandemic, with only half of the needed sample recruited. Secondly, there were some participants who missed sessions and dropped out. Due to this, we use interpolated data with an already small sample. On the other hand, some of the strengths of this study are that this is the first study to explore such a low dose of resistance exercise, the measurements of muscle strength and muscle endurance since they are the gold standard to measure these outcomes. In addition, the exercise programme was simple and easy to follow, all exercises were demonstrated and the researcher made sure each participant was performing the exercises correctly.

This study looked at the effects of a lower dose of resistance exercise in the format of a home-based programme with body mass and band exercises, to overcome some of the barriers to resistance exercise and improve adherence. Even though the study was underpowered, the idea of one-minute bout per day for six days a week does not seem to work. More studies using home-based programmes exploring more doses, such as 2 or 3 sets per muscle group per week are needed in the future. This will increase the knowledge of home-based programmes and might contribute to increasing adherence to muscle-strengthening activities in adults.

2.6 Conclusion

A 12-week home-based exercise programme of one minute a day 6 days a week did not produce any significant changes in muscle strength, muscle endurance, muscle thickness, anthropometry and fat mass, but it did significantly increase free fat mass. Additionally, it showed that perceived enjoyment and a sense of achievement, convenience and experiencing the benefits of the exercises are essential to keep exercising in the long term in order to maintain the improvements of muscle strength and endurance obtained. More home-based resistance exercise studies with higher doses and with designs that overcome resistance exercise barriers are needed to determine the effects of home-based resistance exercise programmes in healthy adults muscle strength and to explore more ways of increasing the adherence to muscle-strengthening guidelines.

Chapter 3 Effect of a home-based REsistance exercise vs a home-based FLEXbility exercise programme on muscular endurance and flexibility in healthy adults (REFLEX).

COVID 19 Statement:

The study described in this chapter was devised and undertaken in response to the COVID-19 pandemic preventing any face-to-face research interactions from being possible for most of 2020 and 2021. This meant that the ONE study had to be paused mid-data collection and the Mechanisms of Insulin Resistance in South Asians (MIRSA) trial which was originally meant to form a major part of my PhD was postponed and not forming part of my PhD. Development of the REFLEX study started in April 2020 and ethics approval was obtained on 5th August of 2020. The first group of participants recruited started the programme in September 2020 and finished in December 2020, and this formed the first sample. This initial work identified challenges with accurately making assessments of muscular strength via online video call measurements. The measurements of outcomes were therefore modified and an ethics amendment was submitted and approved. More details are explained in the Methods Section. Additionally, due to the same restrictions the exercise programme was delivered through a web app and the qualitative interviews were also online with a video call. Participant recruitment started once again in January 2021 and finished in September 2021. Data collection started in January 2021 and finished in December 2021. These participants formed the second sample.

3.1 Introduction

Regular resistance training can lead to a range of health benefits including increases in muscle size and strength (Saric et al., 2018), reductions in body fat, increased metabolic rate, improved glycaemic control, decreased blood pressure, improved blood lipid profiles, reduced blood pressure, increased flow-mediated dilatation and increased cardiorespiratory fitness (Kraemer et al., 2002, Ashton et al., 2020). As a result, National and International physical activity guidelines recommend undertaking muscle strengthening activities involving major muscle groups two days a week or more, alongside at least 150-300 minutes per week of moderate intensity physical activity (or 75-150 minutes per week of vigorous intensity physical activity) (Department of and Social, 2019, WHO, 2022b). However, in England, while 70% of men and 59% of women 16 years old or over met the guidelines for aerobic exercise, only 36% of men and 29% women achieve the guidelines for muscle-strengthening exercise in 2021 (NHS Digital, 2023). Similarly, in Scotland 73% of men and 65% of women 16 years old or over met the guidelines for aerobic exercise, but only 38% of men and 32% women achieved the guidelines for muscle-strengthening exercise and MVPA in 2021 (Birtwistle et al., 2021).

As it was mentioned in the previous chapter, people identify several barriers including the lack of time (Trost et al., 2002, Hurley et al., 2018, Vasudevan and Ford, 2022), the effort involved (Trost et al., 2002, Hurley et al., 2018), lack of purpose, pain due to injury, negative experiences of prescriptive exercise, apathy (Hancox et al., 2019), illness and work commitment (Tulloch et al., 2013). Furthermore, other barriers have been expressed by women, such as worrying about looking ‘manly’ or ‘bulking up’ if they undertake resistance exercise (Dworkin, 2003, Vasudevan and Ford, 2022), family constraints, financial barriers (purchasing equipment or gym membership), unavailability of equipment in the community or home, lack of supervision, lack of support, inadequate knowledge, risk of injury, social stigma, gender-based barriers, boredom (Vasudevan and Ford, 2022), looking weak, not being comfortable in crowded gyms, around men or doing resistance exercise alone, taking too much time and excessive tiredness (Peters et al., 2019).

Thus, identifying approaches to find a safe, enjoyable and accessible programme that minimises the burden of performing resistance exercise is a key issue which could help more people to undertake muscle-strengthening exercises.

The frequency of resistance exercise recommended by the ACSM for optimal gains in muscle size and strength is two to three times per week (ACSM, 2016). However, the gain obtained from doing one session per week is bigger than the gains from doing from one session to two session per week or from two sessions to three sessions per week and so on (Westcott, 2009). Substantial increases in strength (~20%) have been observed with a single session of resistance exercise per week if it is performed to momentary failure; in this context, the specific load does not appear to influence the magnitude of the adaptations (Ismail et al., 2019). Furthermore, it has been found that the frequency of resistance exercise does not influence the magnitude of change in strength or hypertrophy if the volume of exercise (sets per week) is equated (Gentil et al., 2018, Grgic et al., 2018a). Additionally, it has been discussed that even though low volume and high load is effective for increasing muscle strength it can be impractical for remote interventions with limited equipment or untrained participants (Fyfe et al., 2022b).

Thus, a single set of exercise per muscle group per week appears to be an effective dose for adaptation, and programmes using this approach could potentially address the barrier of a lack of time. However this in itself, does not necessarily help overcome the need for access to a gym facility with strength training equipment. Developing protocols that can be performed at home may help with this. Most of the evidence in the literature for home-based resistance exercise comes from studies in older adults (>65 years)(Brandão et al., 2018, Hancox et al., 2019, Kis et al., 2019, Vitale et al., 2020, Mañas et al., 2021) or participants with a medical condition (Payne et al., 2008, Plotnikoff et al., 2010, Miller et al., 2017, Chen et al., 2018, Lund et al., 2019, Wagner et al., 2020), with limited evidence in young and middle-aged healthy adults (Kikuchi et al., 2022, Kikuchi et al., 2023).

One approach to overcome barriers of daily time commitment and access to specialised facilities/equipment is to carry out a resistance exercise programme with low time commitment and performed at home with minimal equipment.

This may be a more convenient way to undertake resistance exercise and improve long-term adherence. We first attempted to study this in the ONE study (Chapter 2). This showed a trend increase in muscle endurance after 12-weeks with one minute per week per muscle group of resistance exercise per day in the resistance exercise group (N=10). Qualitative data indicated that participants enjoyed the programme, but would have preferred more flexibility in how the exercises were distributed throughout the week (frequency), a more varied choice of exercises, and the potential to undertake more than the minimum exercise prescription. The REFLEX study aimed to extend the ONE study in light of these qualitative insights, and to deliver the intervention completely online (via an app), given the COVID-19 pandemic during 2020 and 2021 and the social distancing restrictions. This approach also facilitated trialling the online delivery platform for potential future widescale implementation. We planned to deliver this as a randomised control trial (RCT) with a comparison group undertaking a flexibility exercise programme (which would be expected to improve flexibility but not muscular endurance) in order to minimise drop-outs and increase adherence to the study.

3.2 Study Aims

The primary aim of this study was to compare the effects of a home-based resistance exercise programme delivered via an online app vs a home-based flexibility programme on muscular endurance in healthy adults who do not engage in resistance exercise.

Secondary aims were to determine: a) participants' adherence to both exercise programmes, b) participants' choice of weekly exercise volume (compared to minimum prescription) in both exercise programmes c) participants' distribution of exercise throughout the week in both exercise programmes, d) the effects of the exercise programmes on well-being.

3.3 Methods

3.3.1 Inclusion and Exclusion criteria

Inclusion criteria for this study were: male or female, aged between 18-64 years old, undertaking ≤ 30 min a week of aerobic vigorous physical activity (Ainsworth *et al.*, 2011) and were not undertaking any form of resistance exercise. Exclusion criteria included failure of the Physical Activity Readiness Questionnaire Plus (PAR-Q+), performing 30 minutes or more of vigorous intensity exercise from the IPAQ, having a job that compromises manual labour, a history of cardiovascular disease, diabetes and any other illness that would prevent the participation in a resistance exercise or flexibility exercise programme.

3.3.2 Study Samples

The first sample of participants recruited in the first part of the trial was N=13, while the second sample recruited on the second part was N=95. More details of recruitment of the second sample is in the results section below.

3.3.3 Ethics

The REFLEX Study was approved by the MVLS College Ethics Committee (200190188) (Appendix K; Appendix L). The study underwent three amendments (Appendix M; Appendix N; Appendix O). In addition, the REFLEX Study is registered in clinicaltrials.gov (NCT04574674).

Participants had at least two days to read the participant information documents (Appendix P; Appendix Q). After that, they attended an online video call to answer any questions, gave informed consent and their voice was recorded. Participants could withdraw at any time from the study without consequence or reason. Data obtained was anonymised and was not passed outside the research team. In case of exclusion data was not kept by the researchers, while in case of withdrawal, data obtained from participants was kept.

3.3.4 Overview of the study

Participants after being recruited for the study, underwent a screening procedure during a video call with a researcher to determine their eligibility for the study. After screening, participants were sent a link with the questionnaires to complete them before the baseline measurements during a video call. Participants were also sent a link with videos demonstrating the tests so that they would familiarize themselves with the exercise tests. Participants underwent baseline measurements during a video call in which muscle endurance, flexibility were measured After baseline, participants were randomised to a flexibility exercise group or resistance exercise group. They were given a link to access the programme instructions and programme exercise videos and diary. After starting their programme participants attended an online appointment during their 6th week to measure the same outcomes. The questionnaire link was sent prior to their appointment. Finally, participants had a 12-week measurement within 48 hours of finishing the programme to measure the same outcomes and the questionnaires link was sent prior to the appointment. A subsample of the study was recruited for interviews with in a month after the 12-week measurement. Below is shown an overview of the study protocol (Figure 17).

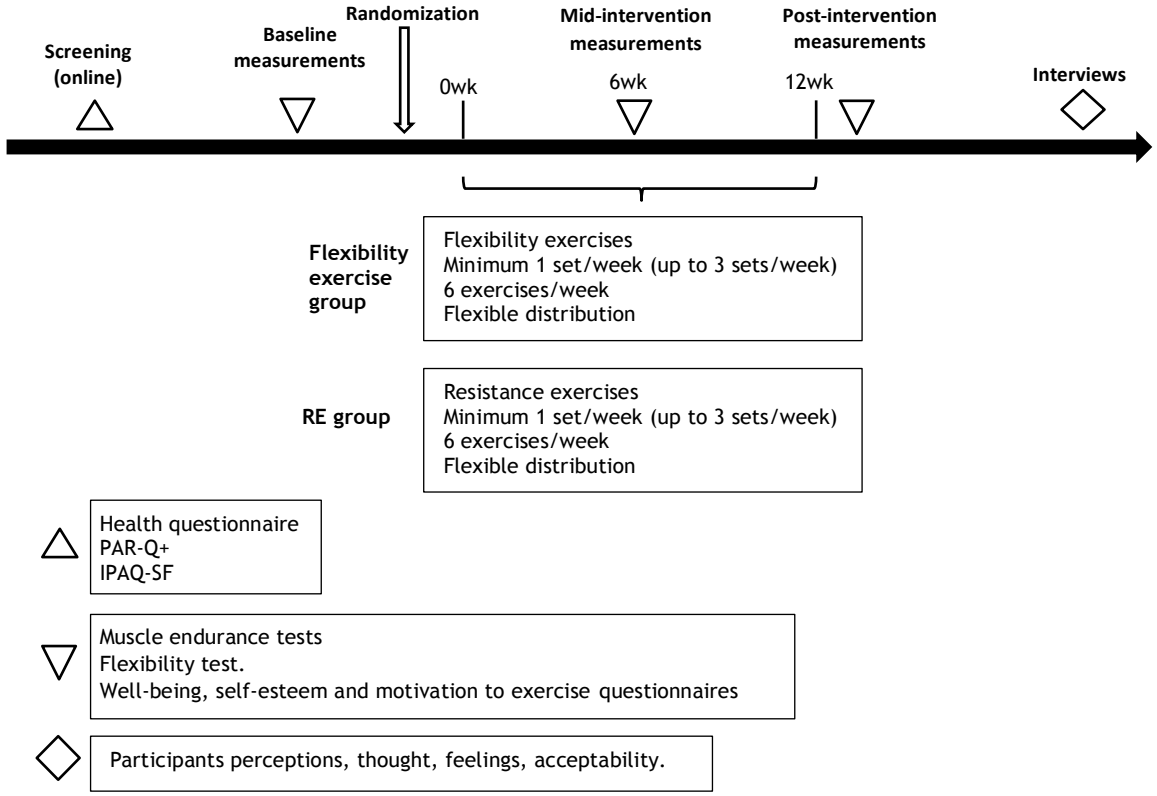


Figure 17. Study protocol overview. Abbreviations: RE: Resistance group; PAR-Q+; Physical activity readiness questionnaire; IPAQ-SF: International Physical Activity Questionnaire short form.

3.3.5 Screening procedures

a) Health questionnaire

All participants undertook a health questionnaire (Appendix R) to determine their health history and exclude any participants with history of diabetes, cardiovascular disease or any other illness.

b) Physical Activity Readiness Questionnaire (PAR-Q+)

Participants were asked to fill the Physical Activity Readiness Questionnaire Plus (Appendix S) to determine their safety to undertake physical activity.

c) International Physical Activity Questionnaire Short form (IPAQ-SF)

All participants undertook the International Physical Activity Questionnaire Short Form (IPAQ-SF) (Appendix T) to determine their physical activity levels and exclude any participant that did 30 minutes or more of vigorous intensity

physical activity per week, a job with manual labour, or perform any kind of resistance exercise.

3.3.6 Muscle endurance tests

a) Developing and pilot testing muscle endurance tests

At first, muscle endurance was measured with three tests: push-up test, crunch test and squat test. These tests were used for the first group of participants (first sample) recruited between September and December 2020.

Prior to the baseline measurement session, participants were sent a link to each exercise test to get familiarised with the test at home before the measurement. All initial tests were performed and supervised during an online video call. The camera was positioned at an angle that favoured the appropriate observation of each test to ensure participants were performing the correct technique. All tests were performed at baseline (0-weeks), 6-weeks and post-intervention (12-weeks). In addition, all participants were sent links to access the exercise tests videos of each exercise test (Appendix U) prior to their measurement appointment in order for them to familiarise with the test.

Muscle endurance tests were taken at baseline by two researchers MFGT/AM or MFGT/PM. At 6-weeks and post-intervention only AM or PM took the measurements to be blinded to the group allocation.

Push-up test

Male participants were asked to perform the test starting in the standard "down" position (hands pointing forward and under the shoulder, back straight, head up, using toes as the pivotal point) (Figure 18). Female participants were asked to do the test in the "knee push-up" position (legs together, lower leg in contact with the mat with ankles in plantar-flexed, back straight, hands shoulders width apart, head up, using knees as the pivotal point) (Figure 19).

(a)

(b)

Figure 18. Push-up test position for male participants, a) Initial position, b) down position.

(a)

(b)

Figure 19. Push-up test position for female participants, a) Initial position, b) down position.

Participants were asked to perform the maximum number of push-ups until fatigue or until the researcher told them to stop. Participants were asked to follow a signal with a cadence of 40 beats per minute, with one beat up and with the following down, and so on. Therefore the participants did 20 reps per minute. Participants needed to keep their back straight the whole time, to fully straighten their elbows and return to the down position and their stomach could not touch the mat. Two warnings were given before stopping the test in case it was not performed correctly. The criteria for stopping the test were to not keep their body straight on their way down or up, not to complete 90 degrees of arms' flexion on their way down or not to fully extend their arms on their way up. The maximal number of push ups performed consecutively without rest was counted as the score (ACSM, 2018).

Crunch tests

Participants were asked to perform the maximum number of crunches without rest. They were asked to lie on a mat in supine position with their knees bent in 90 degrees and feet on the floor. Their arms were extended to the sides with fingers touching a piece of masking tape. A second piece of tape was placed beyond the first piece 12 cm apart (subjects younger than 45 years old) or 8 cm apart (subjects 45 years old or over). Participants had to follow a sound signal with a cadence of 40 beats per minute. At the first beep, the subject slowly lifted the shoulder blades off the mat by flexing supine until fingertips reached the second tape and with the second beep, the participants went back to the starting position (Figure 20). The participants did 20 reps per minute. The test is stopped when the participant strained forcibly or was unable to maintain the appropriate technique within two repetitions in a row. The maximal number of crunches performed consecutively without rest was counted as the score (ACSM, 2018).


(a)

(b)

Figure 20. Crunch test, (a) initial position, (b) crunch position.

Squat test

Participants were asked to perform the maximum amount of squats as possible without rest. The participant's starting position was standing in front of a chair with feet slightly wider than their hips and their toes pointing in front of them (or diagonally). They had to follow a sound signal with a cadence of 80 beats per minute. At the first beep, the participants went down until their thighs were horizontal to the floor (squat position) until they touched the seat of a chair. With the second beep, the participants stood again (initial position) (Figure 21). If the participant wished to do so, they could use their arms to keep balance while they are going down. The participants did 40 reps per minute. The test is

stopped when the participant strained forcibly or was unable to maintain the appropriate technique within two repetitions in a row. The maximal number of squats performed consecutively without rest was counted as the score (ACSM, 2018).


(a)

(b)

Figure 21. Squat test, (a) initial position, (b) squat position.

Initial Results

A total of 13 participants were recruited and underwent baseline measurements. Three participants dropped out of the study after baseline measurements and one after 6-week measurements. A total of 9 participants had complete data.

Group comparisons for each test can be seen in Table 10, Table 11 and Table 12. Individual results can be seen in Figure 22, Figure 23, Figure 24, showing a big variability in the participants' results in the flexibility group and floor effect. Floor effect occurs when the test is too difficult for many of the participants and several of them obtain score 0, which causes a skewness in the distribution of scores (Colman, 2009).

Table 10. Push-up test group comparison (reps) (Mean ± SD).

Group	Baseline measurement	6-week measurement	12-week measurement
Flexibility group	3.1 ± 4.15	5.4 ± 5.9	6.4 ± 6.2
Resistance group	8.3 ± 6.9	13.8 ± 3.4	16.5 ± 1.3

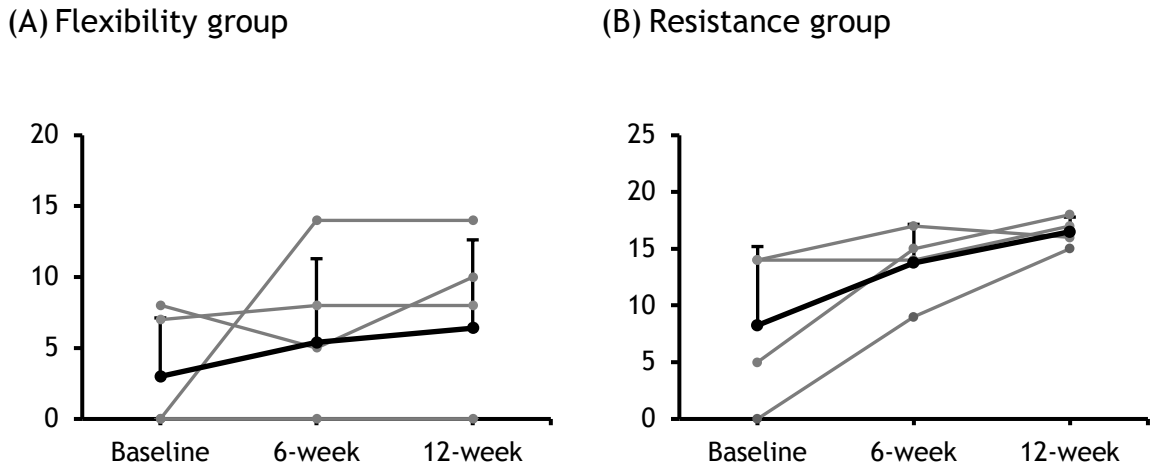


Figure 22. Push up test individual results and mean for each group for the first study sample. (•) Individual results, (•) Mean ± SD.

Table 11. Crunch test group comparison (reps) (Mean ± SD).

Group	Baseline measurement	6-week measurement	12-week measurement
Flexibility group	26.4 ± 18.0	37.6 ± 38.3	20.2 ± 13.1
Resistance group	34.5 ± 8.4	28.8 ± 2.8	30.5 ± 4.4

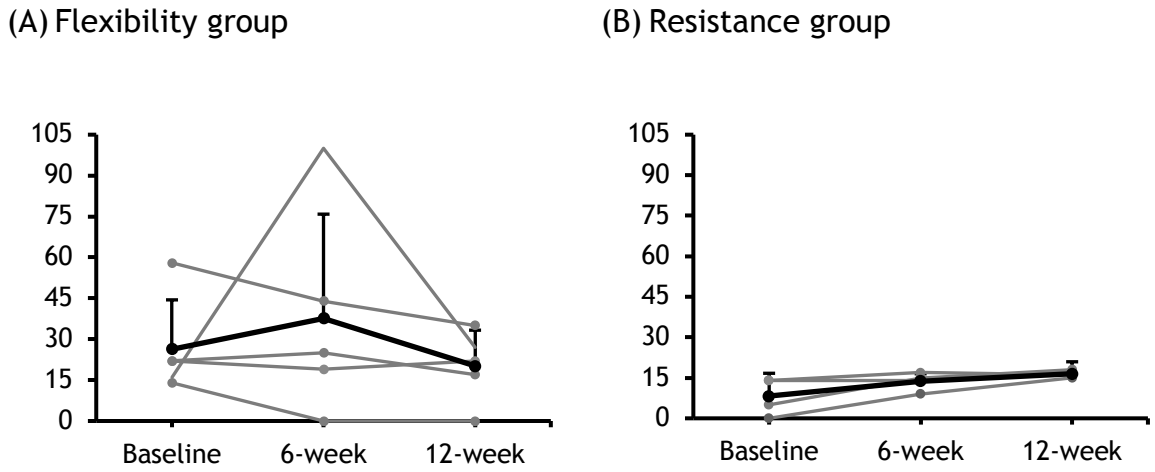


Figure 23. Crunch test individual results and mean for each group for the first study sample. (•) Individual results, (•) Mean ± SD.

Table 12.Squat test group comparison (reps) (Mean ± SD).

Group	Baseline measurement	6-week measurement	12-week measurement
Flexibility group	22.0 ± 26.5	24.4 ± 17.5	26.6 ± 21.5
Resistance group	43.8 ± 6.2	35.8 ± 5.5	43.0 ± 4.1

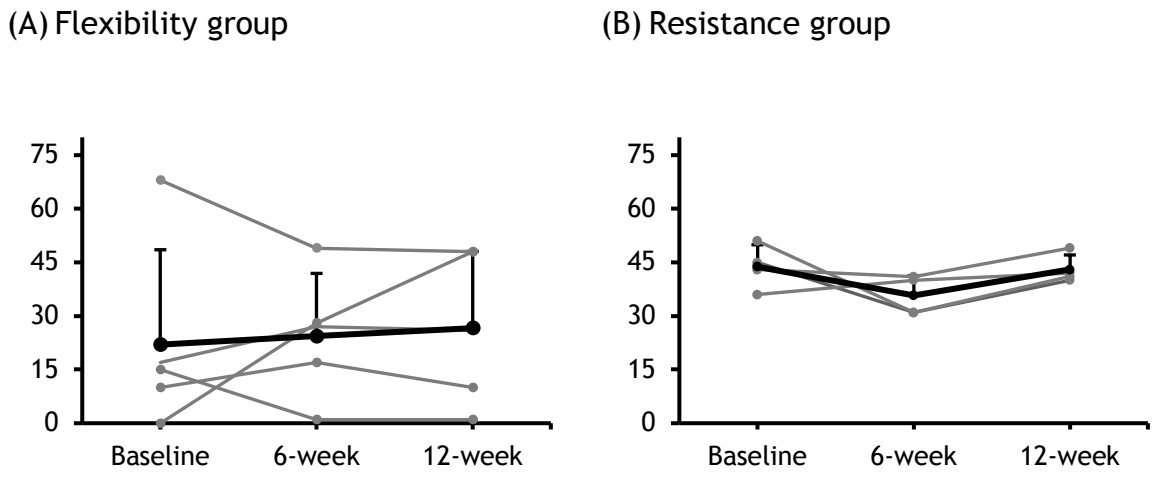


Figure 24. Squat test individual results and mean for each group for the first study sample. (•) Individual results, (•) Mean ± SD.

Problems identified during the measurements

Internet connection issues

Due to an unstable internet connection several measurement sessions would experience interruption of the video during the measurement making it extremely difficult for the researcher to keep counting the repetitions with the audio signal. Adding to this, sometimes the audio would be unsynchronised with the video making it difficult to count. This was for all three tests.

Push-up test

Some participants were not able to perform properly a single repetition of the push-up test, which can be seen in Figure 22. Several female participants were not able to perform push-ups on their knees and some male participants were not able to perform push-ups on their feet for all measurement sessions (baseline, 6-week and post-intervention). In this situation, we encountered a floor effect.

Crunch test

It can be seen in Figure 23 that several participants decreased their number of repetitions, and some increased and then decreased. This is not what it is usually expected. Normally, we would normally expect participants to stay

stable or increase their number of repetitions. This can happen for some participants, but the fact that this happened with several of them showed that there was a problem with the test.

Squat test

Similar to the push-up test we encountered the problem that some participants were not able to perform a squat until their thighs were horizontal in coordination with the cadence of the signal. In addition, some participants decreased the number of repetitions after baseline measurements, which was a similar problem to the crunch test.

Conclusion

This made it difficult to consider these tests reliable and appropriate for this online study. We think these tests might have worked if they were taken with the researcher and participant onsite, but due to the measurement being remotely by a video call, we decided to change these tests and choose more simple ones.

Solutions

The solutions proposed for the muscular endurance tests can be seen below. All the final methods will be explained in detail below.

Push up test

We decided to create a push-up test with different levels so that anyone could perform the tests at their own basal capability. We decided to remove the metronome and just ask participants to perform the maximal number of push-ups until they could not complete another repetition (fatigue).

Plank test

We decided to change the crunch test to a plank test (ACSM, 2018, Bohannon et al., 2018). This test is a much simpler static test so the researcher only needed to time the plank and observe the participant’s form until they could not

continue to hold it. This test has been found to be highly reliable (ICC of 0.915) (Bohannon et al., 2018).

Half-squat test

We decided to change the squat test to a half-squat test (Goldring et al., 2014). Similar to the plank test, this is a static test with the participant had to perform a half-squat resting their back on the wall for as long as possible. The researcher had to time the time and observe the participant's form until they could not continue to hold it.

b) Main Study muscle endurance tests

Muscle endurance was measured with three tests: push-up test, plank test and half-squat test always undertaken in that order. Prior to the baseline measurement session, participants were sent a link to each exercise test to get familiarised with the test at home before the measurement. All tests were performed and supervised during an online video call. The camera was positioned at an angle that favoured the appropriate observation of each test to ensure participants were performing the correct technique. All tests were performed at baseline (0-weeks), 6-weeks and 12-weeks. In addition, all participants were sent links to access the exercise tests videos of each exercise test (Appendix U) prior to their measurement appointment in order for them to familiarise with the test.

Similarly to the previous muscle endurance tests, the main study tests were taken at baseline by two researchers MFGT/AM or MFGT/PM. At 6-weeks and post-intervention only AM or PM took the measurements to be blinded to the group allocation.

Push-up test

Participants were asked to perform the maximum number of push-ups until fatigue or until the researcher told them to stop due to not maintaining appropriate form. Two warnings were given before stopping the test in case it was not performed correctly. The criteria for stopping the test were not keeping their body straight on their way down or up, not completing 90 degrees of arm

flexion on their way down or not fully extending their arms on their way up (ACSM, 2018).

Depending on the participants' skills during the baseline measurement, the appropriate level of push-ups was chosen. The highest difficulty level performed correctly by each participant was chosen. The following level of difficulty was performed and failed by the participant to ensure the correct level was chosen. The same level of push-ups was performed for baseline, 6-weeks and post-intervention testing. The push-up levels were the following in increasing level of difficulty:

Push-ups on a wall

Participants were asked to stand with their feet between 90-120 cm in front of a wall. The specific distance was chosen according to the participants' comfort and it was recorded for future measurements They had to position their hands on the wall at shoulder height and width. Each participant was asked to flex their elbows until 90 degrees (right angle) and extend them again while keeping their whole body straight during the movement (Figure 25).

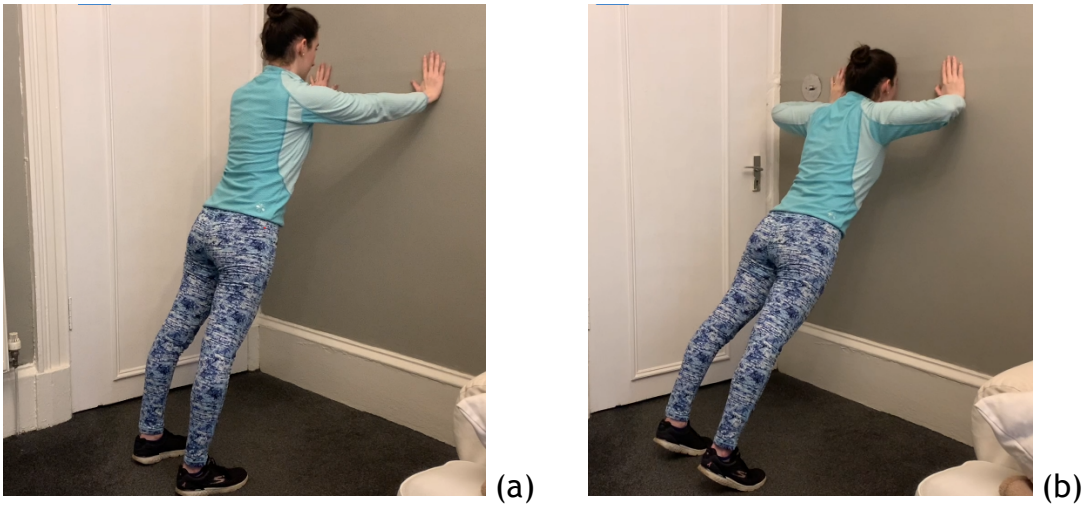

(a) (b)

Figure 25. Push up on a wall initial position (a) and mid position (b).

Push-ups on a worktop

Participants were asked to select a surface around 90 cm high, usually in their kitchen. The height of the surface was recorded for future measurements. Participants were asked to stand with their feet between 90-120 cm in front of

their worktops. The distance chosen was recorded for future measurements. They had to position their hands on the edge of the worktop and could use a cloth under for comfort if it was desired. Once the participant was ready, he or she was asked to flex their arms until 90 degrees (right angle) and straighten their arms again, while keeping their whole body straight during the movement (Figure 26).


(a)

(b)

Figure 26. Push up on a worktop initial position (a) and mid position (b).

Push-ups on knees

Participants were asked to kneel on the floor on a comfortable surface (rug, exercise mat, etc). After, they were asked to keep their lower leg in contact with the floor with their ankles in plantar flexion, hands on the floor under their shoulders, arms extended, head up and a straight back. They were instructed to go down until the arms reached a right angle and straighten them again while using their knees as the pivotal point and keeping their back straight during the whole movement (Figure 27). Their stomach could not touch the floor.


(a)

(b)

Figure 27. Push up on knees initial position (a) and mid position (b).

Push-ups on feet

Participants were asked to use a comfortable surface (rug, exercise mat, etc). They were asked to put their hands on the floor under their shoulders and pointing forward, with their arms extended, back and legs straight, and their feet on the floor using their toes. They were instructed to go down until the arms reach a right angle and straighten them again while using their toes as the pivotal point and keeping their back and legs straight during the whole movement (Figure 28). Their stomach could not touch the floor.


(a)

(b)

Figure 28. Push up on feet initial position (a) and mid position (b).

Plank test

Participants were asked to use a comfortable surface (rug, exercise mat, etc). They were asked to lie down on the floor with their forearms and their toes in contact with the floor. Once they were ready they were instructed to lift their body in the air and keep their whole body straight horizontal to the floor. The aim was to keep that position as long as possible (Figure 29). The time that they were able to keep that position was recorded in seconds. The test stopped if the participant stopped the exercise on their own or if the researcher told them to stop. The criteria for stopping the test was not keeping their whole body straight. Two warning were given before stopping the test.

Figure 29. Plank test.

Half-squat test

Participants were asked to stand in front of a wall with their back facing the wall. They were instructed to lean their back to the wall and lower their body into a sitting position until their ankles, knees and hips reached 90 degrees or a right angle. Their legs were at their hips width with their toes and knees facing forward during the test. They were asked to cross their arms during the test. They were instructed to keep that position (Figure 30) for as long as they could and the time was recorded in seconds. The test stopped if the participant stopped the exercise on their own or if the researcher told them to stop. The criteria for stopping the test was not keeping the half-squat position (Goldring et al., 2014).

Figure 30. Half squat test.

3.3.7 Flexibility

The gold standard of flexibility measurement is the assessment in a laboratory of a specific joint. It needs to be performed after a warm-up period (ACSM, 2018). Several methods are used, like visual methods, change of reach distance or using devices. The goniometer is the most widely used, and it is used for specific joints. They can be manually operated or electronic. Other devices are Leighton flexometer and inclinometers (ACSM, 2018). The method used in this study was the sit-and-reach test which is explained below:

a) Sit-and-Reach test

The participants were asked to sit down on the floor or a comfortable surface of preference without shoes and their legs extended. They were asked to have a deep breath and while exhaling to reach their toes with both hands as far as possible and their head down (Figure 31). They were instructed to hold their position for approximately two seconds. Once they reached this position they were asked to measure the distance between the tip of their fingers to their toes in centimetres. If the participants did not reach their toes, the value recorded was negative, if they were able to pass their toes the value was positive and if the participant was able to reach their toes exactly the value recorded was zero (Figure 31).

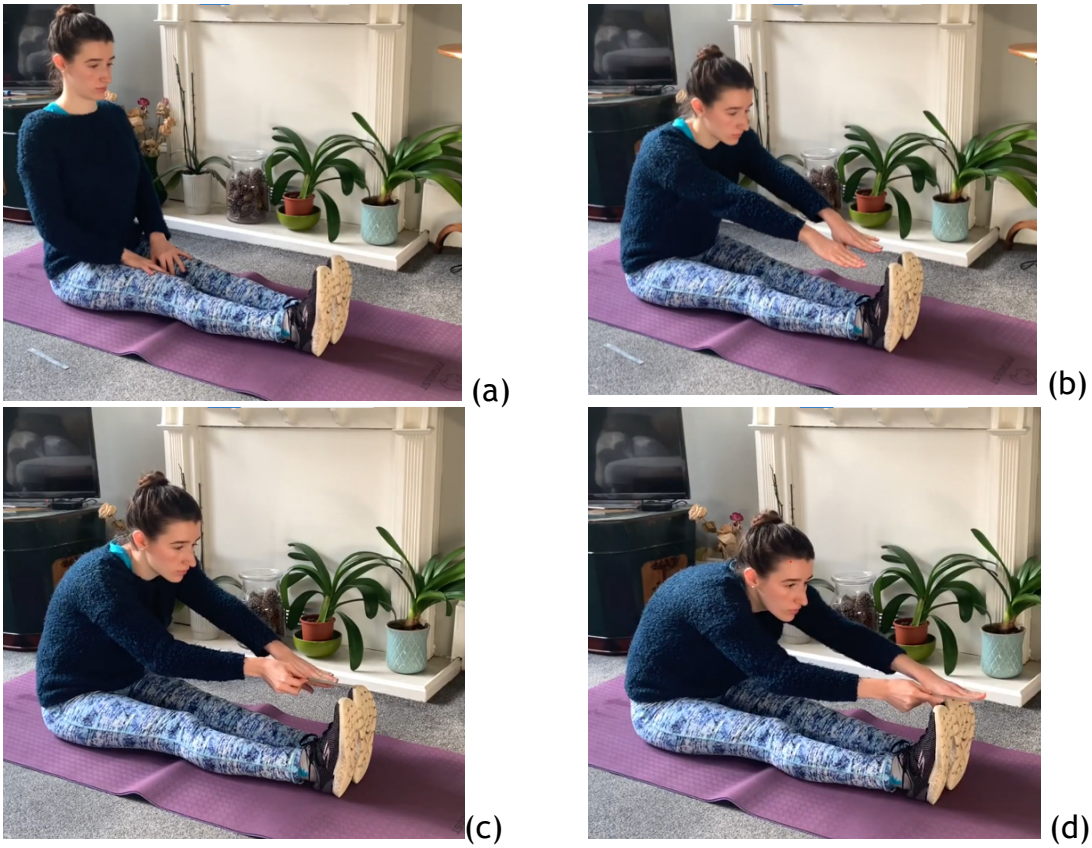


Figure 31. Sit and reach test initial position (a), reaching toes position (b), measurement if not reaching toes (c) and measurement if past their toes (d)

Similarly to the main study tests, the sit-and-reach test was taken at baseline by two researchers MFGT/AM or MFGT/PM. At 6-weeks and post-intervention only AM or PM took the measurement to be blinded to the group allocation.

3.3.8 Questionnaires

Participants were asked to complete the EQ Visual Analogue Scale, the Warwick-Edinburgh Mental Wellbeing Scale, Subjective vitality Scale, Rosenberg's self-esteem questionnaire and an adapted version of the BREQ-2 questionnaire to measure wellbeing, self-esteem and motivational regulation to physical activity. All participants completed the questionnaires on their own via an online link during the week and prior to their measurement appointment at baseline, 6-week and post-intervention. The questionnaires completed are described below:

a) EuroQol Visual Analogue Scale (EQ VAS):

The EQ Visual Analogue Scale (EQ VAS) (Appendix V) was used for recording the participant's self-rated health, reflecting their own judgement. It is a visual

analogue scale from 100 to 0. The endpoints are labelled “The best health you can imagine” and “The worst health you can imagine” respectively. Participants were asked to rate their health “today” (on the specific day they were answering all the questionnaires) (EuroQol, 2009).

b) Warwick-Edinburgh Mental Wellbeing Scale

The Warwick-Edinburgh Mental Wellbeing Scale (WEMWBS) (Appendix W) was used to assess different aspects of mental well-being, including psychological functioning, affective-emotional aspects and cognitive-evaluative dimensions (Tennant et al., 2007).

The scale consists of 14-items and it is used for general population groups. Participants were asked to tick the box for each item, that best described their experience over the last weeks. The options were “none of the time (1)”, “rarely (2)”, “some of the time (3)”, “often (4)” and “all of the time” (5). The total score is the total sum of the 14 items, ranging from 14 to 70 (Stewart-brown and Janmohamed, 2008).

c) Subjective Vitality Scale

Participants were assessed with two versions of the Subjective vitality Scale. Both versions have 7 items and were used to measure participants’ vitality and energy (Ryan and Frederick, 1997) (Appendix X).

Firstly, they were assessed with the individual difference level version (IDLV). Participants were asked to rate each statement to the degree each one was true for them in their general life. The ratings were “not at all true” (1), (2), (3), “somewhat true” (4), (5), (6) and “very true” (7). Secondly, they were assessed with the state-level version (SLV). Participants were asked to rate each statement according to “how they are feeling right now” (at the exact moment they were answering the questionnaires). The ratings were “not at all true” (1), (2), (3), “somewhat true” (4), (5), (6) and “very true” (7).

The total score for both scales is the average of the items, with exception of item 2 which is the reverse score (substruction of score item 2 from 8 before the average of the six items).

d) Rosenberg's Self-esteem questionnaire

Participants' global self-worth was measured by the Rosenberg's self-esteem questionnaire (Appendix Y). The questionnaires consist of 10 items that measure positive and negative feelings about the self. Participants were asked to answer each item using a 4-point Linkert scale ranging from strongly disagree to strongly agree (Rosenberg, 1965).

e) Adapted Behavioural Regulations in Exercise Questionnaire (Adapted BREQ-2)

Participants' motivation for physical activity participation was measured by an adapted version of the BREQ-2 questionnaire (Appendix Z). The original version of the BREQ-2 was created to measure motivational regulation. It consists of 19 items that participants need to answer using a scale ranging from "not true for me" (0) to "very true for me" (4). The questionnaire consists of five subscales: (1) intrinsic (items 4, 10, 15 and 18), (2) identified (items 3, 8, 14 and 17), (3) introjected (items 2, 7 and 13), (4) extrinsic (items 1, 6, 11 and 16) and (5) amotivation (items 5, 9, 12 and 19) (Markland and Tobin, 2004).

The adapted version used in this study consisted of 15 items. Items 5, 6, 14 15 and 17 were removed, item 13 was slightly modified and a new item was created for item 15. It has six sub-scales: (1) intrinsic (items 4, 8 and 13), (2) identified (items 3 and 6), (3) introjected (items 2, 5 and 11), (4) extrinsic (items 1, 9 and 12), (5) amotivation (items 7, 10 and 14) and integrated (item 15).

3.3.9 Randomisation and blinding

After baseline measurements, all participants were randomly assigned (1:1) to two groups, a flexibility exercise group and a resistance exercise group (RE group). Randomisation was done by a researcher outside the research team with a computer programme and was sent to the website developers separately. Participants found their group allocation after baseline measurements on the web app.

Due to the characteristics of the intervention, the blinding of the participants was not possible. In addition, after baseline measurements, only the main

researcher knew group allocation due to the administration of the study. The researchers (AM and PM) that performed the measurements at six weeks and twelve weeks were blinded for group allocation during the study period.

3.3.10 Intervention

All participants were asked to follow a 12-week home-based exercise programme. Participants were instructed to perform a minimum amount of resistance or flexibility exercise of one set/week for each of the six exercises and had the opportunity to increase their volume of exercise to two sets or three sets/week per exercise if it was their choice. The six exercises that they were asked to perform were two different leg exercises, one shoulder and arms exercise, one chest exercise, one core exercise and one back exercise.

In addition, participants were able to distribute the exercises during the week according to their preference (all in one day or spread over several days of the week, etc.). Participants were encouraged to have a minimum of one day of rest per week.

Video Instructions for the website and the exercise programme were given to the participants according to their allocated group via the website (Appendix AA). Participants were able to access this video during the 12-weeks of the programme.

a) Flexibility exercise group

Flexibility exercise consists of stretching exercises with the objective of increasing a joint ROM. The main types of flexibility exercises can be generally classified as static and dynamic. Static flexibility exercises consist of holding a position with the specific muscle tensed with a stretching feeling. This can be done passively by another person or actively by the same person doing the stretch. Dynamic flexibility exercises consist of active stretching (moving a limb with full ROM several times) and ballistic stretching (rapid alternating movements or bouncing at the end of ROM). It is known that static flexibility exercises increase ROM between 15 and 30 seconds (Page, 2012). Additionally, it has been found that dynamic and static seem to improve ROM similarly acutely and over time with training (Page, 2012).

The flexibility exercise group was asked to perform 6 flexibility exercises per week (two different for legs, one shoulder and arms, one chest, one back and one core). Participants were able to choose an exercise for each category every week on the website. A list of the exercises available for the flexibility group can be found in Table 13.

Table 13. Flexibility group exercises.

Muscle Group	Exercise
Legs	Quadriceps stretch Hamstring stretch Piriformis stretch Glutes and hip rotators stretch Adductors stretch Hip-flexor stretch One Knee to chest stretch Calf stretch
Shoulders and arms	Shoulder (cross arm) stretch Biceps stretch Triceps
Chest	Chest (pectoralis) stretch
Back	Low back stretch Knees to chest stretch
Core	Abdominals (core) stretch Cat-dog stretch

Video instructions were given via the website for each exercise (Appendix AB). Participants performed passive static stretching exercises. They were asked to stretch to the point of feeling tightness or slight discomfort, to hold the stretch for 30 seconds (each side) and repeat that twice (in total 60 seconds of stretching per side) according to the ACSM's guidelines for flexibility exercises (ACSM, 2016).

Participants were asked to record each exercise session they performed during the 12-week exercise programme, recording the exercise chosen for each category and whether they had completed it. Participants were able to access their records on the website.

b) Resistance exercise group

Participants in the RE group were asked to perform a total of 6 exercises per week (2 different leg exercises, 1 shoulder exercise, 1 chest exercise, 1 back exercise and 1 core exercise). Participants had the opportunity to choose the exercise they wanted to perform for each category every week on the website. Each exercise had several levels. A full list of the exercises and their levels can be seen in Table 14.

Table 14. Resistance exercise group exercises and levels.

Muscle Group	Type of exercise	Levels	Exercise
Legs	Squat	1	Squat on chair
		2	Squat
		3	Slow squat
		4	Squat jump
		5	Squat on one leg
	Deadlift	1-4	Deadlift with band 1-4
	Front lunges	1	Front lunges with a wall
		2	Front lunges short step
		3	Front lunges long step
		4	Front lunges and jump
Shoulders and arms	Upright row	1-4	Upright row with band 1-4
	Lateral raise	1-4	Lateral raise with band 1-4
	Shoulder press	1-4	Shoulder press with band 1-4
Chest	Push ups	1	Push ups on a wall
		2	Push ups with knees
		3	Push ups with feet
		4	Push ups with feet on a chair
		5	Push ups with a clap
Back	Seated row	1-4	Seated row with band 1-4
	Seated wide row	1-4	Seated wide row with band 1-4
Core	Plank	1	Plank with hands and knees
		2	Plank with hands and feet
		3	Plank with forearms and wide feet
		4	Plank with forearms and closed feet
		5	Dynamic plank
		6	Superman plank
	Crunches	1	Crunches with hands on legs
		2	Crunches with hands on legs with a pause
		3	Crunches with arms crossed on chest
		4	Crunches with hands behind the head
		5	Crunches with hands behind the head and raised legs
		6	Crunches with hands behind the head, raised legs and a twist

At the beginning of the exercise programme, participants were asked to choose a level at which they were able to perform between 6-20 repetitions. During each exercise session in the programme, they were asked to complete as many repetitions as possible until they were not able to perform the exercise anymore. If the participant was able to perform >20 repetitions, he/she was able to progress to the next exercise level. For the plank exercise, participants were able to progress to the next level of difficulty once they could maintain the plank posture for 60 seconds. Participants in this group received a complete set of resistance bands (5 bands of different tensions) to perform the band exercises. Participants were able to access video instructions for each exercise and level via the website (Appendix AC).

Participants were asked to record each exercise session they performed during the 12-week exercise programme, recording the exercise and level chosen for each category and the number of repetitions or time (for plank exercises) achieved. Participants were able to access their records on the website.

3.3.11 Development of Webapp

A mobile-friendly website (webapp) was developed between the researchers and a Software Development Company (Big Motive) to deliver the intervention (flexibility or resistance exercise programme) to the participants. The development started in July 2020 and finished in September 2020. Adjustments were made when necessary throughout the study period (Sept 2020 – September 2021).

The webapp consisted of a user interface and a researcher interface. The User interface was for the volunteers who wanted to participate in the study and for the participants of the study. This interface, was divided in four different interfaces, pre-screening and interest, user and group allocation, instructions, exercise programme and exercise diary. On the other hand, the researcher interface was for the main researcher and the app developers. Both interfaces are detailed below:

a) Participant Interface:

Pre-screening and interest

A link was provided in the publicity posters for people who had an interest in participating in the study. The link would take the person to the study website with a short questionnaire to determine the volunteer's suitability for the study. The questions asked were: What is your age? Do you perform more than 30 min of physical activity? Do you perform strength exercises? According to the answers of the participants, suitable people were asked to provide a name and email address to register their interest. People that were not suitable had a message appear that they were not suitable for the study and their data was not recorded.

User and group allocation interface

After baseline measurements, each participant was activated in the system and was sent a unique link to create their username and password. Once they were logged in the participant was allocated to a group, resistance exercise or flexibility exercise.

Instructions interface

After group allocation participants were sent by email a link to a video explaining how to navigate the webapp, how to choose the exercises, how to see the exercise videos and how to complete the exercise diary (Figure 32, Figure 33). In the webapp, they were directed to a video explaining the exercise programme and what the participants were expected to do during the 12-week programme. There were specific videos for the flexibility programme and the resistance programme (Appendix AC).

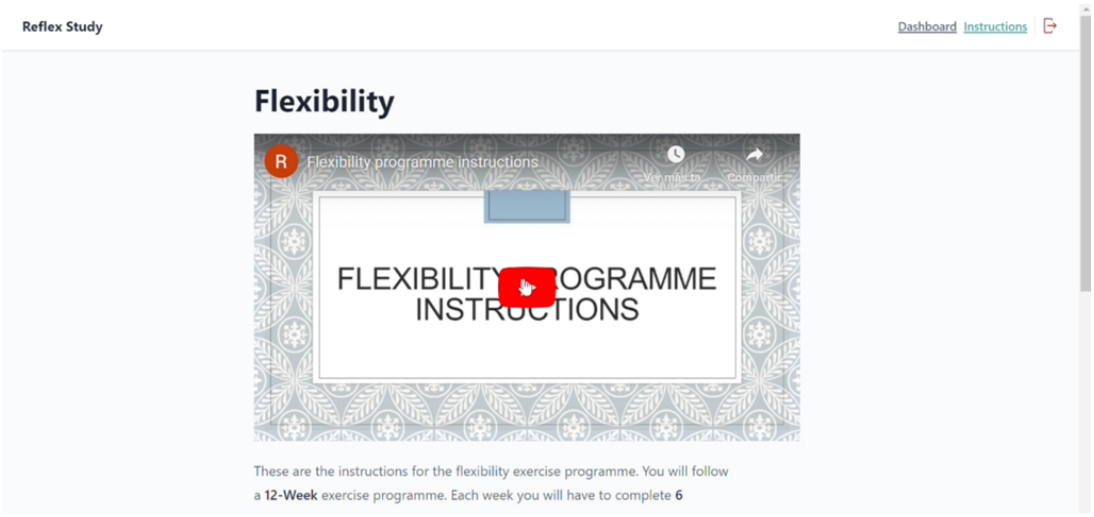


Figure 32. Screenshot of instructions interface, flexibility programme.

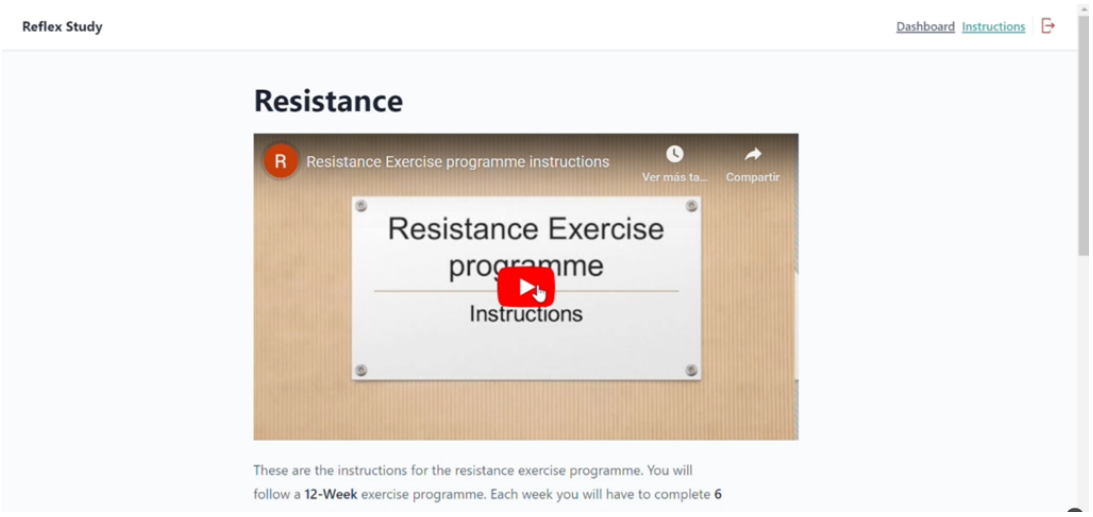


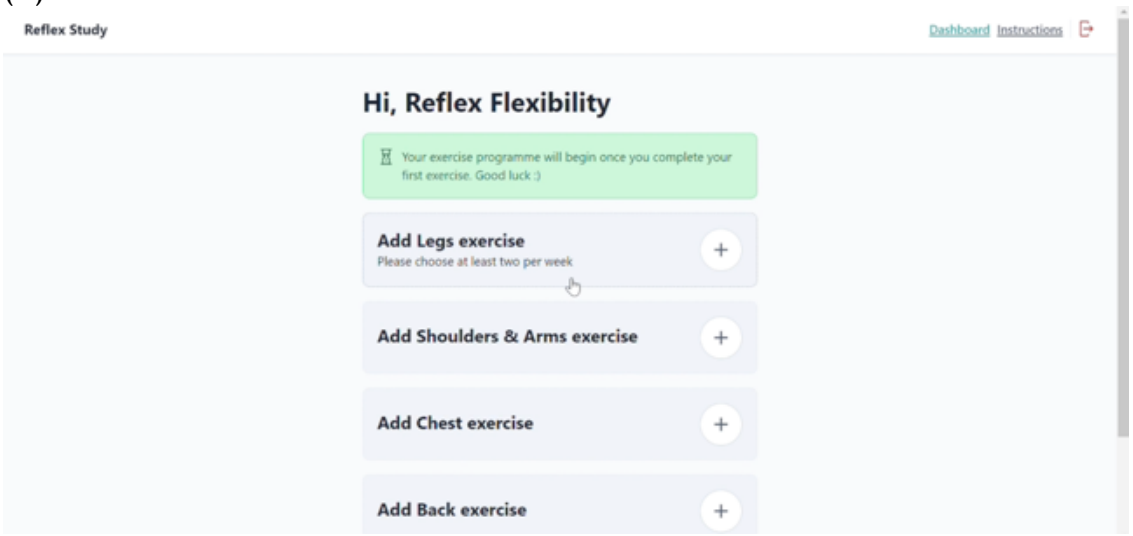
Figure 33. Screenshot of instructions interface, resistance programme.

Exercise programme interface

Once participants watched the instruction videos they were directed to the exercise programme interface. There they had the six exercises, which after clicking a drop-down menu would appear to choose the exercise and then the level. After the exercise completion, the participant would click “Exercise complete” and would be redirected to the exercise programme interface (Figure 36, Figure 38). The resistance group also needed to write the number of repetitions or time achieved (depending on the exercise) before clicking complete.

Every week the interface would reset for them to choose the exercises again. The interface showed which week the participant was in.

(A)



(B)

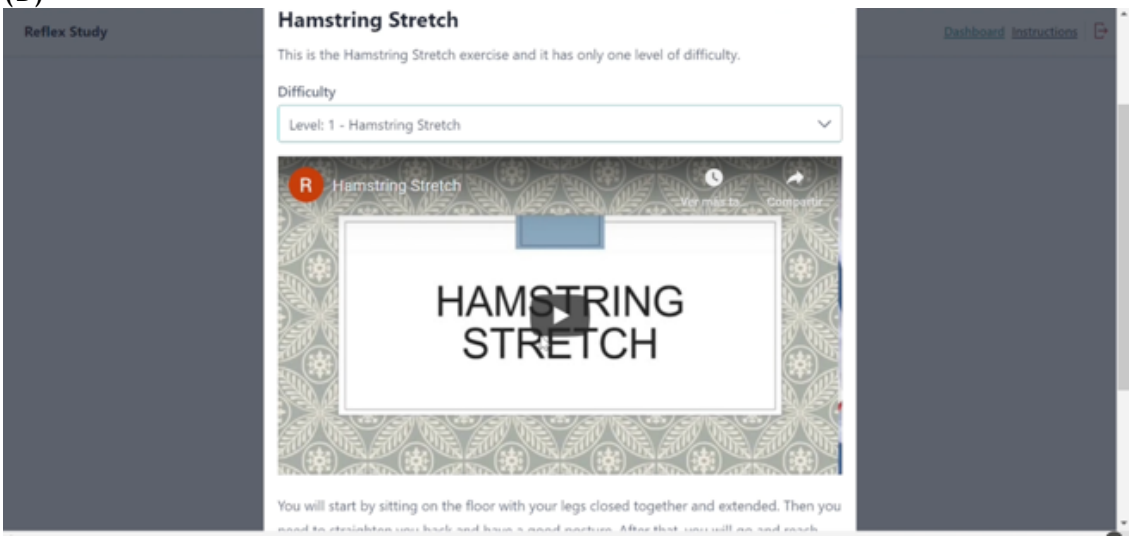
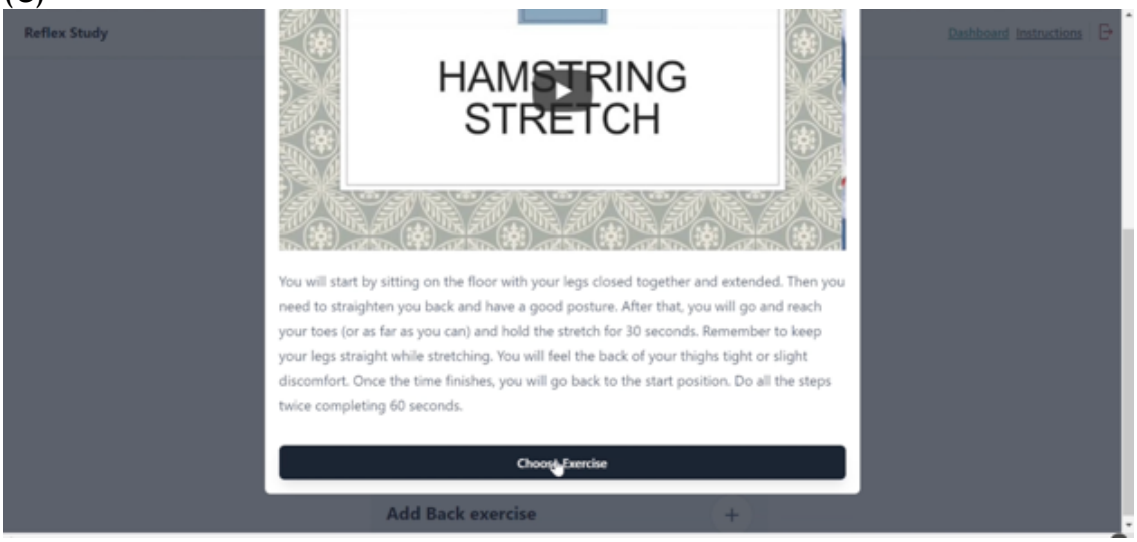
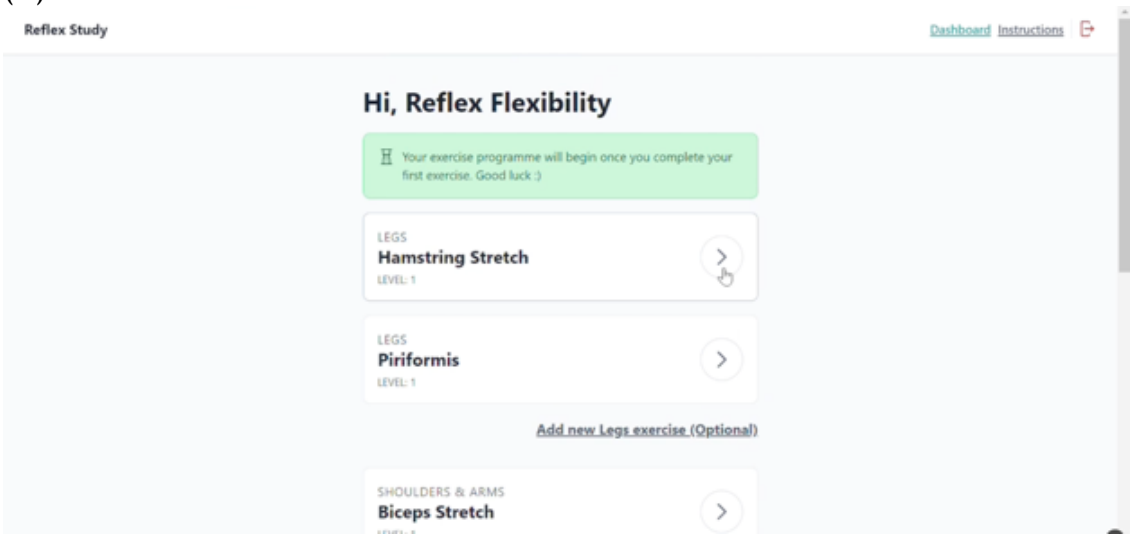


Figure 34. Screenshot exercise programme interface, flexibility programme. (A) choosing exercise, (B) and (C) choosing the exercise type and level, (D) starting the exercise, (E) watching the video and completing the exercise, and (F) the first exercise complete.

(C)



(D)



(E)

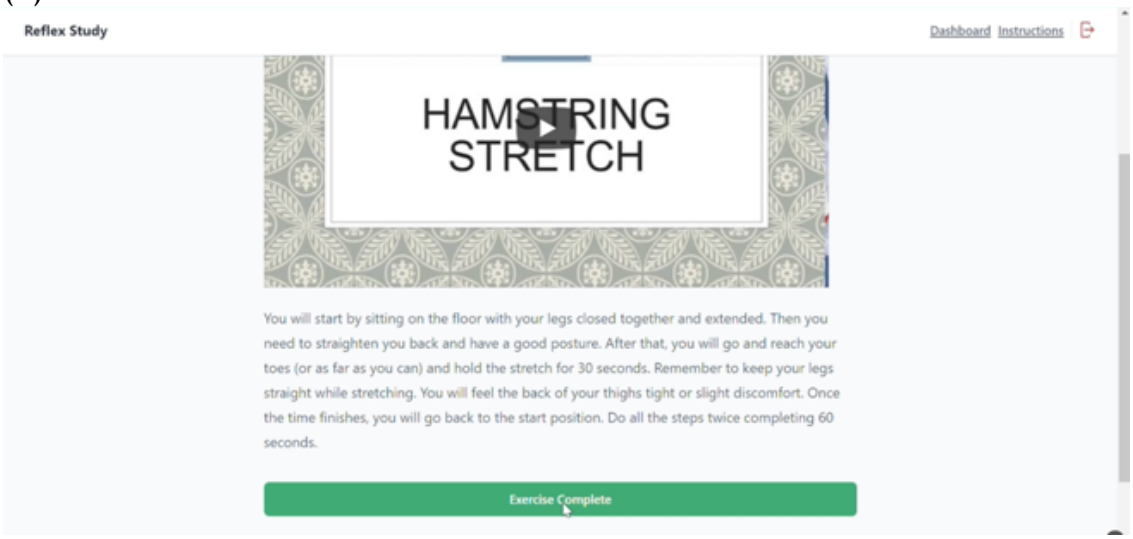


Figure 35. Screenshot exercise programme interface, flexibility programme. (A) choosing exercise, (B) and (C) choosing the exercise type and level, (D) starting the exercise, (E) watching the video and completing the exercise, and (F) the first exercise complete.

(F)

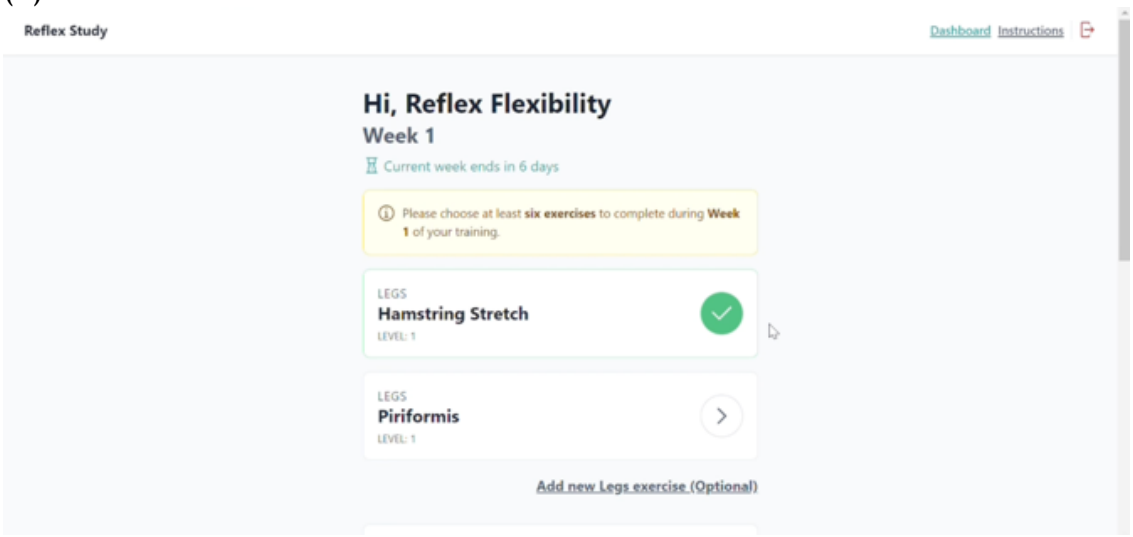
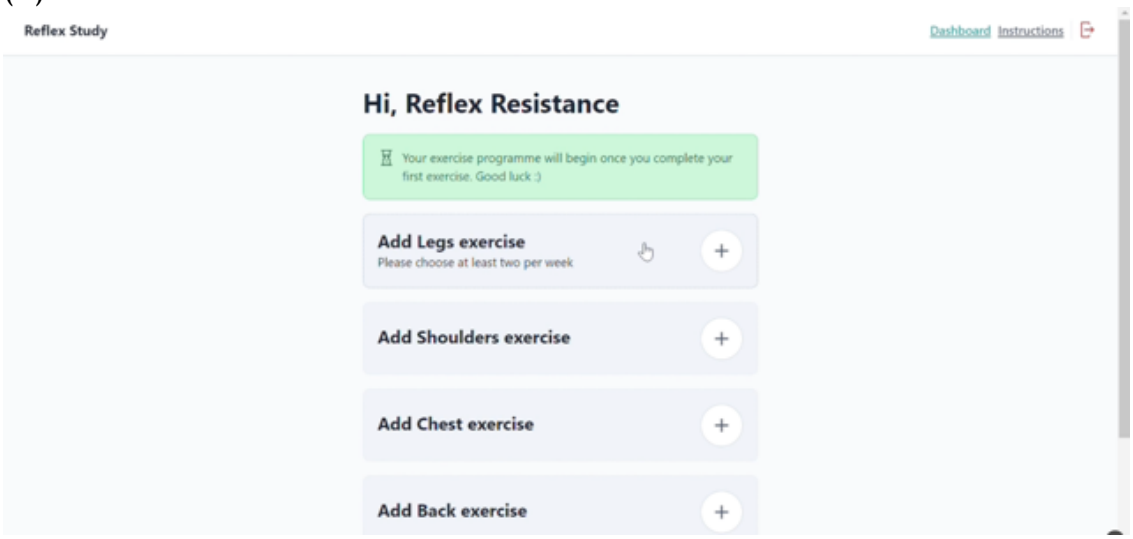
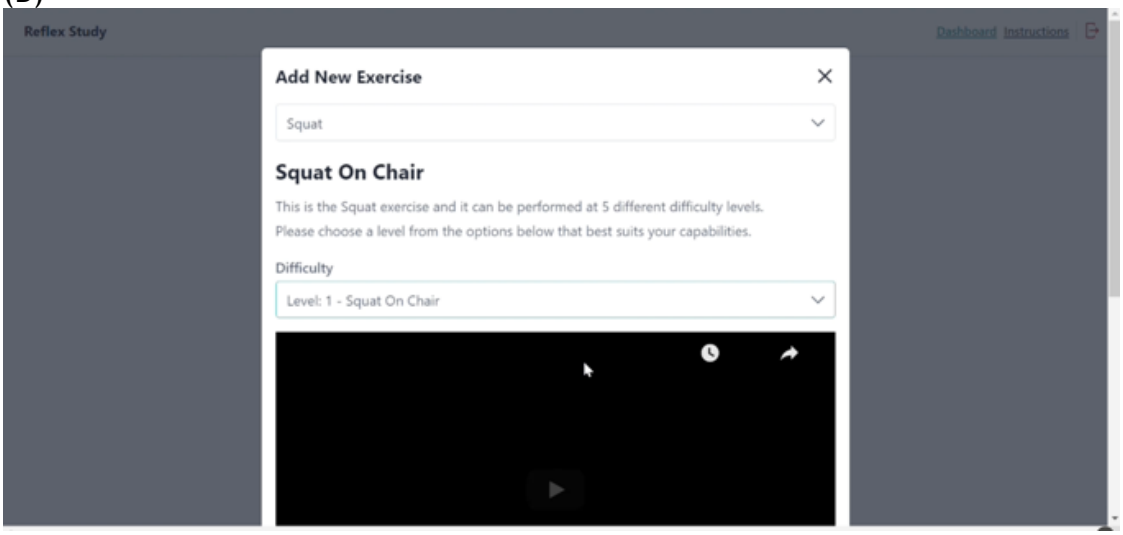


Figure 36. Screenshot exercise programme interface, flexibility programme. (A) choosing exercise, (B) and (C) choosing the exercise type and level, (D) starting the exercise, (E) watching the video and completing the exercise, and (F) the first exercise complete.

(A)



(B)



(C)

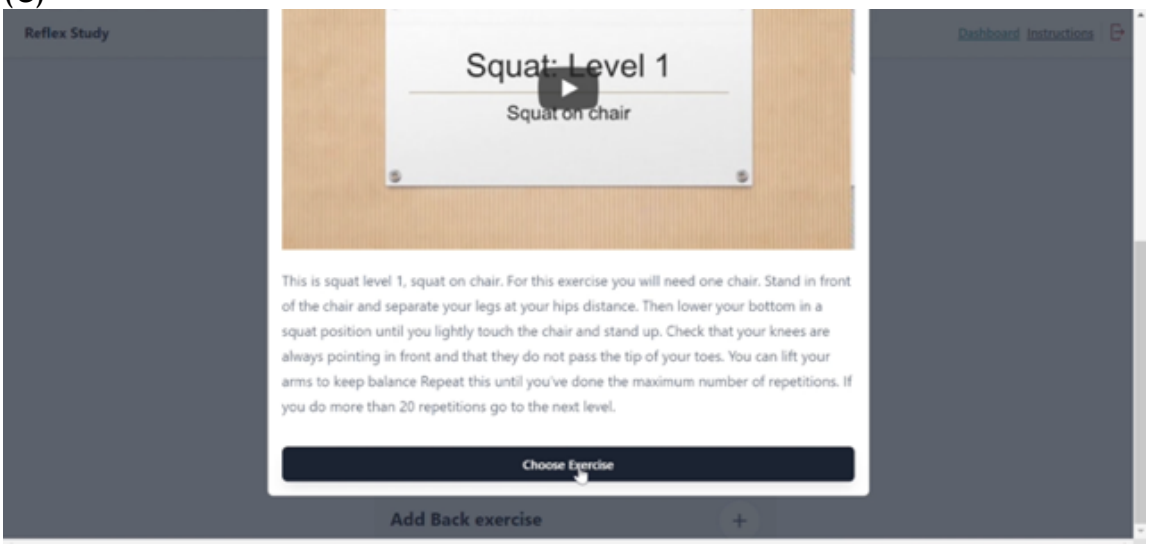
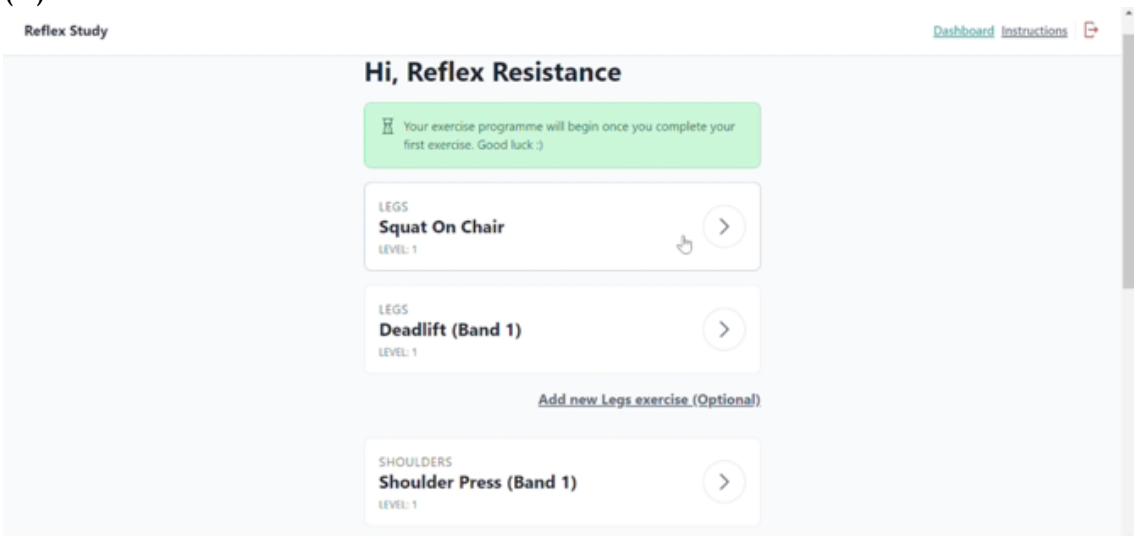
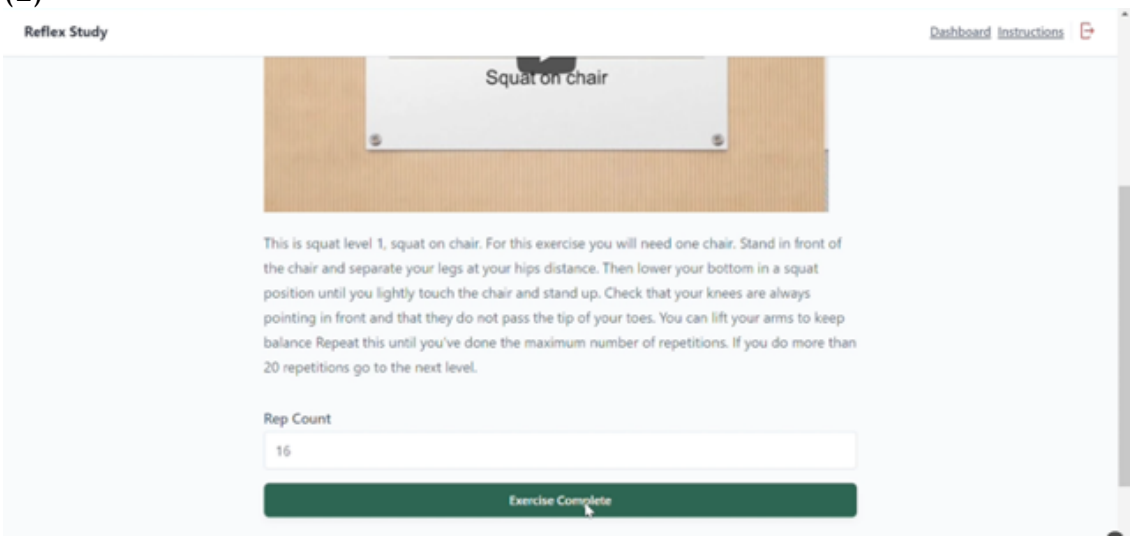


Figure 37. Screenshot exercise programme interface, resistance programme. (A) choosing exercise, (B) and (C) choosing the exercise type and level, (D) starting the exercise, (E) watching the video and completing the exercise, and (F) the first exercise complete.

(D)



(E)



(F)

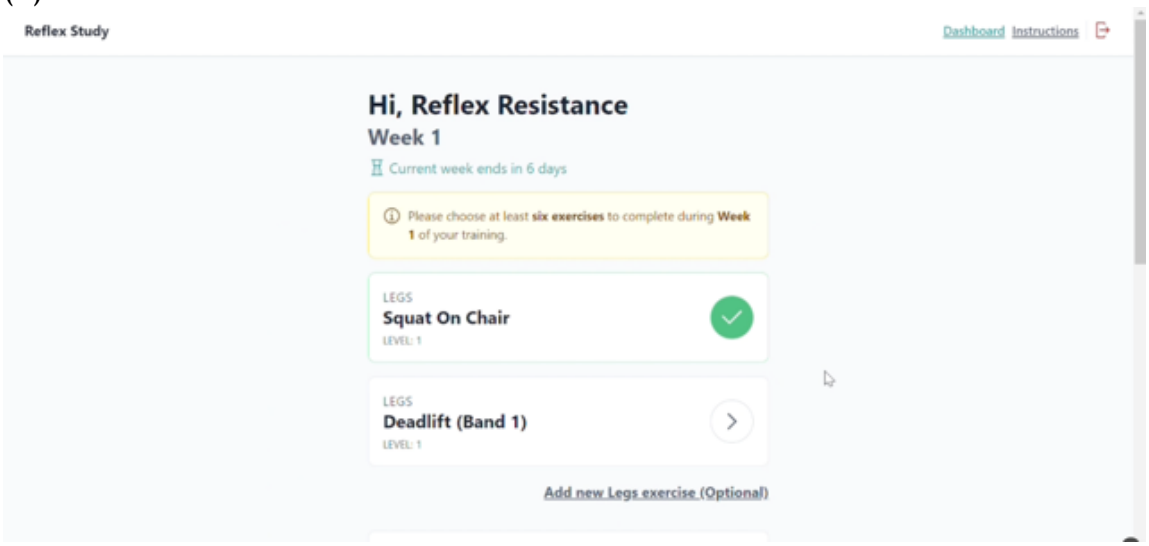


Figure 38. Screenshot exercise programme interface, resistance programme. (A) choosing exercise, (B) and (C) choosing the exercise type and level, (D) starting the exercise, (E) watching the video and completing the exercise, and (F) the first exercise complete.

Exercise diary

Participants were able to access an exercise diary interface and see which exercises they have completed during the programme. The resistance exercise group was able to see the number of repetitions/time achieved for each exercise and level. Participants were able to see their results in the form of a graph. For the same exercise, each level was in a different graph due to time and resource constraints during the development period.

b) Researcher interface

The researcher interface consisted of a back panel in which the researcher was able to see the people who submitted their interest to participate in the study, activate participants in the webapp to start the programme, see each participant group allocation and see the participants chosen exercises and performance (repetitions/time recorded).

3.3.12 Statistical analysis

a) Sample size and power calculation

There are limited published data available evaluating the effects of resistance exercise on muscular endurance. A previous investigation has reported an 8.7 kg increase for muscle strength for bench press after a resistance exercise training, with a 9.9 kg SD for change in muscle strength (Radaelli et al., 2015); thus with power of 90% and an alpha of 0.05, groups of 29 participants were needed. Considering 20% of drop out during the study, we aimed to recruit 36 participants per group, for a total of 72 participants.

Preliminary data from 7 participants from the ONE Study showed a difference of 8.5 repetitions for press-up endurance (over primary outcome) pre to post-intervention with a SD of 7.06 in baseline press-up endurance. While this low n means that we are not confident to use these data in our power calculation, these data suggest that we would require 16 participants per group to detect this difference with 90% power and alpha 0.05. Our power calculation using muscular strength as the outcome is likely therefore to be conservative.

b) Statistical analysis

Stata 18® was used for the statistical analysis. Descriptive data for adherence and distribution of exercise throughout the week are reported. Kolmogorov. Differences between groups were assessed by 2-way ANOVA (group x time) with repeated measures on the time factor. Statistical significance was accepted at $p<0.05$. A post-hoc analysis for trends was done if there was any significance found. A per-protocol analysis was performed to analyse completers versus non-completers between groups and between time points. Sphericity was tested with Mauchly's test. Participants were considered completers if they completed 80% or more of the minimum exercise session (72 sessions in total over the 12-week period) and if they completed a minimum of 5 muscle groups per week.

3.4 Results

3.4.1 Study Sample

A total of 95 participants were screened for the study. Twenty participants were excluded after screening for not meeting inclusion criteria, and 75 participants underwent baseline measurements. After this, 75 participants were randomly allocated into a flexibility exercise group (N=36) and a RE group (N=39). A total of 61 participants underwent the 6-week measurements and a total of 55 participants underwent the 12-week measurement. Overall, a total of 55 participants were included in the statistical analysis. More details can be seen in Figure 39.

The final sample size was 55 participants (48 female, 6 male). From the 55 participants, 26 (23 female, 3 male) were allocated to the flexibility group and 29 (26 female, 3 male) to the RE group.

3.4.2 Descriptive outcomes

Baseline descriptive outcomes for the entire sample, flexibility group and RE group are presented in Table 15. There were no significant differences between groups at baseline for age, push up test, plank test, half squat test and sit-and-reach test.

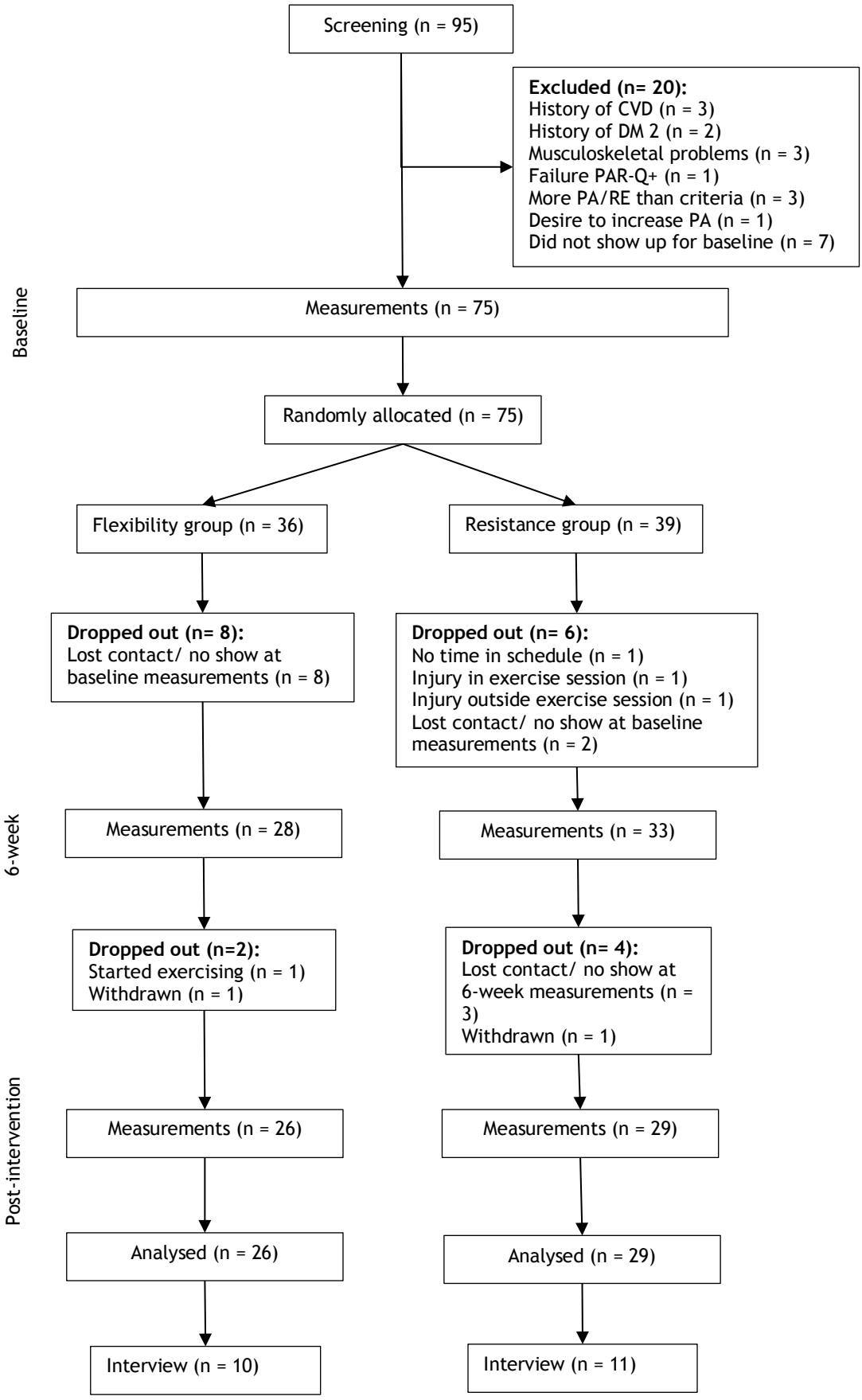


Figure 39. Reflex Study flow diagram. N considering only primary outcome. CVD: Cardiovascular disease, DM 2: Type 2 diabetes mellitus, PA: Physical activity, RE: Resistance exercise.

Table 15. Baseline descriptive outcomes.

	Overall (N=55)		Flexibility group (N=26)		RE group (N=29)	
	Mean ± SD	Min - Max	Mean ± SD	Min - Max	Mean ± SD	Min - Max
Age (years)	49.0 ± 9.23	26 - 63	50.6 ± 8.9	26 - 62	47.5 ± 9.4	31 - 63
Push up test (reps)	12.3 ± 7.0	3.0 – 40.0	10.4 ± 5.1	3 - 24	13.9 ± 8.0	5 - 40
Plank test (s)	45.5 ± 40.0	4.6 – 253.3	49.5 ± 50.0	4.6 – 253.3	41.9 ± 28.8	9.9 – 129.3
Half squat test (s)	36.6 ± 23.4	5.3 – 105.5	35.2 ± 23.0	5.8 - 100	37.9 ± 24.0	5.3 – 105.5
Sit-and-reach test (cm)	-0.6 ± 11.0	-27.0 – 16.5	-2.45 ± 10.0	-26.7 - 15	1.1 ± 11.8	-27.0 ± 16.5

Abbreviations: RE (resistance exercise), SD (standard deviation).

3.4.3 Muscle endurance outcomes

The values (mean ± SEM) for the push-up test, plank test and half squat test for all time points can be seen in Table 16. There was a significant overall effect of time for push-up test, plank test and half squat test, but there were no significant differences between the groups over time (group*time interaction) for all three tests. The per-protocol results for muscle endurance outcomes can be seen in Table 17. There were no significant differences between groups, completers and non-completers, over time (group*time*completion interaction). Sphericity assumption was met.

The individual differences for each exercise group and the group mean difference for push-up test (Figure 40), half squat test (Figure 41) and plank test (Figure 42) are shown below.

Table 16. Muscle endurance outcomes during the programme.

	0-weeks	6-weeks	12-weeks	Time *p*-value	Group*Time *p*-value
Push up test (reps) (mean ± SEM)					
Flexibility group	10.4 ± 0.9	13.69 ± 1.3	15.4 ± 2.2	<0.00001*	0.324
RE group	13.9 ± 1.5	15.2 ± 1.3	16.9 ± 1.4		
Plank test (s) (mean ± SEM)					
Flexibility group	49.5 ± 9.8	46.8 ± 7.3	56.0 ± 9.3	0.001*	0.08
RE group	41.9 ± 5.4	50.8 ± 5.6	53.9 ± 5.6		
Half squat test (s) (mean ± SEM)					
Flexibility group	35.2 ± 4.5	40.7 ± 3.9	41.6 ± 4.2	0.0002*	0.162
RE group	37.9 ± 4.6	42.9 ± 5.0	52.2 ± 4.9		

Flexibility group N=26, RE group N=29. *p-value < 0.05, statistical significance.

Table 17. Muscle endurance per-protocol analysis.

	0-weeks	6-weeks	12-weeks	Group*Time*Completion *p*-value
Push up test (reps)				
(mean ± SEM)				
Flexibility group				
Completers				
Non-completers				0.395
RE group				
Completers (N=18)				
Non-completers (N=13)				
Plank test (s)				
(mean ± SEM)				
Flexibility group				
Completers				
Non-completers				0.983
RE group				
Completers				
Non-completers				
Half squat test (s)				
(mean ± SEM)				
Flexibility group				
Completers	37.01 ± 5.16	39.64 ± 4.47	43.09 ± 5.86	
Non-completers	32.26 ± 8.66	42.44 ± 7.63	39.10 ± 5.19	0.750
RE group				
Completers	41.55 ± 6.61	46.55 ± 7.77	56.68 ± 7.17	
Non-completers	32.77 ± 5.27	37.60 ± 4.97	45.89 ± 6.06	

Flexibility group N=26, RE group N=29. *p-value < 0.05, statistical significance.

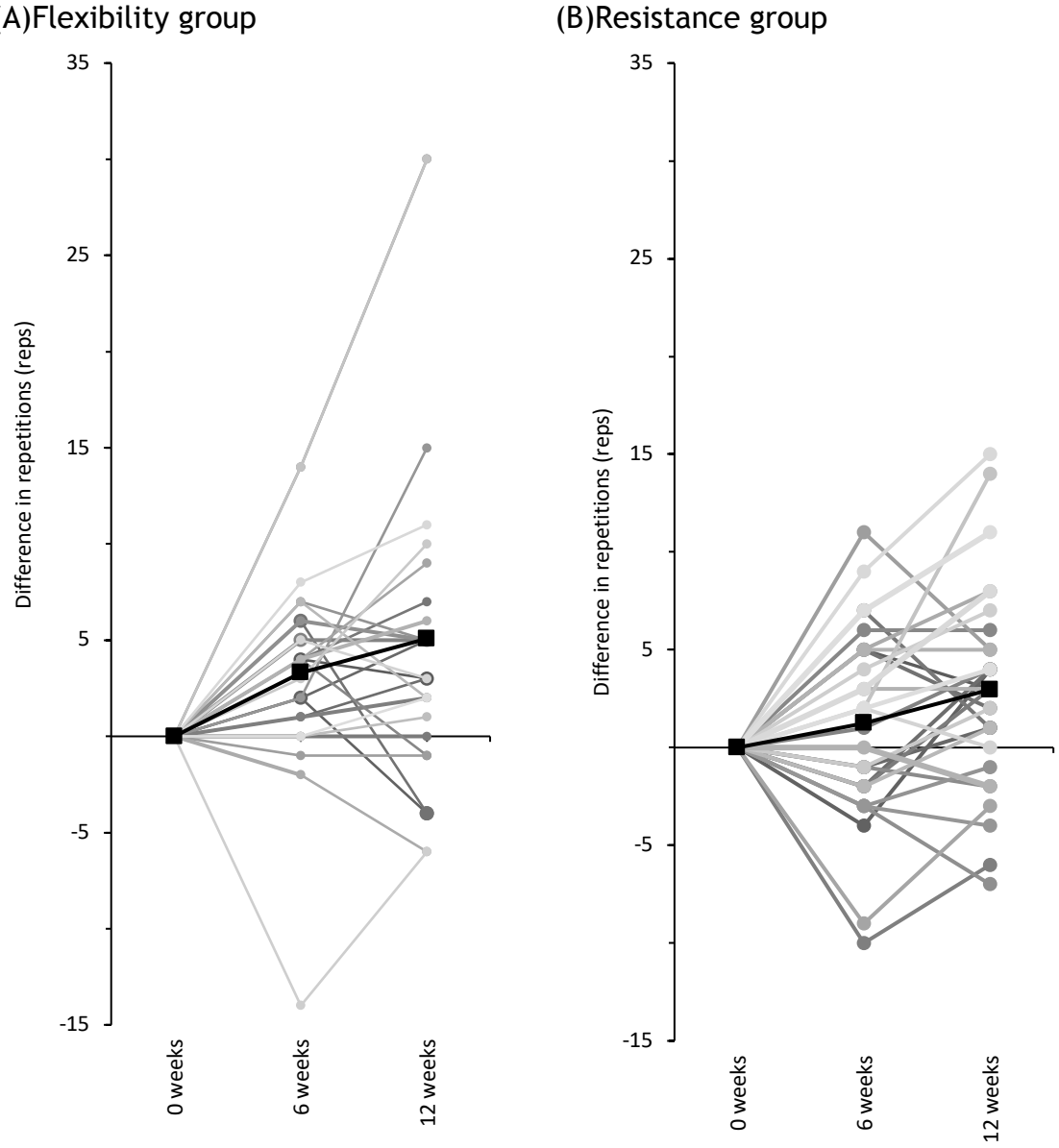


Figure 40. Push up test individual differences during the programme. (A) Flexibility group, (B) Resistance group, (●) Individual values. (■) Mean.

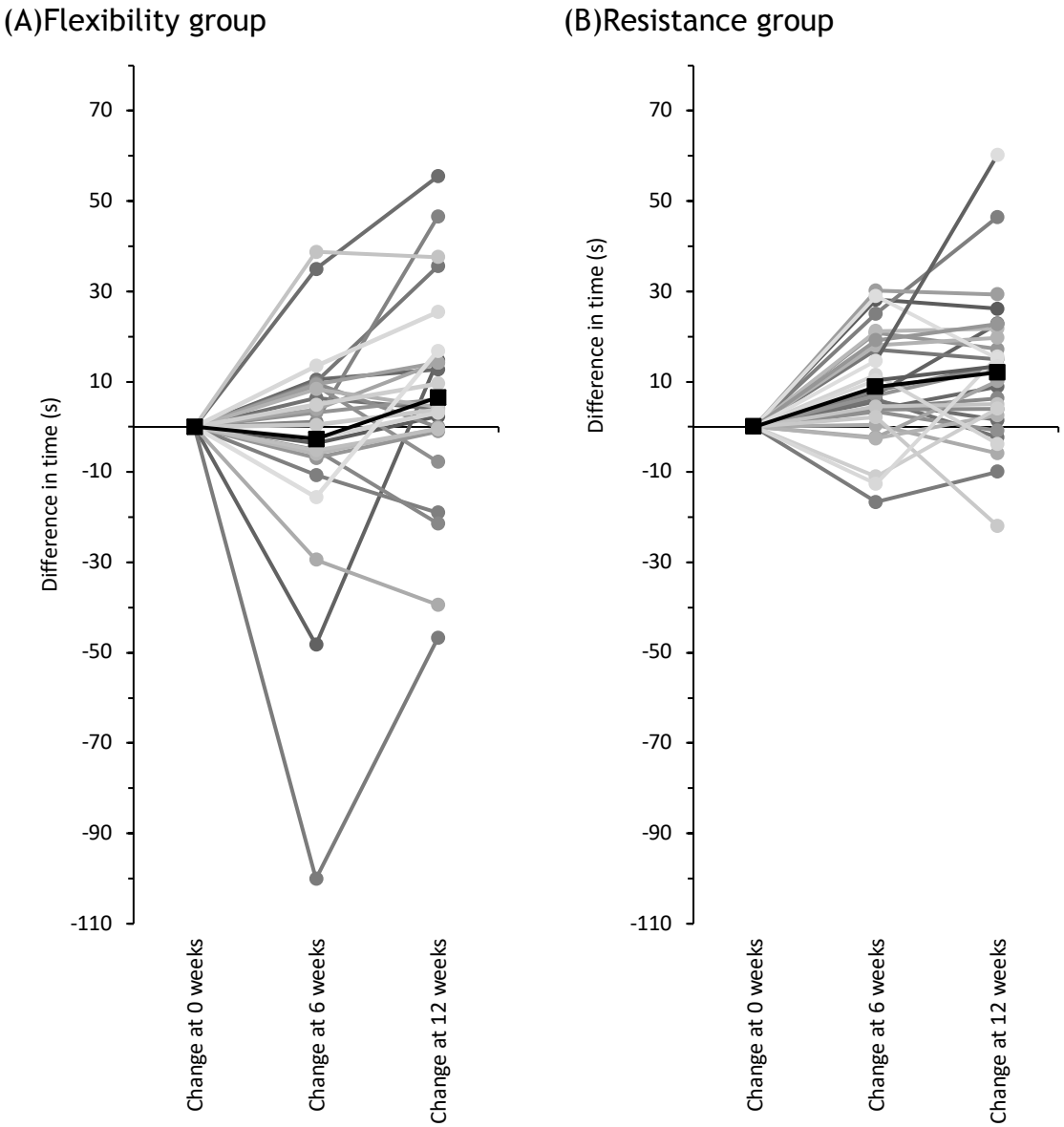


Figure 41. Plank test individual differences during the programme. (A) Flexibility group, (B) Resistance group, (●) Individual values. (■) Mean.

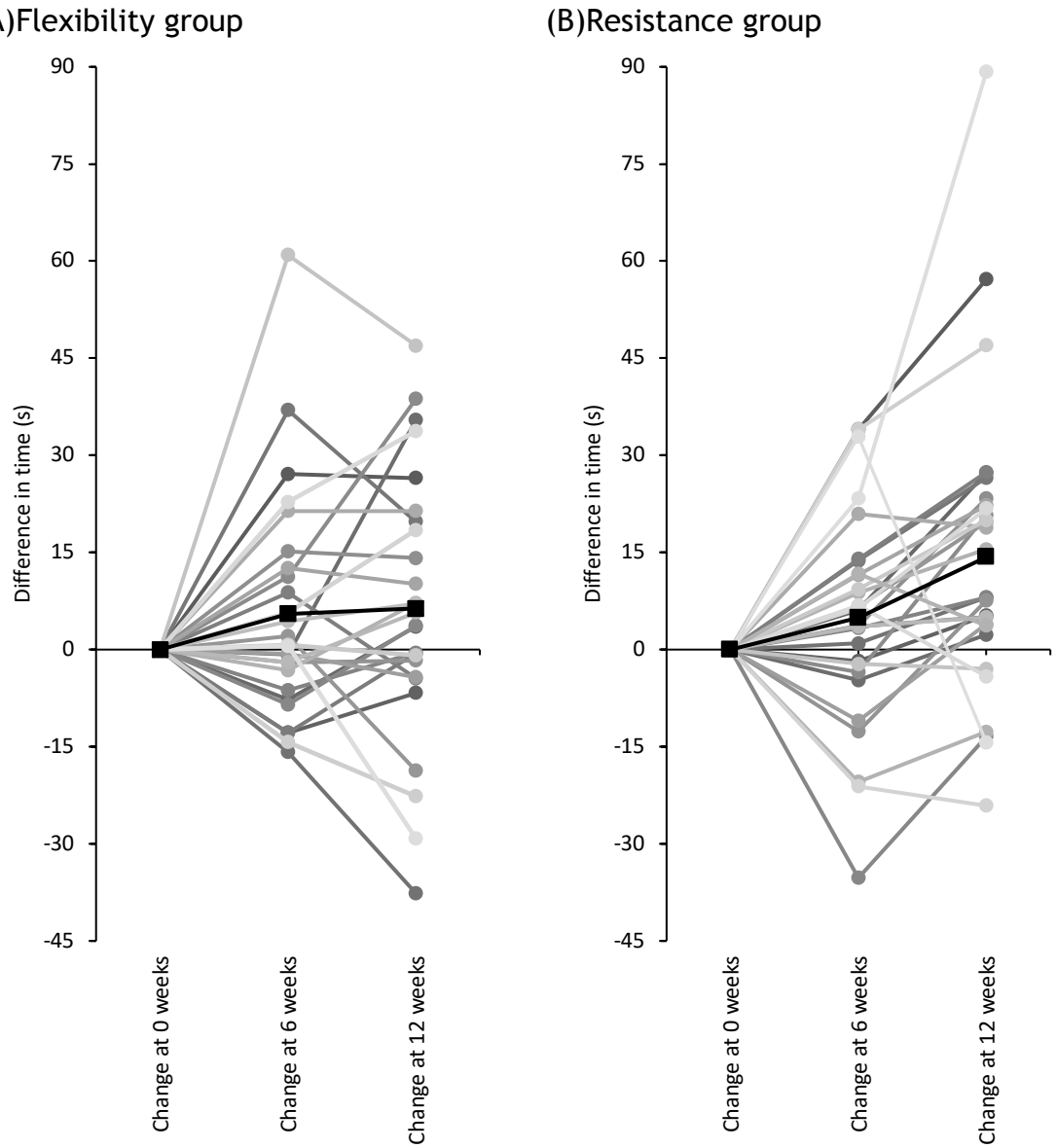


Figure 42. Half-squat test individual differences during the programme (A) Flexibility group, (B) Resistance group (●) Individual values. (■) Mean.

3.4.4 Flexibility outcome

The values for the sit-and-reach test for each time point can be seen in Table 18. There was a significant overall effect of time ($p<0.00001$*), while there were no significant differences between groups over time. Per-protocol results for the sit-and-reach test showed no significant difference between group, completers and non-completers over time (Table 19). Sphericity assumption was met.

Below are shown the individual differences for each exercise group and the group mean difference for the sit and reach test (Figure 43).

Table 18. Sit and reach test during the programme.

	0-weeks (mean ± SEM)	6-weeks (mean ± SEM)	12-weeks (mean ±SEM)	Time *p*-value	Group*Time *p*-value
Sit-and-reach test (cm)					
Flexibility group	-2.45 ± 1.96	-0.03 ± 2.05	2.10 ± 2.10	<0.00001*	0.385
RE group	1.09 ± 2.19	3.60 ± 2.26	4.16 ± 2.21		

Flexibility group N=26, RE group N=29. *p-value < 0.05, statistical significance.

Table 19. Sit-and-reach per protocol analysis.

	0-weeks (mean ± SEM)	6-weeks (mean ± SEM)	12-weeks (mean ± SEM)	Group*Time*Completion *p*-value
Sit-and-reach test (cm)				
Flexibility group				
Completers	-2.38 ± 2.23	1.52 ± 2.50	3.00 ± 2.46	
Non-completers	-2.57 ± 3.81	-2.50 ± 3.57	0.65 ± 3.89	0.548
RE group				
Completers	2.18 ± 2.71	5.44 ± 2.84	6.42 ± 2.46	
Non-completers	-0.46 ± 3.76	1.00 ± 3.69	0.96 ± 3.99	

Flexibility group N=26, RE group N=29. *p-value < 0.05, statistical significance.

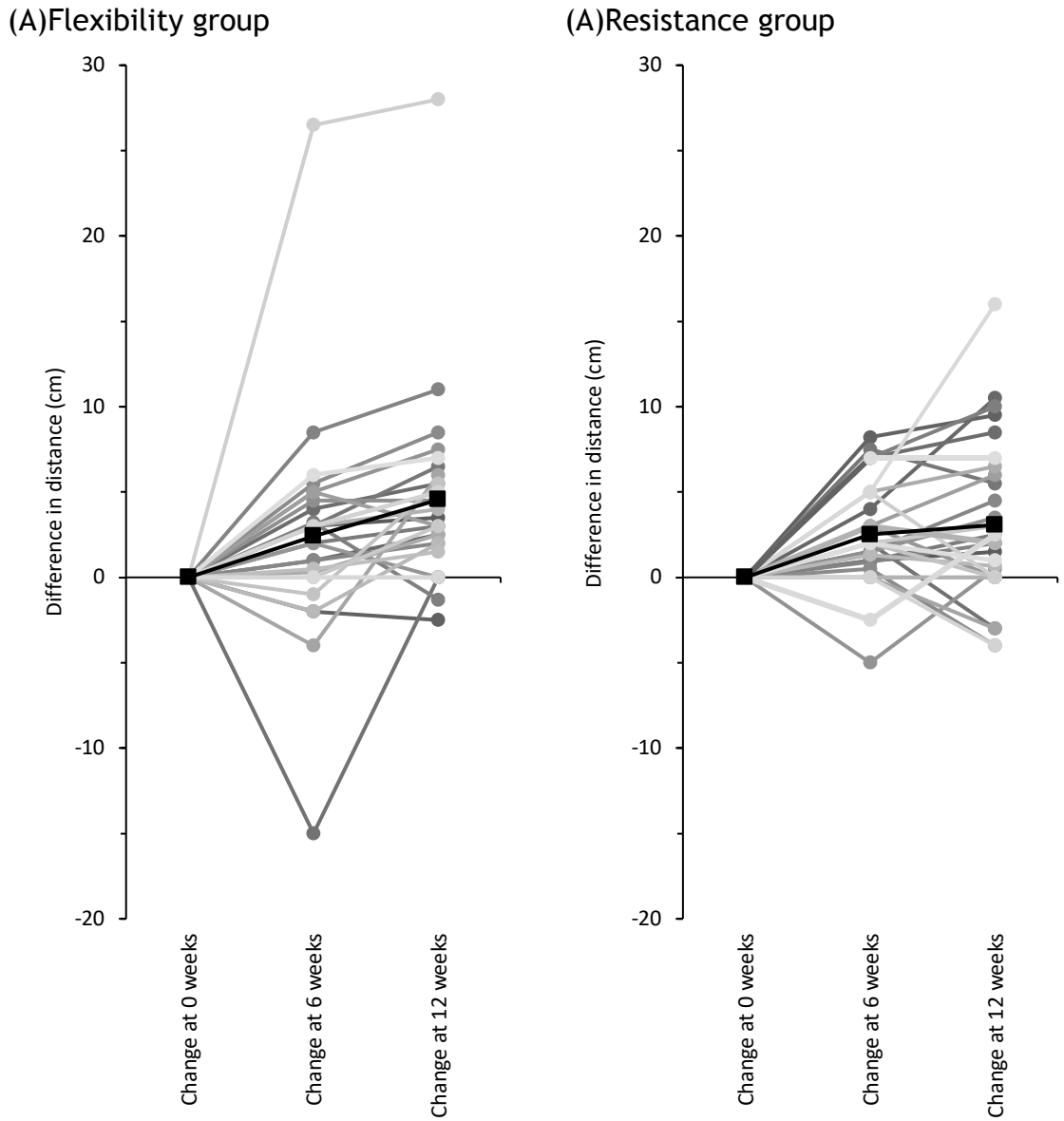


Figure 43. Sit-and-reach test individual differences during the programme (A) Flexibility group, (B) Resistance group (●) Individual values. (■) Mean.

3.4.5 Questionnaires outcomes

Changes in time for the EQ-VAS, WEMWBS, IDVL, SVL and Rosenberg's questionnaire can be seen in Table 20 and the modified BREQ-2 outcomes can be seen in Table 22.

There was a significant overall effect of time for WEMWBS and Rosenberg's questionnaires. There were no significant overall effects of time for the rest of the questionnaires. Additionally, there was a significant difference between the groups over time (group*time interaction) for Amotivation in the BREQ-2 adapted questionnaire. The post-hoc analysis for trend for Amotivation showed a

significant linear trend in the flexibility group (p=0.031), and an increase of 0.321 in the score from baseline to post-intervention. There were no other significant differences between the groups over time for the other variables. Sphericity assumption was met.

The per-protocol analysis showed a significant difference between groups, completers and non-completer over time for the EQ-VAS. The post-hoc analysis for trend showed a significant linear trend for the resistance group/non-completers (p=0.0114) with an increase of 3.353 in the score. Finally, it also showed a significant difference between groups, completers and non-completer over time for the SLV. The post-hoc analysis for trend showed a significant linear trend for the flexibility/completers (p=0.005) with an increase of 0.319 in the score. There were no other significant differences in the per-protocol analysis for the rest of the variables.

Table 20. Questionnaires' outcomes during the study.

	0-weeks (mean ± SEM)	6-weeks (mean ± SEM)	12-weeks (mean ± SEM)	Time *p*-value	Group*Time *p*-value
EQ-VAS					
Flexibility group	72.04 ± 2.88	72.96 ± 3.14	73.00 ± 3.31	0.460	0.919
RE group	75.62 ± 2.17	76.93 ± 2.02	77.81 ± 2.12		
WEMWBS					
Flexibility group	48.54 ± 1.44	49.50 ± 1.60	49.96 ± 1.63	0.014*	0.620
RE group	50.03 ± 1.46	52.50 ± 1.46	52.89 ± 1.78		
IDVL					
Flexibility group	3.81 ± 0.23	3.94 ± 0.18	3.99 ± 0.22	0.167	0.968
RE group	4.16 ± 0.18	4.33 ± 0.18	4.37 ± 0.23		
SLV					
Flexibility group	3.67 ± 0.19	3.74 ± 0.20	3.97 ± 0.25	0.095	0.842
RE group	3.79 ± 0.17	4.07 ± 0.22	4.15 ± 0.26		
Rosenberg's					
Flexibility group	28.23 ± 1.14	28.54 ± 1.17	28.68 ± 0.98	0.028*	0.431
RE group	30.59 ± 1.01	31.57 ± 0.89	32.41 ± 1.12		

0-weeks Flexibility group N=26, RE group N=29; 6-weeks Flexibility group N=24, RE group N=28; 12-weeks Flexibility group N=25, RE group N=27. *p-value < 0.05, statistical significance. EQ-VAS: EuroQol Visual Analogue Scale; WEMWBS: Warwick-Edinburgh Mental Wellbeing Scale; IDVL: Subjective vitality Scale individual difference level version, SLV: Subjective vitality Scale state-level version; Rosenberg's: Rosenberg's self-esteem questionnaire.

Table 21. Questionnaires per protocol results.

	0-weeks (mean ± SEM)	6-weeks (mean ± SEM)	12-weeks (mean ± SEM)	Group*Time*Completion *p*-value
EQ-VAS				
Flexibility group				
Completers	69.69 ± 3.14	75.00 ± 3.59	72.80 ± 3.45	
Non-completers	75.80 ± 5.56	69.56 ± 5.98	73.30 ± 6.73	0.002*
RE group				
Completers	79.29 ± 2.64	77.00 ± 2.82	78.06 ± 2.89	
Non-completers	70.42 ± 3.23	76.82 ± 2.88	77.45 ± 78.06	
WEMWBS				
Flexibility group				
Completers	48.88 ± 1.51	48.40 ± 1.96	51.07 ± 2.12	
Non-completers	48.00 ± 2.97	51.33 ± 2.78	48.30 ± 2.59	0.329
RE group				
Completers	47.06 ± 1.79	50.24 ± 2.06	51.69 ± 2.29	
Non-completers	54.25 ± 1.95	56.00 ± 2.43	54.64 ± 2.89	
IDVL				
Flexibility group				
Completers	3.76 ± 0.16	3.96 ± 0.18	4.18 ± 0.24	
Non-completers	3.89 ± 0.54	3.90 ± 0.41	3.7 ± 0.42	0.524
RE group				
Completers	4.05 ± 0.26	4.16 ± 0.26	4.32 ± 0.31	
Non-completers	4.32 ± 0.21	4.60 ± 0.22	4.45 ± 0.35	
SLV				
Flexibility group				
Completers	3.56 ± 0.17	3.95 ± 0.26	4.33 ± 0.27	0.038*
Non-completers	3.86 ± 0.42	3.39 ± 0.31	3.43 ± 0.44	

RE group				
Completers	3.67 ± 0.22	3.74 ± 0.27	3.97 ± 0.34	
Non-completers	3.96 ± 0.29	4.58 ± 0.32	4.42 ± 0.40	
Rosenberg's				
Flexibility group				
Completers	28.63 ± 1.35	28.67 ± 1.62	29.93 ± 1.12	
Non-completers	27.60 ± 2.09	28.33 ± 1.68	26.80 ± 1.67	0.575
RE group				
Completers	30.53 ± 1.50	31.41 ± 1.22	32.44 ± 1.71	
Non-completers	30.67 ± 1.28	31.82 ± 1.33	32.36 ± 1.25	

0-weeks Flexibility group N=26, RE group N=29; 6-weeks Flexibility group N=24, RE group N=28; 12-weeks Flexibility group N=25, RE group N=27. *p-value < 0.05, statistical significance. EQ-VAS: EuroQol Visual Analogue Scale; WEMWBS: Warwick-Edinburgh Mental Wellbeing Scale; IDVL: Subjective vitality Scale individual difference level version, SLV: Subjective vitality Scale state-level version; Rosenberg's: Rosenberg's self-esteem questionnaire.

Table 22. Modified BREQ-2 outcomes during the study.

	0-weeks (mean ± SEM)	6-weeks (mean ± SEM)	12-weeks (mean ± SEM)	Time *p*-value	Group*Time *p*-value
Amotivation Score					
Flexibility group	1.39 ± 0.14	1.41 ± 0.12	1.72 ± 0.23	0.623	0.030*
RE group	1.47 ± 0.16	1.44 ± 0.15	1.33 ± 0.14		
Extrinsic Score					
Flexibility group	1.65 ± 0.12	1.67 ± 0.13	1.83 ± 0.17	0.923	0.098
RE group	1.71 ± 0.18	1.74 ± 0.14	1.58 ± 0.16		
Introjected Score					
Flexibility group	2.91 ± 0.17	2.65 ± 0.17	2.79 ± 0.19	0.294	0.951
RE group	2.65 ± 0.17	2.48 ± 0.16	2.62 ± 0.19		
Identified Score					
Flexibility group	3.71 ± 0.19	3.44 ± 0.19	3.48 ± 0.21	0.723	0.207
RE group	3.78 ± 0.15	3.86 ± 0.17	3.82 ± 0.17		
Integrated Score					
Flexibility group	2.27 ± 0.25	2.42 ± 0.26	2.36 ± 0.24	0.412	0.814
RE group	2.69 ± 0.26	2.93 ± 0.25	2.59 ± 0.26		
Intrinsic Score					
Flexibility group	2.95 ± 0.23	2.93 ± 0.22	2.92 ± 0.22	0.775	0.780
RE group	3.15 ± 0.21	3.20 ± 0.22	3.27 ± 0.23		

0-weeks Flexibility group N=26, RE group N=29; 6-weeks Flexibility group N=24, RE group N=28; 12-weeks Flexibility group N=25, RE group N=27. *p-value < 0.05, statistical significance.

Table 23. Modified BREQ-2 per protocol results.

	0-weeks (mean ± SEM)	6-weeks (mean ± SEM)	12-weeks (mean ± SEM)	Group*Time*Completion *p*-value
Amotivation Score				
Flexibility group				
Completers	1.56 ± 0.21	1.43 ± 0.15	1.77 ± 0.29	
Non-completers	1.10 ± 0.07	1.38 ± 0.23	1.63 ± 0.40	0.423
RE group				
Completers	1.51 ± 0.24	1.53 ± 0.23	1.39 ± 0.23	
Non-completers	1.42 ± 0.19	1.30 ± 0.14	1.25 ± 0.11	
Extrinsic Score				
Flexibility group				
Completers	1.63 ± 0.15	1.68 ± 0.15	1.65 ± 0.21	
Non-completers	1.67 ± 0.19	1.66 ± 0.25	2.10 ± 0.29	0.181
RE group				
Completers	1.81 ± 0.27	1.61 ± 0.19	1.48 ± 0.22	
Non-completers	1.58 ± 0.18	1.95 ± 0.20	1.73 ± 0.20	
Introjected Score				
Flexibility group				
Completers	2.74 ± 0.22	2.53 ± 0.23	2.56 ± 0.27	
Non-completers	3.17 ± 0.26	2.86 ± 0.21	3.14 ± 0.18	0.185
RE group				
Completers	2.65 ± 0.25	2.32 ± 0.21	2.73 ± 0.27	
Non-completers	2.64 ± 0.20	2.73 ± 0.22	2.46 ± 0.23	
Identified Score				
Flexibility group				
Completers	3.47 ± 0.25	3.30 ± 0.21	3.30 ± 0.27	0.676
Non-completers	4.10 ± 0.25	3.67 ± 0.36	3.75 ± 0.35	

RE group				
Completers	3.82 ± 0.21	3.94 ± 0.23	4.06 ± 0.21	
Non-completers	3.71 ± 0.23	3.73 ± 0.25	3.46 ± 0.25	
Integrated Score				
Flexibility group				
Completers	1.81 ± 0.26	2.13 ± 0.31	1.93 ± 0.21	
Non-completers	3.00 ± 0.39	2.89 ± 0.42	3.00 ± 0.47	0.248
RE group				
Completers	2.78 ± 0.36	2.88 ± 0.30	2.81 ± 0.33	
Non-completers	2.58 ± 0.40	3.00 ± 0.45	2.27 ± 0.41	
Intrinsic Score				
Flexibility group				
Completers	2.73 ± 0.28	2.80 ± 0.28	2.80 ± 0.27	
Non-completers	3.30 ± 0.37	3.14 ± 0.36	3.10 ± 0.38	0.996
RE group				
Completers	3.12 ± 0.29	3.31 ± 0.29	3.40 ± 0.32	
Non-completers	3.20 ± 0.30	3.05 ± 0.36	3.09 ± 0.34	

0-weeks Flexibility group N=26, RE group N=29; 6-weeks Flexibility group N=24, RE group N=28; 12-weeks Flexibility group N=25, RE group N=27. *p-value < 0.05, statistical significance.

3.4.6 Exercise training programme outcomes

Overall, a total of 74 participants started the intervention (Flexibility group N=36, Resistance group N=38). Only one participant from the resistance group did not start the programme during the 12 weeks of the intervention period. The overall volume, number of muscle groups completed and days exercised can be seen in Table 24 below.

Table 24. Overall adherence, volume and frequency.

	Flexibility group (N=36)	RE group (N=38)
	Mean ± SD	Mean ± SD
Muscle groups		
Number of weeks with 6 completed muscle groups	6.1 ± 4.2	6.6 ± 4.1
Number of weeks with 5 completed muscle groups	6.9 ± 4.2	7.6 ± 4.1
Volume		
Total number of sets completed over 12 weeks	68.3 ± 63.2	66.1 ± 49.2
Percentage of prescribed sets completed	94.8 ± 87.8	91.7 ± 68.4
Frequency		
Days exercised	1.3 ± 1.3	1.5 ± 1.4

a) Adherence

Only 55.6% of the flexibility group and 57.9% of the resistance group completed at least 80% of the minimum amount of exercise sessions prescribed. Additionally, only 36% of the flexibility group completed 10 or more weeks of the programme, while only 47% of the resistance group did. On the other hand, 64% of the flexibility group and 53% of the resistance group completed less than 10 weeks.

The mean of muscle groups completed by both exercise groups throughout the 12-week exercise programme can be seen in Figure 44.

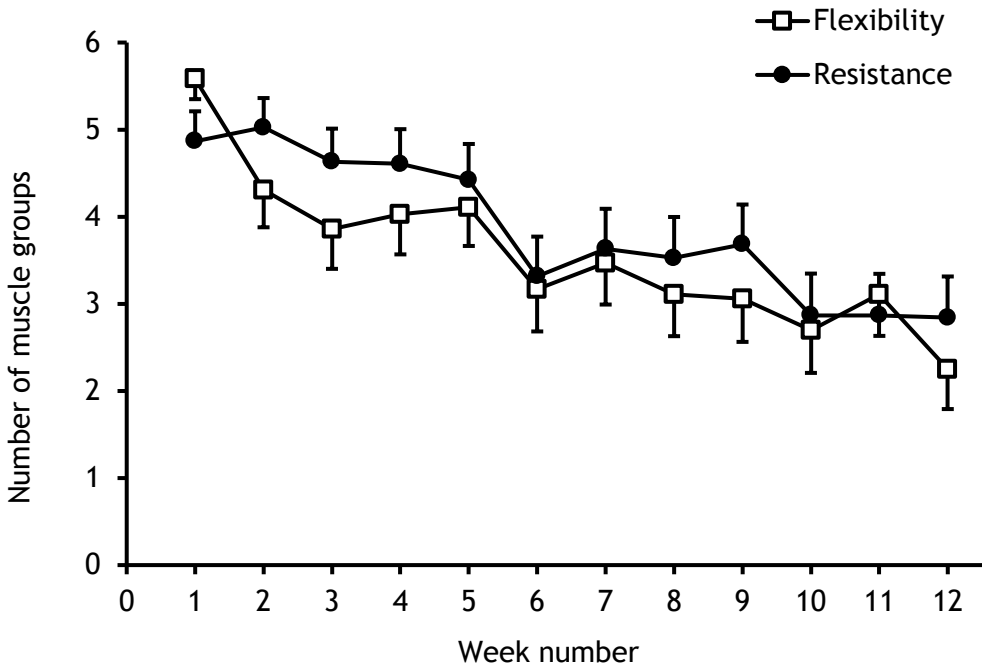


Figure 44. Number of muscle groups completed per week during the programme, mean (±SEM).

The percentage of participants completing at least 5 muscle groups throughout the 12-week exercise programme can be seen in Figure 45. The percentage of participants completing the 6 muscle groups throughout the 12-week exercise programme can be seen in Figure 46.

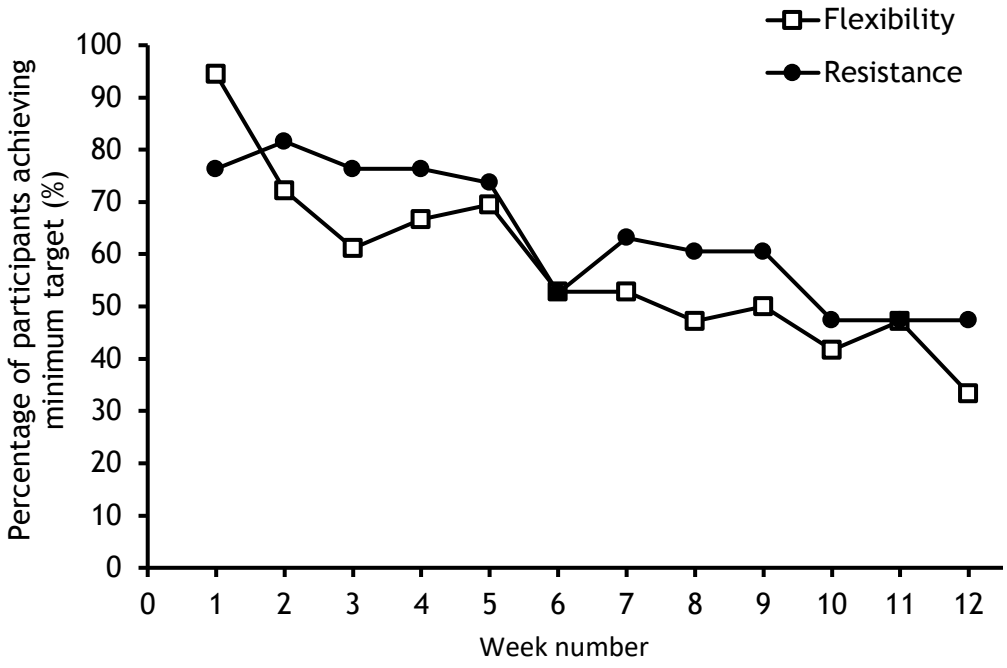


Figure 45. Percentage of participants achieving minimum target muscle groups (≥ 5) per week during the exercise programme.

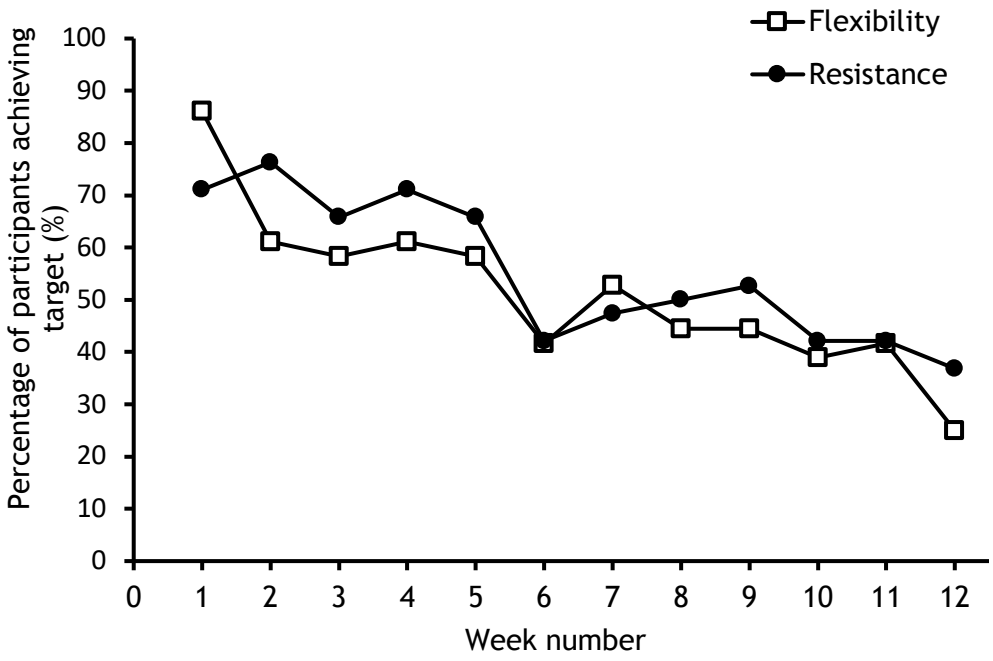


Figure 46. Percentage of participants achieving target muscle groups (6) per week during the exercise programme.

b) Volume

The mean number of sets exercised by the flexibility group and the RE group over the 12-week exercise programme can be seen in Figure 47.

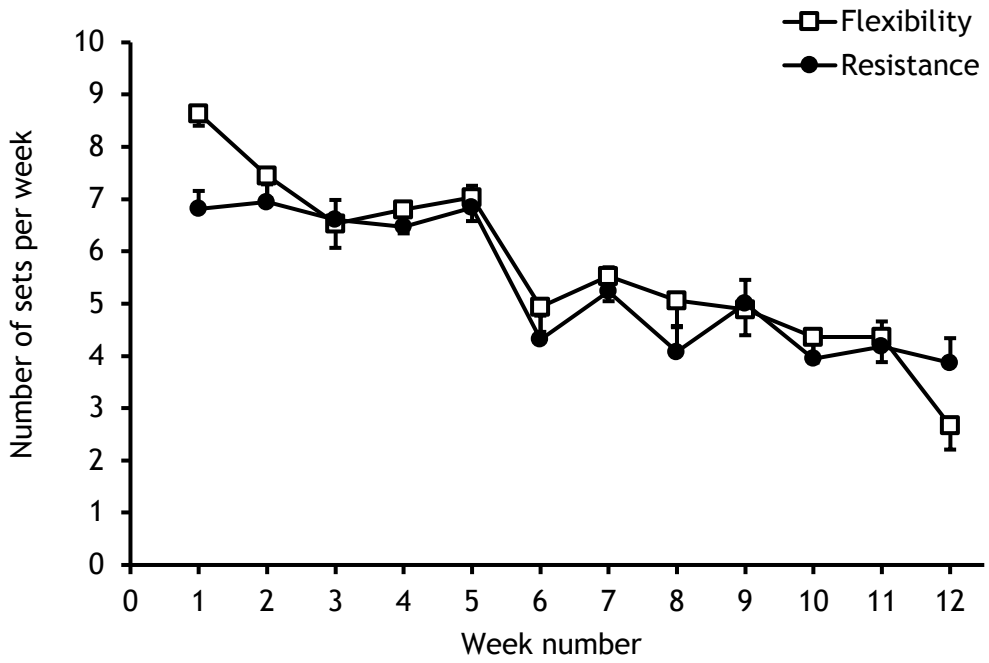


Figure 47. Number of sets exercised per week during the programme, mean (±SEM).

c) Frequency

The percentage of participants mean frequency of exercised days over the programme can be seen in Figure 48.

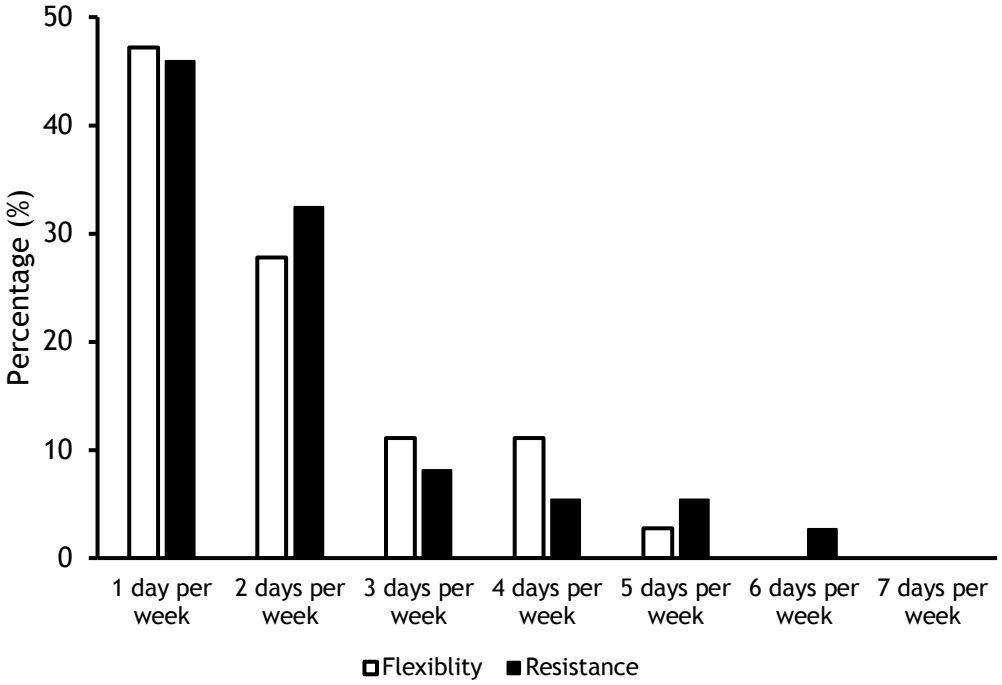


Figure 48. Percentage of participants mean chosen frequency of days exercised during the exercise programme.

The mean frequency of days exercised during the programme can be seen in Figure 49.

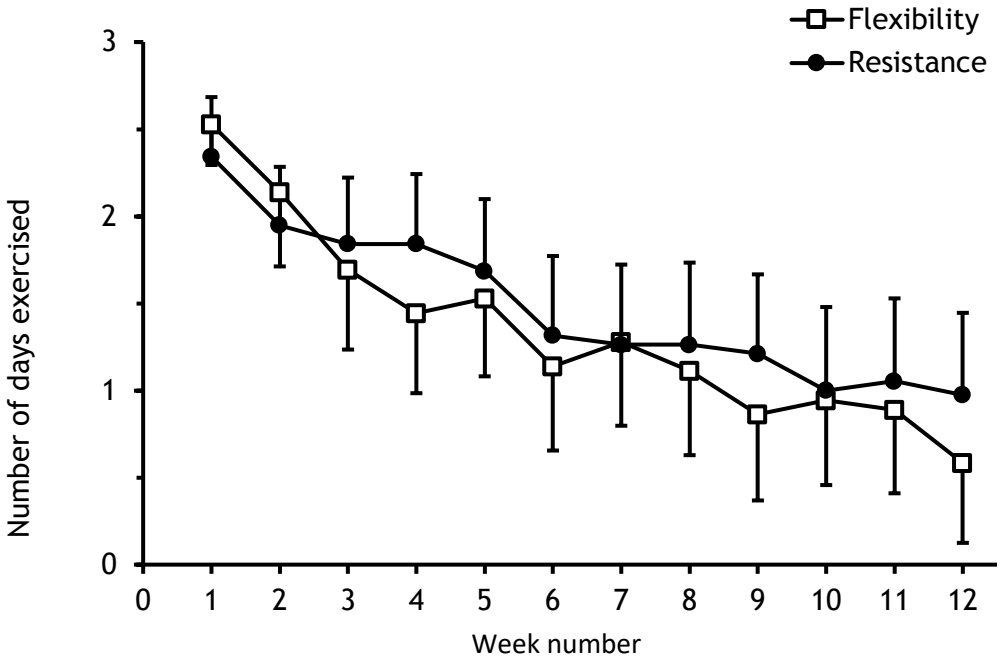


Figure 49. Frequency of days exercised per week during the programme, mean (±SEM).

3.4.7 Adverse events

There was only one adverse event reported during the REFLEX exercise programme. A participant from the RE group reported doing the deadlift exercise with an exercise band when suddenly felt pain in her right knee and following inflammation. The participant reported the issue to the researcher and it was advised to seek medical help and to stop the exercise programme. During the visit with the General Practitioner, the participant was diagnosed with a mild ligament strain. After that, the participant decided to drop out of the programme and recover from her injury.

3.5 Discussion

The primary aim of this study was to determine the effects of an app-based home-based resistance exercise programme vs an app-based home-based flexibility programme on muscular endurance and flexibility. Performance in the push-up test, plank test and half-squat test improved over time in both groups overall, but there was no difference in the improvement between the resistance and flexibility groups. There were also no differences between groups for completers vs non-completers in the per-protocol analysis for the three variables.

The significant changes over time with no differences between groups in the push-up test might suggest a learning effect for the test. However, it is also possible that the flexibility programme improved muscular endurance. Recent evidence from a metanalysis has shown that static stretching has the potential to improve muscle strength, with higher benefits in samples with a higher female proportion and older participants (Arntz et al., 2023). This needs to be considered with caution since the REFLEX study measured muscle endurance and not strength, though both are part of muscular function. This effect was not expected, in fact, the flexibility programme was given to the ‘control’ group to try to reduce drop-outs as it was felt that individuals not randomised to an online exercise programme may have been reluctant to continue with the trial. A study looking at the effects of a 12-week strength and flexibility exercise programme (combined or isolated) in women, found that the flexibility group had an increase in leg press strength ($p=0.0187$), but not bench press ($p=0.1757$)

pre to post (Leite et al., 2015). This could explain the results of the REFLEX Study.

Some studies have investigated the effects of home-based resistance exercise on indices of muscle function, some finding improvement in muscle strength (Tsekoura et al., 2018, Al Ozairi et al., 2023, Kikuchi et al., 2023). Firstly, a factor could be the length of the programme. Al Ozairi et al, intervention was 20-weeks longer (32 weeks) than the REFLEX Study. Nevertheless, Tseokoura et al. was the same length and Kikuchi et al (2023) was shorter (8 weeks). Secondly, the dose prescribed could be another factor. One study that found improvements in muscle strength, prescribed higher doses of resistance exercise. It looked at the effects of a 32-week home-based resistance exercise programme in adults with type 2 diabetes. The programme consisted of three sessions per week with each session having exercises for major muscle groups (squat, press up, calf raise, band seated low row, lunge, band lateral raise, and plank). During the first four weeks the participants had to do one set for each exercise, and from week five onwards participants had to perform three sets for each exercise (Al Ozairi et al., 2023). However, the other two studies had a similar volume of exercise per week (Tsekoura et al., 2018, Kikuchi et al., 2023). Kikuchi et al. (2023), a pilot study in middle-aged adults looked at the effects of an online home-based programme. It prescribed with 2 sessions a week, with each session having nine exercises (18 sets in total) (Kikuchi et al., 2023), which is the same volume as the highest volume a participant could choose to do in the REFLEX study. Though, this needs to be considered with caution, since the minimum was to perform 6 exercises per week (6 sets) and not everyone chose to do the 18 sets every week. In addition, this study did not have a control group so the results need to be considered with discretion. Tseokoura et al. (2018) looked at the effects of a 12-week group-based versus a home-based exercise programme in elderly people with sarcopenia. It prescribed between 1-2 sets for eight exercises (8-16 sets in total) which is lower than the REFLEX study. Moreover, this programme consisted of resistance exercises, balance exercises and 100 min of walking per week (Tsekoura et al., 2018), while the REFLEX study only consisted of resistance exercises. A randomised controlled trial comparing at the effects of one, three and five sets, found that all the training volume groups increased muscle strength compared to the controlled group, with three

sets and five sets showing a significantly greater increase than one se. This study showed that even though three sets and five sets were better than one set, one set still produced strength gains (Radaelli et al., 2015).

On the other hand, other studies looking at the effects of home-based resistance exercise programmes did not find any effects on muscle strength (Vitale et al., 2020) or physical function (Vitale et al., 2020, Fyfe et al., 2022a). Vitale et al. looked at the effects of a 24-week home-based resistance exercise in older adults during the Covid-19 pandemic involving 4 sessions a week, each session lasting 60 min (45 min of resistance exercise), 8 different exercises (upper and lower body), starting from 3-4 sets per week and each set with at least 12 repetitions (both increased as the programme progressed). Even though the volume prescribed is much higher and had a longer intervention compared to the REFLEX study, their lack of significant differences in grip strength and lower limb muscle strength results could be explained by having a small sample size. The other study that is in agreement with the REFLEX study looked at the effects of a 4-week online home-based resistance exercise Snacking programme in older adults. Participants needed to perform 5 exercises, each one for 1 minute with 1 minute rest in between, with the exercises progressing at week 3 (Fyfe et al., 2022a). Though this study had older adults as their sample and a shorter programme compared to the REFLEX study.

A secondary aim was to determine the effects of the exercise programmes on well-being. There was a significant overall effect of time in wellbeing and self-esteem, a significant difference between groups for Amotivation in the BREQ-2 questionnaire, a significant difference between groups and completers/non-completers for self-rated health (EQ-VAS) and vitality and energy (SLV). A pilot study by Kikuchi et al. looked primarily at the effects of home-based resistance exercise on mental health and well-being in middle-aged adults. It found significant improvements in the Center for Epidemiologic Studies-Depression Scale (CES-D) from pre to post measurements, though it did not find any changes for the Well-being Index (WHO-5) and the Kessler Psychological distress Scale (K6) (Kikuchi et al., 2023).

Other secondary aims of this study were to determine participants' adherence, participants' choice of weekly exercise volume and participants' distribution of

exercise. Almost 58% of the RE group and 55.6% of the flexibility group completed at least 80% of the minimum volume prescribed. If we look at adherence in terms of completed weeks (at least 5 muscle groups completed) the adherence decreases with only 47% of the RE group and 36% of the flexibility group completed 10 weeks or more. With these results, it is possible to infer that some participants completed the minimum volume of exercise per week, but not all muscle groups required. A pattern that happened more in the flexibility group than the resistance group. This could be an indicator of personal preferences regarding the exercises. There are mixed results in the literature regarding adherence. Some studies reported higher adherence, with 87.5% of total exercise sessions in the home-based group (minimally supervised with foru phone calls and four visits) (Tsekoura *et al.*, 2018), with 85.29% of participants completing 85% or more of the exercises prescribed (minimally supervised with weekly chats) (Zhang et al., 2022) and 100% of participant retention and an overall adherence of 87% completing the prescribed exercise sessions, with 97% for one session, 82% for two sessions and 81% for three sessions (unsupervised, but had to return exercise diary every week) (Fyfe et al., 2022a). On the other hand, another study showed lower adherence of 49% of sessions in the intervention group (first three session supervised and then one per month) (Al Ozairi et al., 2023). These differences can be attributed to having different, volume of the prescription, level of supervision, length of programme or how they measure adherence. Zhang et al (2022) used a similar way to measure adherence compared to the REFLEX study, but the exercise programme was minimally supervised with weekly chats with the participants, while the REFLEX Study was unsupervised (Zhang et al., 2022). The pilot study by Fyfe et al. had a similar programme to the REFLEX exercise programme, but the length of the programme was only 4-weeks long while the volume of exercise prescribed per week was higher (for all groups) compared to the REFLEX study (Fyfe et al., 2022a). Finally, Al Ozairi et al. (2023) considered adherence to exercise sessions, which depending on the week had a different number of sets per exercise and as mentioned previously the overall amount of sets is higher than the present study. The REFLEX study, on the other hand, considered adherence to each set, since participants could distribute their sets throughout their week as they wished. Additionally, Al Ozairi et al. (2023) intervention was considerably longer than the REFLEX study, which can be also a reason for a lower adherence.

However, it is relevant to mention that it did have three supervised sessions at the beginning and also once a month, in addition to online or phone messages as reminders for each session, while the REFLEX study did not have any kind of supervision, just an update before each measuring session. A systematic review and meta-analysis looking at the role of supervision in resistance exercise training included 12 studies with a total of 577 participants. It found that there was a small difference in adherence between supervised resistance exercise (91.5% [95%CI = 82.7% to 96.0%]) and unsupervised resistance exercise (87.1% [95%CI = 71.2% to 94.9%]) (Fisher et al., 2022). Adittionlly, it has been shown that adherence can be affected by several factors such as exercise history, social support (higher support tends to lead to higher adherence) and length of the treatment (long and complicated decreases adherence) (Mahmood et al., 2023), which could explain the difference in the REFLEX study results compared to the literature.

The resistance and flexibility group started below the prescribed amount of MG and showed a constant decrease as the study progressed, with an important decrease at 6 weeks, with the RE group having a higher adherence than the flexibility for most of the programme. In addition, the number of sets completed per week was higher than the minimum at the start of the programme, but dropped substantially at 6-weeks and kept decreasing up to around half of the sets prescribed until the end of the programme with the RE group always having higher volume than the flexibility group. Participants chose to distribute their exercise mainly on one day and two days a week, being one day a week the most chosen for both groups. When we saw the mean frequency during the programme, both groups start the first week between two and three days a week, which decreases as the programme progresses until reaching one day a week for the RE group and half a day for the flexibility group. It is interesting to see that the adherence and volume of exercise of the participants decrease as the programme progresses. The results of the present quantitative study, clearly show that this intervention was not able to make participants adhere consistently over time. This could be due to not producing any changes in exercise regulators, as shown previously in the lack of significant changes in the adapted BREQ-2 questionnaire. More details will be discussed in the following chapter of this thesis (Chapter 4: REFLEX qualitative interviews).

There are several limitations to this study. Firstly, gold standard measurements for muscle strength and muscle endurance were not possible due to the restricted conditions imposed by the Government due to the COVID-19 pandemic. Secondly, the assessments that were used had to be adapted and were delivered remotely via an online call, which can affect the reliability and validity of these tests. Thirdly, because the intervention was delivered remotely, we decided to give the control group an intervention that would not interfere with the primary outcomes so that we could minimise the dropouts. Finally, the sample size calculation might have been overconfident in looking at a small study effect, which could have led to the REFLEX study being underpowered to detect the difference between the groups.

On the other hand, the strengths of this study are that the intervention was delivered online which made recruitment easier and it allowed to recruit people from all over the UK, USA and Europe. Additionally, this study contributes valuable information on people's behaviour towards resistance exercise which helps towards the goal of increasing the resistance exercise guidelines compliance.

3.6 Conclusion

Overall, it can be concluded that a 12-week home-based resistance exercise programme and a 12-week flexibility exercise programme improved muscle endurance, flexibility, wellbeing and self-esteem, thought there were no significant differences between them. Additionally, there was no differences for exercise motivation regulation in healthy adults, except for amotivation. More studies with higher sample sizes, other assessments and different volumes of home-based resistance exercise are necessary to increase the evidence of this kind of exercise programmes in healthy adults.

Chapter 4 Effect of a home-based REsistance exercise vs a home-based FLEXbility exercise programme on muscular endurance and flexibility in healthy adults (REFLEX) Qualitative Interviews.

4.1 Introduction

The ONE Study (Chapter 2) was the first attempt to design a home-based resistance exercise programme that targeted some of the barriers to resistance. It found that convenience, enjoyment, sense of achievement, progression, self-monitoring and obtaining the benefits of resistance exercise made participants adhere to the programme and keep exercising. However, participants in the ONE Study had a few suggestions to improve the exercise programme. These included having more freedom in how to fit the exercise programme into their everyday life, having a higher diversity of exercises, and more exercise volume and progression in the exercises.

Other studies have found similar results. A study looking at the feasibility of a 10-week online home-based resistance exercise programme in older adults (Vikberg et al., 2022). It found that clear instructions, a straightforward and flexible programme and were important for the participants. They also thought the exercise was not time-consuming, liked having progression, improved their muscular strength, and felt joy and satisfaction with themselves for completing the programme (Vikberg et al., 2022) . Another study by Fyfe et al. (2022) looked at the feasibility and acceptability of a remotely delivered, home-based resistance exercise “snacking” programme. It showed that having brief frequent exercise sessions with minimal equipment allowed the integration of the programme into the participants’ daily routines and improved the feasibility of the programme (Fyfe et al., 2022a). It is relevant to mention that these studies have been done in older adults (65 years old and over) and not adults (between 18-64 years old). Additionally, young women in the resistance group of a 10-month exercise training programme expressed their enjoyment of the resistance exercises and progression (Lambert et al., 2020).

Therefore, it was important to create a programme that considers the barriers to resistance exercise in addition to convenience, enjoyment, sense of achievement, flexibility, simpleness, diversity, progression and the benefits of the exercise in healthy adults between 18 and 64 years old. As a result, the REFLEX Study was created. Participants underwent a 12-week online delivered home-based resistance exercise programme. More details of the programme can be found in Chapter 3 (REFLEX Study).

4.2 Study Aim

The aims of this study were a) to explore participants' perceptions, feelings, thoughts, enjoyment, tolerance and acceptability of both an online home-based resistance exercise programme, but also the comparator flexibility programme; and b) to evaluate the Theory of Change developed from the ONE Study.

4.3 Methods

4.3.1 Sample

Subsamples of the resistance exercise group (N = 11) and flexibility exercise group (N=10) were recruited at the end of the exercise programme to take part in a single online qualitative interview after the 12-week measurements. Purposive sampling was undertaken to include a range of views of men and women, of younger and older participants, and of those who completed/did not complete the exercise programmes. The participants' characteristics for the resistance exercise group can be seen in Table 25. The participants' characteristics for the flexibility group (comparator group) can be seen in Table 26. Both tables show each participant age group, gender and if they completed the exercise programme or not.

Table 25. REFLEX Study Qualitative Interviews Resistance exercise group characteristics.

Age group	Gender	Completion
<35 y	Female	Completer
<35 y	Female	Completer
35-50 y	Female	Completer
35-50 y	Female	Non completer
35-50 y	Female	Non completer
35-50 y	Male	Completer
>50 y	Male	Non completer
>50 y	Female	Completer
>50 y	Female	Completer
>50 y	Male	Completer

Abbreviations: (y) years

Table 26. REFLEX Study Qualitative Interviews Flexibility group characteristics.

Age group	Gender	Completion
<35 y	Female	Completer
35-50 y	Female	Completer
35-50 y	Female	Non-completer
35-50 y	Male	Non-completer
>50 y	Female	Completer
>50 y	Female	Non-completer
>50 y	Female	Completer
>50 y	Male	Non-completer
>50 y	Male	Completer
>50 y	Female	Completer

Abbreviations: (y) years

4.3.2 Qualitative Interviews

The qualitative interviews were conducted by MFGT (N=13) and Anthony Muchai Manyara (AMM) (N=8) and supervised by CG. RE and flexibility group participants underwent online in-depth semi-structured interviews (duration of 34:18 ± 9:14 (mm : ss) (mean ± SD)) within a month after the end of the intervention period (via Microsoft Teams), to understand barriers, facilitators, thoughts, opinions of the programme and the ways in which they incorporated the programme into their daily routine. A topic guide was developed by MFGT and CG to explore the views, thoughts, opinions and experiences of the participants. An initial topic guide was developed by MFGT based on the ONE Study topic guide. Later it was discussed and adapted considering the different elements of the REFLEX Study by MFGT and CG. After one interview in which both researchers attended (MFGT and CG) the topic guide was finalised to ensure that all topics were discussed during the interviews (**Appendix AD**). A summarized version of the topic guide can be seen below in Table 2.

Table 27. Topic Guide Questions (summarized version).

Participation in the study	Can you tell me about the online exercise programme you did? How did you do the exercises? How did you feel while doing the exercises?
Impact of the programme	Did you notice any changes as a result of doing the programme? Did you continue doing the exercises after the programme ended?
Improving the programme	If you could change something from the programme, what would it be?

4.3.3 Qualitative analysis

Qualitative interview data were transcribed by an external company approved by the University of Glasgow (1st Class Transcription Services). A framework (Ritchie *et al.*, 2003) and thematic analysis were used to analyse the anonymised transcripts by MFG supported by CG to ensure analytic rigour, using an adapted. NVivo 12 ® software to determine participants' perceptions, feelings, thoughts, enjoyment, tolerance and acceptability regarding the resistance exercise programmes.

Initially, both researchers read three transcripts separately and then, in a meeting, agreed on the codes. Sixteen codes exploring participants' experience, thoughts and acceptability of the flexibility and resistance exercise programmes were found. A codebook was developed for the thematic analysis (Appendix AE). After that, MFGT proceeded to code all the transcripts according to the codebook. Codes that had a large amount of data were coded with subcodes (**Appendix AE**). Each of these codes was read separately by each researcher (MFGT and CG), and then a subcodes were developed for each code. After the subcodes were developed for each code with a large amount of data, MFGT proceeded to code each subcode, one code at a time. A list of all codes and subcodes can be seen below in Table 28. Codes covered fitting exercise into daily life, choice of exercise, optimal challenge, experience of the webapp, barriers and facilitators, impact of the programme and suggestions for the programme.

For the codes with a large amount of data and sub-codes, a framework matrix was developed by MFGT (Appendix AF; Appendix AG; Appendix AH; Appendix AI;

Appendix AJ). The matrix consisted of a table with each participant in a row with the ID, exercise group (flexibility/resistance), age range (<35 years old, between 35-50 years old and >50 years old), gender (male/female) and exercise programme completion status (completed/non-completed) and each subcode in a column. A brief summary of each participant and each subcode was made and an illustrative quote was added. After the framework matrices were completed, they were explored to find any patterns in the data by MFGT.

Descriptive summaries were written for each of the sixteen code (Appendix AK; Appendix AL; Appendix AM; Appendix AN; Appendix AO; Appendix AP; Appendix AQ; Appendix AR; Appendix AS; Appendix AT; Appendix AU; Appendix AV; Appendix AW; Appendix AX; Appendix AY) by MFGT and reviewed by CG and five themes with subthemes were developed.

As it is was mentioned previously in chapter 2, the project constantly considers and revises the theory of change (Reinholz and Andrews, 2020). The ONE Study Theory of Change was evaluated against all the qualitative results of the REFLEX Study by MFGT and reviewed by CG in order to develop a Theory of change for resistance exercise. Firstly, it was necessary to recognize the context in which the change will occur. After that, the team underwent a process of backward mapping focusing on the long term outcomes that they wanted to achieve. This long term outcome was accomplished after a medium term and short term outcomes were achieved. Finally, the team defined the linkages between all the elements. A theory of change is normally showed in a visual representation in a diagramme (Reinholz and Andrews, 2020).

Table 28. Codes and subcodes for thematic analysis.

Code	Subcodes
Pre-Study lifestyle	*NA*
Reasons for joining the study	*NA*
Health	*NA*
Choice of exercise	Convenience Hard/Easy to do Improvement or progression Competence Volume of exercise Pain or discomfort Variety or not variety Bands
Progression	*NA*
Experience of doing the exercises	Perception of ability Immediate responses to exercise Doing the exercise right and concerns.
Experience of the webapp	*NA*
Information	*NA*
Programme during daily life	Time of the day and reasons Place of exercise and reasons Disruptions Clothing and equipment and reasons. Pattern of their exercise during the week. Routine Priorities. Weekdays vs weekends COVID
Barriers and facilitators	Convenience Routine and scheduling Work Life events Competing priorities Online exercise programme Exercise intensity and volume Other people Accountability Identity Laziness and tiredness Weather
Motivation to do resistance or flexibility exercises	*NA*
Other people	*NA*
Impact/changes of the programme	Physical changes or lack of them Mental and emotional changes and the lack of them Ripple effect
Suggestions for the programme	*NA*
Selling the programme	*NA*
Other	*NA*

NA: **Not Applicable**

4.4 Results

Five overall themes were found: experiences of the online home-based exercise programmes; fitting exercise into daily life; facilitators, barriers and motivators; impact of the exercise programmes; and suggestions for the programmes.

The theme “experiences of the online home-based exercise programmes” has six subthemes: immediate experience of doing the exercises; experience of the exercise diary and the webapp; choice of exercise and volume, experience of using resistance bands, perception of ability and optimal challenge, and progression and improvement. The theme “fitting exercise into daily life” has three subthemes: pattern and routine, time of the day and place and clothing and equipment. The theme “facilitators, barriers and motivators” has four subthemes: accountability, competing priorities, external circumstances and variety of exercises. The theme “impact of the programme” has four subthemes: physical impact, mental impact and ripple effect. The theme of “suggestions for the programmes” has two subthemes: exercise programme suggestions and webapp suggestions. All these themes and subthemes are presented below with a focus on the ones that were not explored in the ONE Study (Chapter 2).

Finally, the Theory of Change of the ONE Study was evaluated against the REFLEX study results and is presented at the end.

4.4.1 Experiences of the online home-based exercise programmes

This theme includes the participants’ opinions, feelings, ideas, experiences and choices while they were performing the exercise, immediately after it and during the whole programme. Five subthemes were found and they are explained below:

a) Immediate experience of doing the exercises

This subtheme consists in how the participants immediately responded to the exercise, in. physical, mental and other ways on a week-by-week basis. Participants felt different during and after the exercises, which differed in each exercise programme.

Resistance group

Participants in the RE group felt exhausted, flashed or hot, nauseous, tired and had an elevated heart rate while doing the exercises.

> “Especially when we were doing this, like we were having a heatwave, it was like 110 degrees and it was, you know, in the high 90s and stuff. And this house has air conditioning but for most of the study I was in a different house and didn’t have air conditioning. And so, it would be like really hot and I would feel really hot. And when I exercise, I get…I feel like really, like, I get, really like flushed and hot. And then, so like, that and then I also feel like, really sore and I would want to just like, sit, you know. And I was like, I don’t want to get up for a while, I’m just going to sit afterwards.” (RE group, younger than 35 years old, female, completer)

Additionally, some participants expressed feeling sore and achy while doing the exercises.

> "To begin with, the first couple of weeks, not right afterwards, but the next day, I was a bit achy, but then that went away and it didn't seem too long. But I was definitely a bit achy, especially with the first couple of weeks, because I'd done a couple more sets where I’d tried maybe the easy level, but then also done the next level. So, I was more achy those weeks, but not laterally." (RE group, between 35-50 years old, female, non-completer)

Comparatively to the flexibility group, there were more participants in the resistance group who felt a sense of achievement, encouraged, satisfied, pleased with themselves, proactive, good, happy, calm, a boost in the mood and having fun while exercising or after it. These feelings were linked to doing the exercise itself and seeing the progress in their exercise diary.

> "I noticed, you know, whenever I was doing them there would be a boost in my mood which was helpful, which I was kind of aware of anyway. That doing physical activities especially something that kind of was making me sweat would be helpful for my mood. So, yeah, that was helpful." (RE group, younger than 35 years old, female, completer).

Flexibility group

Participants in the flexibility group expressed that while doing the exercises they felt relaxed, calm, invigorated, comfortable and not out of breath.

> "I think sometimes I felt a bit more calm, because I think sometimes the reason you want to get up and go is because you're feeling stressed or you're doing a task that's quite complicated or you think a lot and you're like, oh I just need a bit of a break. And then you do that and come back and feel a bit invigorated, ready to do it, ready to carry on more. No, I think you just felt better for, like, moving, like you said." (FLEX group, between 35-50 years old, female, non-completer)

Just a few participants expressed feeling pain while doing some of the flexibility exercises, which decreased their enjoyment during the programme.

> To be honest, I think there were some I didn't like in terms of where you're sitting back on your legs. So you're in a kneeling position and when I sat back, I think it was just a case of my build, as such, that my ankles didn't have the flexibility to be, sort of, sat on, and that was a bit painful and so I, sort of, didn't like to do those ones. And, also, on the kneeling I found I had a bit of a problem on my right knee. I can't kneel comfortably on it unless I got something padded underneath, I get, sort of, a pain. (FLEX group, over 50 years old, male, non-completer)

Only a few participants in the flexibility group expressed a sense of achievement as a result of doing the exercises, while others were bored, distracted or disappointed because the exercises were not demanding and the lack of progression in the programme.

> "I think they were easy to do so I did them but also they were less demanding on my body and they were verging on doing meditation in a way for me. It wasn't necessarily pushing my body but more my mind and getting in a space of doing an exercise…also got probably bored at one point. I was hoping that maybe midway requirements would change and things would get a bit more intense. I felt like it was a bit less demanding on my body." (FLEX group, younger than 35 years old, female, completer).

b) Experience of the exercise diary and webapp

This subtheme explores the participant's opinions, feelings and experience with the webapp exercise diary function and the webapp interface. Overall, the convenience of the webapp as a whole was very important, however some participants thought it was difficult to use.

Exercise diary

Several participants liked the convenience of the exercise diary.

> "Yeah, I thought it was brilliant to have that as a place. I thought it was much better to have an app than to say, just have a website or something because, you know, I think most of us now you live with your…you have your phone with you a lot. So it was helpful just to have the app there, and I just put it on my front screen, so it was always accessible." (RE group, younger than 35 years old, female, completer)

Additionally, participants in the resistance group liked being reminded of their previous performance.

> "I really liked [the exercise diary]. Again, it was helpful without being too complicated. I think a lot of exercise programmes that I've seen in the past over-complicate things in that they either get too difficult too quickly, or they take too long, or they're just too complicated. I really liked the fact that you could go onto the app and it would say like last week you did 16 push-ups, and it was as simple as that. You could see the chart of how many you've done over the last few sessions." (RE group, between 35-50 years old, male, completer)

Additionally, participants reported that the exercise diary record helped them know what have they previously done and showed them their improvement I performance through time, which they found motivating.

> "I liked it that you could record it. I found it easy to…you could choose, first of all you could choose the exercises on the app and then when you'd completed it you get a tick, and it gave you a record of what. I quite liked the history part of the app. You could look back and see, oh right I have that. I also liked the graph that was on, so you could see where you kind of started and where you were going, which I think again the visual thing is very good for motivation to encourage you, I have improved. Although at the time you don't think you're improving." (RE group, over 50 years old, female, completer)

While a few participants in the flexibility group thought that the exercise diary was confusing, unclear, hard to use and a couple of participants decided not to use it, and therefore they did not follow the programme instructions for recording the exercise.

> "The website wasn't such that it was, sort of, easy to allow you to record what you were doing. Whilst it had a diary function, I just

> basically ignored it because it was just literally you click on it and you can go back into the diary function and there was no follow up whether I had to fill it in or not. (FLEX group, over 50 years old, male, non-complete)

Webapp

Firstly, several participants expressed linking the web app as a whole and found it good. In addition, they thought it was convenient because it was simple, easy to use, clear and straightforward, accessible, user friendly, handy and helpful. Being able to plan their exercise weeks and see their previously chosen exercise videos helped them plan their exercise programme and fit the exercise in their day to day life.

> "I: What did you think about the web app?
>
> P: I thought it was good. I liked the videos, I liked the ability to see what my previous…I don't know, one thing that I would say, when I got to select the exercises for the week, I wouldn't always remember which one I'd done the previous time, so I'd like it to have the history there so I could refresh my memory. So I liked that, like the little videos, I feel like I watched the videos, I think every time, even once I…because I [would switch on 03:16] which ones I would select, so I liked watching the videos to help me remember the right form and things like that, so I did find it helpful" (RE group, between 35-50 years old, female, non-completer)

On the other hand, a couple of participants expressed that the web app was not very straightforward, due to not having a record of which band was used previously or having to choose the exercises every week.

> "I: So what did you think about the web app in general?
>
> P: It's reasonably good in terms of design, but one thing that was frustrating was that every time I was…each week, I had to restart all the exercises. And for some of them, there was no choice, and for all of them, there was no choice of resistance levels but you still had to go through and select it each time. So after 12 weeks, that was annoying, every week having to reset the programme." (FLEX group, over 50 years old, male, completer)

Programme video instructions and exercise videos

Several participants in both groups reported that the exercise programme instructions were clear and straightforward. On the other hand, there were a few participants who did not understand the instructions, could not recall them or did not watch them, affecting their exercise diary due to not choosing the exercise and recording their completion on the webapp during the programme

> "I: Did you ever go back for… when you mentioned that it wasn't very clear to do all the sets, how much volume could you do, did you ever go back, did you watch the videos of the instructions in the beginning?
>
> P: No, no. So I watched them whatever day you said, here you go, I probably left it while the weekend or an evening but, no, I went all through it, I've got my long list here of the options, each one, and I genuinely hope to stay with it. So it's like legs, squat front, lunge, dead lift, and then two shoulder natural raise, shoulder press, and then I've highlighted which one I've done. But I've also made a note of all of them and my intention is to carry on doing them and maybe move up the intensity, because obviously you sent the bands to make use of those bands and to try and get my fitness and health back as well.
>
> I: And did you ever go back to the exercise diary feature, the feedback feature on the top right corner where you could go and see what you have done previously?
>
> P: No. Should I have done? I didn't, I didn't. And, literally, I watched it all through, wrote down what I was going to do, two or three sets, six 20 reps, listed out the legs, the shoulder, the back, the chest, the core, whatever I was doing and then worked through it from there. No, I didn't go back to it." (RE group, between 35-50 years old, female, non-completer)

A couple of participants preferred the written instructions instead of watching the video.

> "It was occasionally have instructions given to you, but luckily they had also typed up what they were saying so it allowed me to read afterwards." (FLEX group, over 50 years old, male, non-completer)

Several participants reported that the exercise videos were good, clear, easy to follow and understand, had good instructions and were useful. One participant mentioned that she would watch the video every time.

"I: What did you think about the video instructions?

P: I thought they were really clear, actually. They were really…and it was really good to have them, so that when I decided to change an exercise, if maybe I hadn't done it for a few weeks, it was there, just as a refresher, to make sure that I was doing it correctly and to check my form and things as well and…because it's easy to think that you're doing it right, if you're not actually looking and doublechecking. So, I actually thought that was really good. And the different variations for the different levels and things, the explanation of that was really good as well. So, I found it really useful, having the video instructions. And I think I watched them actually every week, just to remind myself what I was doing." (RE group, between 35-50 years old, female, non-completer)

On the other hand, some participants reported some issues with the exercise videos during the programmes that affected their experience of doing the exercises.

"Regarding the videos, I found them, whilst instructive, the audio was quiet…But then when they were showing exercise, the volume increased for the background music. It was actually louder than the people telling me, so I felt they should have flipped that. They should have had the people telling me louder so I could actually hear it instead of sitting there with my ears like this so I could hear." (FLEX group, over 50 years old, male, non-completer)

c) Choice of exercise and volume

This subtheme explores the experiences of the participants in choosing the exercises, such as how much exercise they chose to do, their choice of types of exercise, their preferences and their dislikes.

The majority of the participants across exercise groups, genders, age and completion groups chose to do one set per muscle group (six in total) a week. Only few participants did two or three sets per week.

"I did one each day, yeah. That worked best for me. And then I had a rest day as well. So there are six exercises, I think, in a week, so had one day when we didn't do any. Sometimes I'd do a little bit more of one exercise than the set time, but, yeah, I stuck to one exercise per day." (FLEX group, over 50 years old, female, completer)

Resistance group

Table 29 shows each participant's exercise preferences mentioned during their interview. Participants in the resistance group felt that push-ups, lunges, squats, seated row, lateral raise, crunches and plank were hard to do.

> "There was an exercise, I think, because I do…I don't have much strength in my arm, so I recognise that, there was…I don't know what it's called but your band and you're standing there and you're kind of going out to the side. Is it called lateral raise? I can't remember, but I know I didn't do that as often, plus avoided because it's harder." (RE group, between 35-50 years old, female, completer)

Flexibility group

Table 30 shows each participant's exercise preferences mentioned during their interview. Some participants felt the exercises were all easy to do, while others said that some exercises were hard such as the arm stretches, leg stretches, abdominal stretch, knees-to-chest stretch and chest stretch.

> "And actually out of all the exercises that was the one that I found most difficult for the simple reason that, although it was explained very well, when you watch the video it's not really quite clear how…whether you're doing it correctly or not. So I was never really quite sure whether I was doing that one correctly or not. It does say in the video you should feel this bit of your body stretching, whatever, but to be honest, with me, because I have quite tight muscles and I'm not young and fit as she is, it's not always the obvious place that you feel the stretch, so that doesn't really help you to know that you're stretching in the right way." (FLEX group, over 50 years old, female, completer)

Table 29. Resistance group chosen exercises and preferences.

Participants			Legs			Arms			Chest	Back		Core	
Age group	Gender	Completion	Squat	Deadlift	Front Lunges	Upright row	Lateral raise	Shoulder press	Push ups	Seated row	Seated wide row	Plank	Crunches
35-50 y	Female	Completer	-	-	-	X	X	-	-	-	-	X	X
>50 y	Male	Non completer	X	-	X	-	X	-	X	X	-	X	-
<35 y	Female	Completer	X	-	X	-	X	X	X	-	-	X	X
>50 y	Female	Completer	X	X?	X	X?	X?	X?	X	X?	X?	-	-
35-50 y	Female	Non completer	X	X	-	-	X	-	X	X	X	X	X
35-50 y	Female	Non completer	X	X	X	-	X	-	-	-	X	X	X
35-50 y	Male	Completer	X	X	X	-	X	X	X	X	X	X	X
<35 y	Female	Completer	X	X	X	-	-	X	X	X	X	X	X
35-50 y	Female	Non completer	X	-	X	-	-	-	X	X	X	X	-
>50 y	Female	Completer	X	X	X	-	X	X	-	X	X	X	X
>50 y	Male	Completer	-	X?	X	X?	X?	X?	X	X	X?	X	-

Legend: (X) Liked/preferred exercise; (X) Did not like/prefer exercise; (X) No preference;(-) No mention of the exercise; (X?) Mention preference broadly; (X?) Mention broadly, (y) years.

Table 30. Flexibility group chosen exercises and preferences.

Participants			Legs									Arms			Chest	Back		Core	
Age group	Gender	Completion	Quads	Hamstring	Piriformis	Glutes and hip	Adductors	Lunge with twist	Hip-flexor	One Knee to chest	Calf	Shoulder	Biceps	Triceps	Chest	Back	Knees to chest	Abdominal	Cat-dog
35-50 y	Female	Completer	X	X?	-	-	-	-	-	-	X?	X?	X?	X?	X?	-	-	-	-
<35 y	Female	Completer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
>50 y	Female	Completer	X	X	-	X	-	-	-	-	X	X	-	X	X	-	-	X	-
35-50 y	Female	Non-completer	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	X
>50 y	Female	Non-completer	-	-	-	-	-	-	-	-	-	X		X	X	-	-	-	X
35-50 y	Male	Non-completer	-	-	-	-	-	X	-	-	-	-	X	-	-	X	-	-	-
>50 y	Female	Completer	X	X	-	-	-	-	-	X	X	X	X		X	X	X	X	X
>50 y	Male	Non-completer	X	-	-	-	-	-	-	-	-	-	-	-	X	X	-	X	-
>50 y	Male	Completer	X	X	-	-	-	-	-	-	X	X	X	X	X	-	-	X	X
>50 y	Female	Completer	X?	X?	X?	X?	X?	X?	X?	X?	X?	X	X	X	X	X?	X?	X	X

Legend: (X) Liked/preferred exercise; (X) Did not like/prefer exercise; (X) No preference;(-) No mention of the exercise; (X?) Mention preference broadly; (X?) Mention broadly, (y) years.

d) Experience of using resistance bands (only resistance exercise group)

This subtheme explores the RE group participants'thoughts and opinions on using resistance exercise bands during the programme. Similarly to the ONE Study, some participants liked the bands and thought they were convenient. A couple of participants had never used resistance bands beforehand and expressed fear of using them for the first time. This fear disappeared once they were familiar with the bands and made them feel confident while using them. This led to a sense of achievement when they progressed to the following band.

> "Using the bands were terrifying, because, especially when you use it for the first couple of times, you think they don't work. You don't kind of instantly, they don't stretch. Then you realise you just have to put in a lot of work, and then finally you're really beginning to feel them. So, I think that was a real positive for me, having never done the bands. If I'd have bought them myself, and watched maybe videos, I don't think I'd have stuck at it, because I think I'd have chickened out to think, I just can't manage with these. I liked the ones with the bands. Again, same reason, because I felt, when you changed to a new colour, it was almost like, hey, look at this, I'm going up a band." (RE group, younger than 35 years old, male, completer)

e) Perception of ability, optimal challenge and worries

This subthemes explores participants' preconceptions of what they can do or not do, health conditions, fitness level, preparedness and worries, in regard to the exercise programme. Participants' thoughts were mixed, some felt that they were able to do the exercises, while others felt that they were difficult and some expressed being worried of injuring themselves.

Some participants from both programmes felt that the exercises were within their capabilities and that they were not demanding, felt confident during the programme and a couple reported having previous knowledge of the exercises.

Additionally, a few felt that their body got in the way of doing some exercises and affected their ability to perform the exercise and several participants expressed having low fitness, flexibility and/or balance.

> "I think is it the quad stretch where you stand on one leg and you get the other leg by the ankle, the first time I attempted that it was

> embarrassing and I was actually…I actually felt quite ashamed of myself. I thought, how could you get in such a state that you can't stand on one leg and comfortably pull the other leg and get in that position, but after about three or four weeks there was a…just doing that exercise with the required repetitions I found there was an improvement in me being able to do that exercise." (FLEX group, over 50 years old, female, completer).

Finally, a couple of female participants expressed worry about doing the exercises properly. One of them was particularly worried about injuring herself if she did not do the exercises properly.

> "I found that a lot of the ones where I was standing I worried a lot about form. So, I worried a lot about form and lunges thinking about whether my knee was going passed my toes and squats and, kind of, thinking about that. So, I enjoyed the floor based ones more, and I think that just reflects like my general sense of these types of strength exercises is that I worry a lot that I'm going to injure myself or something." (RE group, younger than 35 years old, female, completer)

Having exercise videos built-in the app was convenient for the participants because they could come back to watch them anytime.

> "I thought that especially having videos was really, really useful embedded in the app and I found that was very helpful for me in terms of, you know, I had some worries about, like am I doing this right? Is this what it's supposed to look like, so that was really good, especially because they were…like you could see them at any time and just go back and check." (RE group, younger than 35 years old, female, completer)

f) Progression and improvement

This subtheme explores participants experiences, thoughts and perception of their improvement, achievement, physical benefit and progression in the exercise programme. Due to the different nature of each exercise programme, they were explored separately. Overall, feeling achievement and progression was very important for the participants.

Resistance group

A couple of participants liked having several exercise levels.

> "I thought [having different levels] was really good. It…especially for things like push ups, which I would say I would find a bit daunting. It's really good that there were some…that there were lots of different levels, and that you were able to take the time to work out which one to start on for yourself. And for me, there was always a level that I could start on." (RE group, between 35-50 years old, female, non-completer)

Several participants improved in the band exercises, like lateral raise and deadlifts, plank, push-ups and squats. Participants increased the number of repetitions, but not everyone moved to the following level in all exercises.

> "I was more than comfortable at entry level. Apart from legs where I did move up to level two of the videos, I never progressed beyond one and I've never progressed to the advanced bands. But, again, time, I'd like to." (RE group, between 35-50 years old, female, non-completer)

A few participants experienced a decrease in the number of repetitions achieved when moving to the following level. Some felt that the progression was natural, but others were discouraged.

> "I really don't like exercise very much. And so, I was like, well, you know, I'll just do kind of…not the bare minimum because I did try to do as many repetitions as I could do, you know. But sometimes it can feel discouraging when you move up a level and then you, you know, you were doing like 15 or whatever and now you're doing two." (RE group, younger than 35 years old, female, completer)

Participants progressed to the following level after 3-4 weeks or after 7-8 weeks.

> "So I started at level 2 and then I changed to level 3 about two thirds of the way through, so maybe seven or eight weeks." (RE group, 35-50 years old, female, non-completer)

Flexibility group

Some participants felt the benefits of the flexibility exercise in their body which helped them to keep exercising.

> "There was the…funnily enough, there was a chest exercise where you had to put your hand against the wall and I'm still doing that one but that's probably the only one that I'm still doing because I've had a bit of a dicky shoulder and I didn't know what was wrong with it and that exercise seemed to actually help it and improve it so I'm still using that one." (FLEX group, over 50 years old, female, completer)

However, others expressed disappointment and boredom due to the lack of exercise levels and difficulty progression.

> "I remember thinking when I went on to the programme and its levels, and then there was only one level, that was a bit disappointing, I guess, at the time." (FLEX group, over 50 years old, female, non-completer)

g) Experiences with instructions

This subtheme explores participants' experiences thoughts and opinions regarding the instructions for the exercise programme given by the research team, video instructions for the programme and the exercises and in the webapp, including how they learned the exercises. Overall, we found that understanding the instruction was very important for the participants to perform the exercise properly and to use the webapp.

The majority of the participants thought the instructions were clear and straightforward, and that they we re able to understand them.

> "I: What did you think about the instructions at the beginning of the programme? The ones that show you how to navigate the programme and the programme itself it tells you what to do?
> P: The videos?
> I: Not the exercise videos but the two videos on the beginning.
> P: Things were quite clear at that point from what I remember. I had no questions and I knew what I was getting myself into." (FLEX group, younger than 35 years old, female, completer)

Several participants reported that the exercise videos were good, clear, easy to follow and understand, had good instructions and were useful. One participant mentioned that she would watch the video of each exercise she did every time.

> "I: What did you think about the video instructions?
>
> P: I thought they were really clear, actually. They were really…and it was really good to have them, so that when I decided to

> change an exercise, if maybe I hadn't done it for a few weeks, it was there, just as a refresher, to make sure that I was doing it correctly and to check my form and things as well and…because it's easy to think that you're doing it right, if you're not actually looking and doublechecking. So, I actually thought that was really good. And the different variations for the different levels and things, the explanation of that was really good as well. So, I found it really useful, having the video instructions. And I think I watched them actually every week, just to remind myself what I was doing." (RE group, between 35-50 years old, female, non-completer)

On the other hand, some participants reported some issues with the exercise videos during the programmes.

> "Regarding the videos, I found them, whilst instructive, the audio was quiet. It was occasionally have instructions given to you, but luckily they had also typed up what they were saying so it allowed me to read afterwards. But then when they were showing exercise, the volume increased for the background music. It was actually louder than the people telling me, so I felt they should have flipped that. They should have had the people telling me louder so I could actually hear it instead of sitting there with my ears like this so I could ear." (FLEX group, over 50 years old, male, non-completer)

4.4.2 Fitting exercise into daily life

This theme explores how participants fitted their exercise during their daily life, including their exercise pattern and if they developed a routine or not, the place they used, the time of the day/week, if they used clothes and any equipment.

a) Pattern and routine

This subtheme explores the participants' exercise pattern during the week, if they established a routine or not, their planning, use if reminders and any changes. Overall, it was found that participants developed a consistent pattern, with a routine and without one.

The majority of the participants fitted their exercise in a consistent pattern throughout each week during the programme.

> "I: Do you remember how many times a week you did the exercises?

P: It was every day for five days. I was trying to do Monday to Friday, a bit of that." (FLEX group, younger than 35 years old, female, completer)

Some participants, particularly those in the over 50 years old group, chose to fit their exercise randomly during the day depending on their daily activities due to not having a set routine throughout their week.

"I was really flexible, it just depended, again, what I was doing. I tried to do it over a few days, but there were probably a couple of days where it got to the end of the week and I thought, oh I haven't done them, I'd better do them. So I might've done them all in the day – probably not all at the same time, I might've done some in the morning and some later on, but it varied… That was good, it was perfect for me because if I've had to do it at the same time every day or every week, I probably wouldn't have managed to do it every week, so for me that was perfect." (RE group, over 50 years old, female, completer)

Half of all participants (in both exercise groups) preferred doing the exercise on one day a week.

"So, mostly, I did it all in the one evening, but sometimes I did space it out, but not often." (RE group, between 35-50 years old, female, non-completer)

Younger than 35 years old participants tended to do their exercise between one or two days a week, the group between 35-50 years did not have a clear preference, and the over 50 years old group tended to do them one or six days a week.

A couple of participants used a reminder in their phone calendar to help them complete their exercises each week.

I: And you have mentioned that you did your exercises in the evening. Was this the case for the 12 weeks or did this did change during the programme?

P: No, I did that consistently, that was when I knew I would have some time to myself to be able to come and do that. So, yeah, I did that consistently. It helps also just to work it into your day and make sure you remember to do it if you have it at the same time, I found. So I set a reminder on my phone and I'd come do my exercises. (FLEX group, over 50 years old, female, completer)

On the other hand, other participants said to have tried having a stable routine but failed to do so.

> "I think, so I set up a reminder on my phone to say, like do the exercises now but what I found is that I just…I don't know how to say it, because the thing is they don't take long. So, it's not as if it was difficult to fit them in. I think that the thing was that whenever I got the reminder just seemed to be not a good time for certain reasons. So, I set it about six o'clock which I thought is after the work day, but before I would usually have dinner, but sometimes I was out of the house or I was so hungry that I couldn't do them." (RE group, younger than 35 years old, female, completer)

b) Time of the day and place

This subtheme explores the times of the day and the place of exercise the participants tended to choose to do their exercises and their reasons. Participants thought the programmes were convenient because it allowed them to choose when to perform their exercise.

One-half of the 35-50 years old group chose to do their exercise during the evening because it was more convenient due to having small children, while the other half chose the morning. There were no differences between the other age groups.

> "So, I chose the evenings because I have two small children, so it was easier for me to do them undisturbed once they were in their beds. And because of marking during the day, it was…I couldn't fit it in then. And once I get home from work, it's just a very busy time, dinner and bath time and bedtime. So, that was probably the time of day that I have that bit of time to myself that I can get my head into doing it." (RE group, 35-50 years old, female, non-completer)

There were no differences in time of the day between the flexibility and resistance group or completer vs non-completers. However, men tended to choose the morning, while women tended to do their exercises in the evening.

Participants primarily chose to do their exercises in the living room because there was more space. This was the same regardless of exercise group, age group and completion group.

> "In my living room. So, I think…I don't think I did any of them outside the house. I think I did them all in my living room and I suppose that would be perhaps a small factor as well in finding it a bit tricky is that I have a very small home and, you know, we only have one living space. So, if I was doing exercises in here I was kind of…you felt like you're taking over the space a little bit, but yeah I did them all in here." (RE group, younger than 35 years old, female, completer)

Some participants also did their exercises next to their desk, kitchen, dining room, study, spare room, bedroom and bathroom.

> "I'd fit them in…sometimes if I was cooking the tea, I'd think oh I'll just do a couple now. You could be in the kitchen, and you could do a couple now. I do quite like that kind of thing because I'm not really a gym person. You can probably see by my note, how I did and things, I'm not that. It was good that you can fit it into your day-to-day activity." (RE group, over 50 years old, female, completer)

c) Clothing and equipment

This subtheme explores participants' clothing and equipment used during the exercise programme, and any reasons behind it.

Some participants decided to change clothes, while the majority did not feel the need to change. Younger participants tended to change more than the older participants. Most of the flexibility group decided not to get changed.

> "No, because I'm working at home I'm probably in leggings and a t-shirt anyway most of the day so that was quite useful." (FLEX group, 35-50 years old, female, non-completer)

On the other hand, the resistance group did not have a particular preference.

> "No. Pretty much…no, I didn't change into any specific exercise clothes. I didn't use any mats. I would wear jeans and that…not jeans, wearing trousers and a T-shirt I would do the exercise. Partly because I didn't feel they were…I wasn't getting out of breath and I wasn't working up a sweat with them, so I didn't feel as if I needed to sort of change into any physical education clothes." (RE Group, over 50 years old, male, non-completer)

There were no relevant differences between genders and completion groups.

More participants decided to use trainers while exercising instead of being barefoot. There was no clear preference in the age groups, exercise groups and completion groups.

> "I probably would have put my trainers on most of the time. (FLEX group, between 35-50 years old, female, completer)

A couple of participants in the resistance group used shoes while exercising with the resistance bands because they felt pain in the feet and were uncomfortable.

> "I had to have my trainers. Again, I started barefoot but for those where you're pulling it actually hurt underneath your foot. So, again, that was strange having trainers in the house but, no, I did wear trainers." (RE group, between 35-50 years old, female, non-completer)

Participants expressed using extra equipment during their exercise programme. Some participants from both exercise groups reported using an exercise mat and a floor rug.

> "I think I used a mat maybe a couple of times at the beginning, I've got yoga mats there. But then I thought, I can just use the rug in the living room because it's quite a wee pile on it" (FLEX group, between 35-50 years old, female, completer)

A couple of participants in the flexibility group reported using a timer in their phones to time their stretching exercises.

> "It was just a case of setting up the timer on my phone" (FLEX group, over 50 years old, female, completer)

One participant in the flexibility group reported using a towel during the biceps stretching exercise making it easier to do. Also, just one participant in the RE group mentioned using music during her exercises to help her keep doing her exercises and not be bored.

> "I: Okay. So, you mentioned about music, why did you prefer to have some music then doing the exercises?
>
> P: It's nice to, like, I think about the music instead of thinking about, like, you know, oh, my God, I have to do one more exercise or whatever. I can just…[Talking to child]. I kept thinking about, oh, you know, just try and concentrate on the music instead of concentrating

> on, you know, like, oh, I've got to do one more or whatever. And then it's easier if I'm thinking about that, then I can just keep going, as opposed to like… And, also, it's kind of boring." (RE group, younger than 35 years old, female, completer)

4.4.3 Facilitators, barriers and motivators

This theme explores the facilitators as anything that eased, helped, simplified or supported the participants to do the exercises; the barriers as anything that stopped or was an impediment to the participants doing the exercises; and the motivators as anything that motivated the participants to do the exercises or the lack of motivation. Overall, it was found that being accountable and having a good variety of exercises was very important for the participants to do the exercises, while having competing priorities against the programme and external circumstances and the lack of variety of the exercises were the main barriers for the participants to perform the exercise.

a) Convenience

This subthemes explores participants' thoughts and opinions on how the exercise programme convenience or lack of it helped them or stopped them to perform the exercise.

Overall, we found that the convenience of the exercise programmes helped the participants to keep doing their exercise.

> "As I say, initially the curiosity motivated me and I did them when it was convenient and it was like, I could squeeze this in here. And my thinking was eventually, 'cause doing 15 arm raises or whatever doesn't take more than 30 seconds to do and I found I didn't have to transition into gym wear to do them." (RE group, over 50 years old, male, non-completer)

b) Accountability

This subtheme explores how external and internal accountability is very relevant for the participants to keep performing the exercise.

Participants expressed that being held accountable for a research project (external accountability) was one of the main motivators and facilitators to do

the exercises during the programme. This was the same for both exercise programmes.

> "I think it was helpful that it was part of a structured study. If I'd just downloaded that app by myself I would have found it more difficult psychologically to make sure I did it every day I was supposed to do it. The fact that I was going to be tested on my results, and I guess you could see whether I'd done it properly or not, is a good motivator for doing it thoroughly." (RE group, between 35-50 years old, male, completer)

Only one non-completer participant from the RE group expressed their own personal commitment (personal accountability) as a driver to do the exercises.

> "So for me it was perfect because it gave me that, got to do this, and that was my only apprehension of doing it. So, again, it was good because it made my time accountable so I had to do it. Part of the reason that I chose to do it before work is I fall into very bad habits but work doesn't stop because you're at your house, there is no packing it away. So I was just concerned that if it was left until the evening when the kids are in school you get pulled into, have you done this, have you got that, whereas in the morning neither of them wake up so it's my time." (RE group, 35-50 years old, female, non-completer)

c) Competing priorities

This subtheme explores how participants' priorities compete against the exercise programme and how that stopped them from doing the exercises. Participants reported several priorities that competed with the exercise programme. The most mentioned ones were children, family and work. Other priorities include house chores, personal well-being, other people and pets.

For the two younger age groups (younger than 35 years old/between 35-50 years old) the main priority was children.

> "I chose the evenings because I have two small children, so it was easier for me to do them undisturbed once they were in their beds. And because of marking during the day, it was…I couldn't fit it in then. And once I get home from work, it's just a very busy time, dinner and bath time and bedtime. So, that was probably the time of day that I have that bit of time to myself that I can get my head into doing it." (RE group, between 35-50 years old, female, non-completer)

On the other hand, in the group over 50 years old, work was the main one and family the second one.

> "There might have been a couple of times I did them during the day but I think the majority of them were in the evening. Because I've been working during the day, doing things for the family and it's a bit of my time in the evenings." (FLEX group, over 50 years old, female, non-completer).

A few participants were not able to keep up with the number of sessions per week throughout their programme and felt that they needed to reduce the number of days exercised due to other priorities like work and children.

> "I mean it varies, in the early days I was super keen so I was managing six times a week, once school holidays crept in and we're going through major change with our teaching programme and standards and things." (RE group, between 35-50 years old, female, non-completer)

d) External circumstances

This subtheme explores how unexpected different external circumstances or disruptions got in the way of doing the exercises. Participants described how different external things got in the way of performing their exercise such as hot weather, holidays, unexpected events and work.

> "So I did the stretching programme which was once a week although I think I probably missed a few sessions, two or three in the 12-week programme. The first one, I must say, I was at…I went on a working holiday up to Cumbria because my parents are changing their house into a holiday cottage and it's kind of all hands-on deck. So on that Tuesday when I…I think I was planning to do my exercises on the Tuesday but on the Tuesday morning my brother's farm caught on fire and it was right opposite my mum and dad's place so we just…we saw it. It was a big silage shed went up and his building next to it so it was just a…yes, everything went out the window that day. Then I ended up staying up there for two weeks because there was so much work to do so I wasn't great with it but I was still continuing my walking and whatnot." (FLEX group, over 50 years old, female, non-completer)

e) Variety of exercises

This subtheme explores how the variety of exercise or the lack of it influenced the participants in performing their exercise.

The majority of the participants in the resistance exercise group reported choosing different exercises every week, liking the variety of exercises and having a good selection of exercises.

> "I liked them all. I thought it was a really good selection of exercises. I found some more tiring than others." (RE group, between 35-50 years old, male, completer)

Some participants in the flexibility group felt that they did not have enough variety of exercises, while a few felt the exercises were varied.

> "I would have liked to have more diversity or a level up at one point but probably this wasn't the aim of the programme itself but for the future probably it would be interesting to have different levels of improving or more...we function this way that we like rewards and achievement and I think it would have been nice to have the goal itself moving forward and did this, good, let's move on." (FLEX group, younger than 35 years, female, completer)

4.4.4 Impact of the programmes

This theme explores the participants' references to the results they have experienced as a result of the exercise programmes, such as the physical, mental and behavioural impact.

a) Physical impact

This subtheme explores the physical impact of the exercise programmes on the participants, including in their body, strength, flexibility, endurance, pain and others. Due to the different nature of the exercise programmes, these were explored separately.

Resistance group

Similarly to the ONE Study, half of the participants improved their strength and performance. However, three participants did not notice changes in strength.

> "I've noticed…I think my legs are stronger. I do cycle a little and I think I've noticed that going up some hills I'm not…it's easier. My legs have definitely improved. My upper body strength has definitely improved, because lifting things, I can that a lot easier. I even see from doing push-ups that I can do it longer, for more repetitions than

> before. So there's definitely a major difference." (RE group, over 50 years old, female, completer)

A small group of participants experienced other changes, for example improvements in flexibility and weight loss.

> "I: Did you notice any changes as a result of the programme by the end of it?
>
> P: Loads, I had lost just over…I have plenty to lose but I've lost just over a stone in weight through doing them and my mother is convinced my bottom has gone square and flat although my stomach still looks like I'm ten months pregnant. But even my mum commented my back's gone flatter so, yeah, there is a difference." (RE group, between 35-50 years old, female, non-completer)

Flexibility group

Over half of the group reported an improvement in their flexibility, while only a couple did not have any flexibility improvements. Additionally, a few participants reported that the programme helped them feel less pain in their knees, back and shoulder.

> "I've certainly…think I've noticed some improvement in my upper body flexibility." (FLEX group, over50 years old, male, completer)

However, a couple of participants reported having pain in their back and knee due to the exercise programme.

> "One of the exercises did give me some soreness in the back. The exercise that I mentioned with lying on the front and lifting your shoulders up and your arms and trying to bend at the pelvis, that one did leave me with back pain." (FLEX group, over 50 years old, male, completer)

b) Mental impact

This subtheme includes the mental and emotional effect of the exercise programmes on the participants. Similarly as the previous subtheme, the exercise programmes' impact were explored separately.

Resistance group

A few participants in this group experienced mental and emotional changes as a result of the programme. Exercising increased their self-esteem, their confidence and made the feel positive towards change.

> "I feel a little better about myself. Yeah, I've had two babies in the last couple of years and so I've been feeling a little bit just like I…I don't know, exercising made me feel a little bit more like my old self, feel a little better about myself, so I do think that it's been helpful to my…I wasn't like depressed or anything before, but I do think I feel a little better about myself right now than I did at the beginning." (RE group, between 35-50 years old, female, non-completer)

Flexibility group

Half of the flexibility group did not experience any mental or emotional changes. A couple of participants had positive changes. An improvement in competence made them feel better about themselves and having a mental shift about them being able to get fitter.

> "A lot better, a lot better because I think when something is brought to your attention like that, obviously we're all getting older, I'm getting older but you're trying to keep as active as you can and as fit as you can and I think when you are unable to sort of do what would have been a straightforward manoeuvre for me ten years ago and you can't and then you see yourself being able to do it, I think it makes you feel a lot better. I felt a lot better about myself and it gives you a lot of incentive, as far as I'm concerned, I'm going to continue with this programme even beyond the obviously our three months because I could see the benefit to me." (FLEX group, over 50 years old, female, completer)

c) Ripple effect

This subtheme explores how the exercise programmes influences the participants to change their behaviour in different aspects of their daily life, such as diet, physical activity, and others. Some participants in both programmes reported making wider changes as a result of their involvement in the study. It seems that doing both resistance and flexibility exercises encouraged them to think of their health beyond the programme and make healthy lifestyle choices.

> "it enabled me to focus on me a lot more, because I was doing something for me, so…which then spilled over into, okay, right, I can go for a walk. So, there's more kind of add on stuff going on. I could exercise, go for a walk, or I could think about, do I really need to eat that, am I drinking enough water. So, there's all that kind of roll-on benefits." (FLEX group, between 35-50 years old, female, completer)

4.4.5 Suggestions for the programmes

This theme explores different suggestions participants mentioned in order to improve the programmes, including the exercise programme itself and the webapp.

a) Exercise programme suggestions

Several participants suggested increasing the intensity of the exercise because they had the motivation to do the exercise and would gain more benefits from it.

> "so I may have had a preference for it being more intensive because I knew that I was motivated to take part and so had it been more intensive I think I would have done it and it would have had an even bigger benefit, if that makes sense?" (RE group, between 35-50 years old, female, completer)

One participant suggested doing in each session several types of exercises in a circuit mode to be able to keep doing the exercise programme for a longer period of time.

> "I think there was lots of choice, but I only did it for 12 weeks. So, if I had now done that for 20 weeks, I think now I would be at the stage of saying, I've reached all those, now what? Now, that's really hard, because it then is, you know, more things would have to be produced. But then I suppose that might be to do with doing a mix, so you have to do five press ups and then ten squats and then five press ups and ten squats, that's when it turns into more of a synergy type circuit, it would be more like a circuit." (RE group, younger than 35 years old, male, completer)

Another suggestion was to include a higher variety of exercises, particularly for the flexibility exercise programme.

> "In a sense, I think the programme, for the benefit, I think increasing the quantity of the exercises as opposed to what I was currently

> doing. Obviously the programme is only to do it once a week but I think doing it two or three times given how short it takes, that, sort of, I would say, you know, the benefits of that. And because you were doing it more frequently I think it's less likely you'd be that worried if you'd miss a session. Obviously it you're doing it weekly it's more of an impact if you miss a session." (FLEX group, over 50 years old, male, non-completer)

Some participants suggested having a familiarisation session before the programme, check-in sessions during the period of the exercise programme and group exercise sessions with other participants to help them do the exercise and continue to do it later on.

> "I think I need to find something that is maybe more…I can't think of the right word for it but more like a group-based thing or something that there's going to be a group of us doing it. Do you know, there's…but again, it comes back to this thing that if someone else knows that you're having to do it then you have to do it or if you've made plans with someone that you'll meet them and do something then you would stick to that plan. I don't know something…I don't know if that makes sense. Something like that anyway because if I just rely on myself, I won't do it but if I have…if I've made a commitment with…even just to meet someone to do something then I would do that. (FLEX group, over 50 years old, female, completer)

b) Webapp suggestions

Several participants had different suggestions to make the webapp more convenient. Some suggested making some changes in the user interface, such as an easier way of choosing exercises or recording the repetitions. Others proposed a timer function and a voice recognition feature to help them do the exercises and count repetitions. Additionally, others suggested having a built-in reminder in the application and a scheduling function to help them fit their exercise into their everyday life.

> "What it could have done is and I missed quite a few because sometimes you forget, it could do with a reminder, I think, to reminder you. I don't know if they could build in an alarm to remind you." (FLEX group, between 35-50 years old, male, non-completer)

Other suggestions included having a ranking between the participants depending on fitness level and age and receiving encouraging messages after an increase in performance to increase motivation among participants.

> "So if the app allowed it, if enough people were to take part, then you get put into a category that says, congratulations you're not 32 in the ranking of people your age, people your ability, that sort of thing. I think that would be really good fun, because then you're not just pushing yourself for the sake of it. And that might help them." (RE group, younger than 35 years old, male, completer)

Some participants suggested some changes to the exercise videos such as having a more detailed explanation and how the exercises should feel and encouragement to older and unfit people who might struggle with some exercises.

> "Maybe one suggestion, which is when M demonstrates the exercises – she's obviously very flexible and does them really well – it might be for those of us who are older and not so flexible nice to have a kind of if you can't quite do this bit, as long as you're doing that bit that's fine. Don't worry if you can't do it as I'm doing it. So just a bit of encouragement for those of us who are looking at how she's doing the exercises and thinking I can't get even near that. Just to sort of know that the point is not to get to exactly where she is in her demonstration but to be doing a particular part of the stretch. So that might be helpful." (FLEX group, over 50 years old, female, completer)

Finally, one participant suggested that the video exercise demonstrators should smile and look like they are having a good time so that people watching the videos will be motivated to do the exercises.

> "…if they're doing more training videos, should smile. They looked miserable, so they need to look like they're really having a great time in order to get people to interact with it. Sorry, that might be a daft comment, but if they're looking like they're enjoying demoing it, then, oh, that was good, yeah, I want to do that one. Yeah, it might be pretty good." (RE group, younger than 35 years old, male, completer)

4.4.6 Theory of change resistance exercise

The REFLEX Study qualitative analysis informed the refinement of the ONE Study theory of change. All of the components of the ONE Study theory of change were supported (e.g. confidence, enjoyment, progression, achievement, the physical and mental benefit of the exercise, etc), however, as shown in Figure 50, additions (shown in blue) included following instructions, personal and external accountability, external circumstances and priorities. Additionally, because of the online nature of the REFLEX Study, “Webapp” was added as part of the intervention.

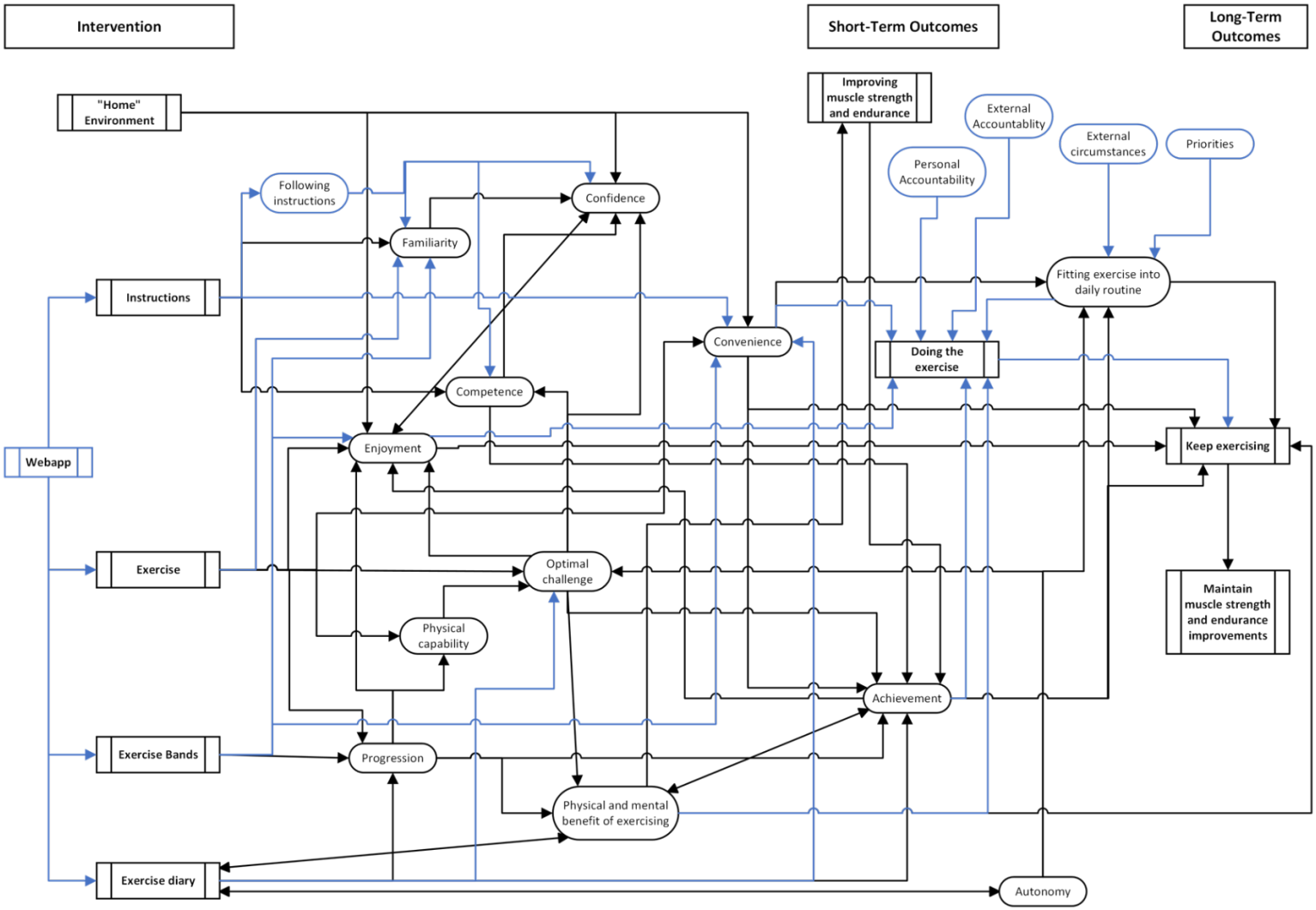


Figure 50. Theory of change REFLEX Study. This figure shows how the intervention elements affect the participants and their connections with each other, and how participants change their behaviour in the short and the long term.

4.5 Discussion

The REFLEX qualitative interviews aimed to explore participants' perceptions and experiences of the online home-based flexibility and resistance programme and to evaluate the theory of change developed from the ONE Study. The results of this study were quite similar to the ONE Study results, such as the importance of the convenience of the exercise programme, enjoyment, progression, sense of achievement and the physical and mental benefits of the programme. However, the REFLEX study found other relevant components. The experience of the REFLEX study programmes was different from the ONE Study because they were delivered online. All REFLEX participants had access to a webapp with instructions videos, exercise videos and the exercise diary, which was found to be convenient. Additionally, understanding instructions and following them was essential for participants to follow the resistance exercise programme, do the exercises properly and complete their exercise diary. It was also found that the participants had different priorities that would compete with the exercise programme and would influence them on how to fit the exercise into their everyday lives. External circumstances affected how participants did the exercise and how they fitted it into their routine. Finally, personal and external accountability were major motivators for the participants to do the exercise during the programme. These results show that the exercise programmes were convenient for the participants since they did not necessarily require them to get changed and wear specific footwear. This allowed them to fit the exercise more easily into their daily life.

It is also relevant to use the REFLEX Study qualitative results to inform the interpretation of the quantitative results reported in Chapter 3. The exercise volume and how participants reported fitting their exercise into their everyday routine agree with the quantitative data. Many participants did not keep the training volume (number of sets per week) chosen at the start of the programme but decreased it as the programme progressed. Additionally, the majority of participants in both groups chose to do all their exercises on one day per week, which was also seen in the previous chapter. The qualitative findings suggest that the decrease in volume and main frequency of exercise chosen by the participants may be due to not having enough time, other (changing) priorities such as work, children and family, and external circumstances that get in the

way of performing the strength exercise. Previous studies have shown that the lack of time (Trost et al., 2002, Hurley et al., 2018, Vasudevan and Ford, 2022), work commitments (Tulloch et al., 2013) and family constraints in women (Vasudevan and Ford, 2022) can be n be a barrier towards resistance exercise, which is similar to the REFLEX Study.

The quantitative results did not show any significant differences in muscular endurance and well-being. However, individual data show that quite a few participants in both groups improved muscle endurance and flexibility. The individual data is in agreement with the qualitative results, which showed that some participants did experience improvements in their performance, muscular strength and flexibility. Additionally, the quantitative results for well-being, and self-esteem in both exercise groups showed significant improvements over time, agreeing with the participants expressing improvements in their mental health. Similarly to the REFLEX Study, a study done in type 2 diabetic adults found that enjoyment and a sense of well-being were frequently expressed by participants performing resistance exercise (Tulloch et al., 2013).

The results of the REFLEX Study are similar to those found in the literature. A study by Vikberg et al. (2022) looked at the feasibility of an online home-based resistance exercise programme in older adults with pre-sarcopenia. Participants were asked to do an online 10-week programme with 3 sessions per week, each lasting 45 minutes. This study found similar results compared to the REFLEX study. It found that having a flexible, not time-consuming, easy to follow, programme with clear instructions was important, and that lack of competence and being unsure of the exercise execution produced insecurity in the participants. Additionally, participants also experienced a ripple effect, increasing their desire to be more active and to make more healthy life choices. They also experienced similar mental and physical benefits compared to the REFLEX study. Participants in this study also expressed that would have liked more feedback during the intervention (Vikberg et al., 2022).

Another study by Fyfe et al. (2022) looked at the feasibility and acceptability of a remotely delivered, home-based resistance exercise “snacking” programme in older adults. It showed that having brief frequent exercise sessions with minimal equipment and straightforward exercises helped participants to integrate the

exercise into their everyday lives and increased self-efficacy (Fyfe et al., 2022a), similarly to the REFLEX study.

A study on young women reported similar experiences in the resistance exercise group. Participants enjoyed the exercises, the challenge and progression of the weights and the flexibility of the sessions. They also reported physical benefits such as muscle gain and strength changes, and the mental benefit of achieving something. However, the women in this group were motivated to participate for the resistance exercise itself (Lambert et al., 2020), and not due to being held accountable as in the REFLEX Study.

The REFLEX study limitations are that due to the number of qualitative interviews, these findings cannot be extrapolated to other population groups. Also, due to the interviews were taken immediately or shortly after the participants finished their programme and measuring sessions (within a month of finishing the programme), it is not possible to know the long term effects of the programme on participants' lifestyle choices. However, having the interviews taken shortly after they finished gives less recall bias which is a strength. Other strengths include the programmes were delivered online through a web app and with online measurement sessions/interviews. This allowed us to recruit a wide variety of people from both genders and different ages, which enriches the quality of the data collected. The interviews included completers and non-completers of the exercise programme, which gives a much richer quality of data regarding the reasons why people did not complete their respective exercise programmes.

4.6 Conclusion

A 12-week online home-based resistance exercise programme showed that convenience, progression, enjoyment, a sense of achievement, experiencing the benefits of the exercises and **following instructions** are relevant for people to do strength exercise. Additionally, it showed that **accountability**, **changing competing priorities** and **external circumstances** affect how people fit the strength exercise into their everyday lives and can get in the way of doing resistance exercise.

Chapter 5 General Discussion

5.1 Introduction

The current UK physical guidelines recommend performing muscle-strengthening activities two days or more per week (Department of and Social, 2019). Currently, less than half of the population in the UK achieve these recommendations (NHS Digital, 2023, Birtwistle et al., 2021). Several barriers to strength or resistance exercise have been identified. It is essential that new ways of performing strength exercise that overcome these barriers are found to increase the number of people achieving the muscle-strengthening guidelines. Convenient home-based resistance exercise programmes with short time commitment, with body mass exercises and resistance bands can be a solution to this.

This thesis aimed to determine the effects on muscle strength, endurance, thickness, thought, experiences, opinions, perceptions, enjoyment, tolerance and acceptability of home-based resistance exercise programmes in healthy adults using a mixed-methods approach. Chapter 2 (ONE Study) aimed to describe the effects of a home-based resistance exercise programme of one minute per day. The results were used to develop a second study with an online home-based programme. This study is described in Chapter 3 (REFLEX Quantitative) and Chapter 4 (REFLEX Qualitative).

5.2 Summary of key findings

a) Physical effects of the home-based resistance exercise programmes

The main findings were that the home-based resistance exercise programmes did not produce significant improvements in muscle strength, endurance, thickness, BMI, waist circumference, fat mass and flexibility. There was only a significant change in fat free mass compared to the control group in the ONE Study. However, individual data from the REFLEX study showed that several participants in the resistance exercise improved in muscle endurance and flexibility. This agrees with the qualitative data of the same study showing perceived improvements in muscle strength, performance, and flexibility. This could mean that even though those changes actually existed, they might have

been too small to show statistical significance. The ONE study sample was known to be underpowered (stopped recruitment due to COVID-19), so that explains the discrepancy between quantitative and qualitative results in this study. However, the REFLEX study sample was complete. Even though the power calculation of the REFLEX study was believed to be conservative, it might have been overconfident, meaning that the sample was too small to detect significance in the outcomes.

b) Mental effects of the home-based resistance exercise programmes

The home-based resistance exercise programme in the REFLEX study did not have any effect on well-being, vitality and energy, self-esteem and physical activity motivation measured with questionnaires. However, some participants in this group reported improvements in self-esteem, confidence and feeling positive towards change. This means that the changes in the sample might have been too small for the statistical tests to detect in the questionnaires' results, or that the questionnaires might not be able to detect small changes in healthy populations. Additionally, in the ONE study participants expressed better mood, feeling happier, better, having more energy and better sleep.

c) Adherence, volume, frequency of exercise

The REFLEX study showed that just over half of the participants completed the minimum volume prescribed in the exercise programme (80% sessions), but less than half of them completed the minimum completed weeks (10 weeks). Participants did not complete all muscle groups every week and the volume of exercise decreased as the programme progressed. Participants started the programme with more sets than the minimum required, but this also decreased as the programme progressed. Participants chose to do their exercise mainly between one and two days per week, but started the programme between two to three days per week and decreased to one day per week by the end of the resistance exercise programme. In the interviews, participants reported that they were not able to keep up with the number of days per week they chose to do at the beginning of the programme and having to reduce the number of sessions per week. Participants explained their decrease in adherence, chosen volume and chosen frequency due to not having enough time, competing

priorities and external circumstances getting in the way of them performing the exercise

d) Thoughts, opinions, experiences, acceptability and Theory of Change of the home-based resistance exercise programmes

Both exercise programmes showed that understanding and following instructions, convenience of the exercise programme, being familiar with the exercises, having progression in the exercise, having a diverse variety of the exercise, enjoyment, confidence, feeling a sense of achievement and obtaining the benefits of the exercise are relevant to participants to do resistance exercise. Additionally, it was found that people have priorities that compete with the exercise and determine how people fit the exercise into their everyday lives. The main priorities that participants described were children, work and family. Also, external circumstances were found to get in the way of people doing their exercise. Finally, external accountability and personal accountability were found to be major motivators to do the exercises during the exercise programme.

5.3 Strength and limitations

a) Strengths of this thesis

The main strength of this thesis is that it involved mixed methods. Using quantitative and qualitative methods is known for producing a much more rich quality of results. The integration of quantitative and qualitative methods that gives much richer data about the impact of the exercise programmes on the participants' daily lives and it gives more insight into how to design and deliver exercise programmes to increase strengthening activities adherence. This thesis was able to show that even if there were no major quantitative results, there were still changes that were perceived by the participants and that they might have been too small to be detected by statistical tests. Additionally, the findings informed a Theory of Change for strength exercises to summarise the mechanisms through with people change their resistance exercise behaviour and the reasons for continuing doing the exercise in the short term. Another strength is that this thesis contributes to the exploration of very low doses of resistance exercise on muscle strength, endurance, muscle mass and body composition.

The online REFLEX study allowed for a wide diversity of gender and age groups in the sample. Additionally, completers and non-completers of the exercise programmes were interviewed, giving a better quality data.

b) Limitations of this thesis

Due to the pandemic, the ONE study had to be stopped and only half of the sample was recruited making the study underpowered. Additionally, having an online study meant that the measurements had to be adapted to be able to measure the desired outcomes. Additionally, having a flexibility group for a control group affected some of the results of the REFLEX study, since the flexibility group improved in some of the outcomes measured as well as the resistance group, making it impossible to determine if the resistance group produced an effect compared to no exercise. This thesis was affected by the COVID-19 pandemic.

5.4 Conclusion and future work

In this thesis, 12-week home-based resistance exercise programmes involving doing at least one set of exercise per week per muscle group did not have effects on muscle strength, muscle endurance, muscle thickness, BMI, waist circumference, or fat mass, but one of them significantly increased fat free mass in healthy. Also, there were no significant changes in well-being, vitality and energy, self-esteem and exercise motivation regulation. However, participants reported physical and mental benefits.

The Theory of Change for resistance exercise showed that convenience of the exercise programme, enjoyment, a sense of achievement, experiencing the effects of strength exercise, progression of the exercise, variety of exercises and familiarity are important for doing resistance exercise. Being accountable for the exercise because being part of a research study was an important motivator to do the exercise.

More home-based resistance exercise programmes with higher volumes, bigger samples and with long period of follow-up are needed in order to produce significant effects on the previously mentioned outcomes, to increase the number of people doing strength exercise and find intrinsic motivators for

strength exercise in order to sustain adherence to the exercise programme in the long term.

Appendices

Appendix A: Approved Proposal

University of Glasgow | College of Medical, Veterinary & Life Sciences

College of Medical, Veterinary & Life Sciences Ethics Committee for Non-Clinical Research Involving Human Participants

APPLICATION FORM FOR ETHICAL APPROVAL

NOTES:
THIS APPLICATION FORM SHOULD BE TYPED NOT HAND WRITTEN.

ALL QUESTIONS MUST BE ANSWERED. "NOT APPLICABLE" IS A SATISFACTORY ANSWER WHERE APPROPRIATE.

The primary remit of this committee is the review of non-clinical research. However, clinical research involving humans, their tissue or data that falls outwith the remit of the NHS Research Ethics Service will also be reviewed by the MVLS committee. If your project involves NHS facilities, or is clinical research, then you must ensure that NHS REC review is not needed before applying to the MVLS REC. The review of the MVLS REC does not obviate the need for NHS review.

Please note – it is now a requirement for a Data Protection Impact Assessment (DPIA) to be completed where processes are likely to involve high-risk personal data. This is likely to be the case for many research projects. If so, you must complete this before submission for ethical review. For research involving personal data, you should give participants a Privacy Notice as well as a Participant Information sheet.

Information on DPIAs and Privacy Notices
https://www.gla.ac.uk/myglasgow/dpfoioffice/gdpr/dpia/
https://www.gla.ac.uk/myglasgow/dpfoioffice/gdpr/privacy%20notices/

Information on the General Data Protection Regulation (GDPR)
https://www.gla.ac.uk/myglasgow/dpfoioffice/

Information on Research Data Management
https://www.gla.ac.uk/myglasgow/datamanagement/

University of Glasgow policy on surveys of students for research purposes

https://www.gla.ac.uk/myglasgow/senateoffice/policies/studentengagement/studentsurveys/policyonstudentsurveys/

Project Title:

The ONE Study: Effect of one minute of resistance exercise per day on muscular strength

Has this application been previously submitted to this or any other ethics committee?
No

If 'Yes', please state the title and reference number.

Is this project from a commercial source, or funded by a research grant of any kind?
No

If 'Yes', has it been referred to Research Support Office?
Has it been allocated a project Number?
Give details and ensure that this is stated on the Informed Consent Form.

Insurance Coverage and Restrictions:
****Please Note: The Insurance restrictions set out below relate to research of a clinical nature. Non clinical research is not subject to restriction and no additional insurance is required****

The University insurance cover is restricted under specific circumstances, including, but not limited to the following -

- **work involving the use of research participants outside Great Britain, Northern Ireland, the Channel Islands or the Isle of Man**
- **the use of hazardous materials**
- **non CE marked medical devices**
- **molecules or compounds developed and manufactured at the University of Glasgow**
- **number of participants in excess of 5000**
- **work involving research participants known to be pregnant at the time of the project**

All such projects must be referred to Research Support Office and coverage confirmed before ethical approval is sought. Please contact Dr Debra Stuart in the University's Research Governance Office: debra.stuart@glasgow.ac.uk

Please tick here if this project has been referred to the Research Office to confirm adequate insurance coverage. ☐ **Support**

Please tick here if the project includes a technique involving incision, of skin, insertion of a device or object, ingestion of medicines or food substances. ☐ **piercing**

Please tick here if the project involves work on human participants that will be conducted within the Imaging Centre of Excellence (ICE) ☐

Date of submission:
22 May 2019

Name of all person(s) submitting research proposal:
Professor Jason Gill
Dr Stuart Gray
María Fernanda Gabler Trisotti
Meghan McLoone

Position(s) held:

Professor of Cardiometabolic Health	JG
Lecturer in Exercise and Metabolic Health	SG
PhD Student Cardiovascular Sciences (Research)	MFG
MSc Sport and Exercise Science and Medicine	MM

School/Group/Institute/Centre:
Institute of Cardiovascular and Medical Sciences (JG, SG and MFG)

Address for correspondence relating to this submission:
BHF Glasgow Cardiovascular Research Centre, University of Glasgow, Institute of Cardiovascular and Medical Sciences, College of Medical, Veterinary and Life Sciences, Glasgow, G12 8TA

Email address: Jason.Gill@glasgow.ac.uk
Stuart.Gray@glasgow.ac.uk
m.glabler-trisotti.1@research.gla.ac.uk
xxxxxxxx@student.gla.ac.uk

Name of Principal Researcher (if different from above, e.g., Student's Supervisor):
Jason Gill

Position held:

Undergraduate student project:
No If 'Yes', please state degree being undertaken:

Postgraduate student project:
Yes If 'Yes', please state degree being undertaken:

PhD Cardiovascular Sciences (Research)
MSc Sport and Exercise Science and Medicine

For postgraduate student projects, please state whether this a research (PGR) or taught (PGT) degree:

PGR and PGT

1. Describe the purposes of the research proposed. Please include the background and scientific justification for the research. Why is this an area of importance? Please try to describe why the research is novel and experimental.

We do not need a comprehensive review of the topic area: a short summary that is sufficient for the reviewers to understand the study is sufficient. Bullet points and references to more detailed texts are both acceptable.

A resistance training programme can lead to a variety of health benefits including significant increases in muscle size and strength (1). Other potential health benefits of resistance training include reduction of body fat, increased metabolic rate, improve insulin sensitivity, blood glucose tolerance and blood lipid profiles (2). Home-based exercise programmes with the use of elastic resistance bands are becoming increasingly more popular and could may well be used as an alternative to resistance training for patients with prescribed exercise programmes as they are portable and cost effective (3). Several studies have revealed elastic resistance band training and conventional resistance training provide similar increases in muscle activation when relative loadings were matched (4–6), however there is a lack of studies on sedentary population.

The current physical activity guidelines for England and Scotland recommend undertaking muscle strengthening activities involving major muscle groups two days a week or more, and to undertake at least 150 minutes per week of moderate intensity physical activity (or 75 minutes per week of vigorous intensity physical activity) (7). However, in England, while 66% of men and 58% of women over met the guidelines for aerobic exercise, only the 31% of men and 23% of women achieved the guidelines for both aerobic and muscle-strengthening exercise in 2016 (8). In Scotland, 67% of men and 58% of women met the aerobic exercise guidelines in 2012, but only 27% of adults met the guidelines for resistance exercise, 30% men and 23% of women (9). This may be because performing resistance exercise may be more burdensome than aerobic exercise which can more easily be incorporated into daily activities. Thus, identifying approaches to minimise the burden of performing resistance exercise and identifying the minimal amount of resistance training which can provide benefits is a key issue which could help more people to undertake muscle strengthening exercises.

Evidence from meta-analyses suggests that while exercising each major muscle group two or more times per week appears to be optimal to maximise strength gains, substantial increase in strength are observed with a single session of exercise per week (10,11). There is also evidence that a single set of exercise per muscle group is sufficient to induce substantial strength changes provided if exercise is performed to failure (12). As a lack of time can often is a common barrier to exercise adoption (13), it is important to develop an approach to undertake resistance training with minimal time commitment. One approach is to split a typical single session of resistance exercise involving several exercises across different muscle groups into separate 1-minute micro-sessions where a different muscle group is exercised on each day. This may be a more convenient way to undertake resistance exercise for some people. The purpose of this study is to determine the effects of a one-minute-per-day home-based resistance exercise training on muscular strength.

1. Saric J, Lisica D, Orlic I, Grgic J, Krieger JW, Vuk S, et al. Resistance Training Frequencies of 3 and 6 Times Per Week Produce Similar Muscular Adaptations in Resistance-Trained Men. J Strength Cond Res [Internet]. 2018 Oct;1. Available from:

https://journals.lww.com/nsca-jscr/Fulltext/publishahead/Resistance_Training_Frequencies_of_3_and_6_Times.95086.aspx
2. Kraemer WJ, Ratamess NA, French DN. Resistance training for health and performance. Curr Sports Med Rep [Internet]. 2002;1(3):165–71. Available from: https://doi.org/10.1007/s11932-002-0017-7
3. Iversen VM, Mork PJ, Vasseljen O, Bergquist R, Fimland MS. Multiple-joint exercises using elastic resistance bands vs. conventional resistance-training equipment: A cross-over study. Eur J Sport Sci [Internet]. 2017;17(8):973–82. Available from: https://doi.org/10.1080/17461391.2017.1337229
4. Aboodarda SJ, Hamid MSA, Che Muhamed AM, Ibrahim F, Thompson M. Resultant muscle torque and electromyographic activity during high intensity elastic resistance and free weight exercises. Eur J Sport Sci. 2013;13(2):155–63.
5. Aboodarda SJ, Shariff MAH, Muhamed AMC, Ibrahim F, Yusof A. Electromyographic activity and applied load during high intensity elastic resistance and nautilus machine exercises. J Hum Kinet. 2011;30(1):5–12.
6. Andersen CH, Mortensen OS, Poulsen OM, Zebis MK, Andersen LL, Bjornlund IBT. Muscle Activation and Perceived Loading During Rehabilitation Exercises: Comparison of Dumbbells and Elastic Resistance. Phys Ther. 2010;90(4):538–49.
7. World Health Organization. Global Recommendations on Physical Activity for Health [Internet]. 2011 [cited 2019 Mar 28]. p. 1. Available from: https://www.who.int/dietphysicalactivity/physical-activity-recommendations-18-64years.pdf?ua=1
8. Scholes S. Health Survey for England 2016 Physical activity in adults [Internet]. 2017. 20 p. Available from: https://files.digital.nhs.uk/publication/m/3/hse16-adult-phy-act.pdf
9. Bromley C, Dowling S, Gray L, Hinchliffe S, Hughes T, Leyland A, et al. The Scottish Health Survey [Internet]. Vol. 1, The Scottish Health Survey. 2012. Available from: www.scotland.gov.uk
10. Grgic J, Schoenfeld BJ, Davies TB, Lazinica B, Krieger JW, Pedisic Z. Effect of Resistance Training Frequency on Gains in Muscular Strength: A Systematic Review and Meta-Analysis. Sport Med [Internet]. 2018;48(5):1207–20. Available from: https://doi.org/10.1007/s40279-018-0872-x
11. Gentil P, Bottaro M, Giessing J, Steele J, Fisher J, Campos MH, et al. Effects of equal-volume resistance training with different training frequencies in muscle size and strength in trained men. PeerJ. 2018;6:e5020.
12. Ismail AD, Aba Alkhayl FF, Wilson J, Johnston L, Gill JMR, Gray SR. The effect of short duration resistance training on insulin sensitivity and muscle adaptations in overweight men. Exp Physiol [Internet]. 2019;(October 2018):2–7. Available from: http://doi.wiley.com/10.1113/EP087435
13. Trost SG, Owen N, Bauman AE, Sallis JF, Brown W. Correlates of adults' participation in physical activity: review and update. Med Sci Sport Exerc. 2002;34(12):1996–2001.
14. Radaelli R, Fleck SJ, Leite T, Leite RD, Pinto RS, Fernandes L, et al. Dose-Response of 1, 3, and 5 Sets of Resistance Exercise on Strength, Local Muscular Endurance, and Hypertrophy. J Strength Cond Res [Internet]. 2015;29(5). Available from: https://journals.lww.com/nsca-jscr/Fulltext/2015/05000/Dose_Response_of_1,_3,_and_5_Sets_of_Resistance.25.aspx

2. Describe the design of the study and methods to be used. If multiple methods are to be used, please describe them each in turn. Include details of the study sample size and how you decided this. Statistical advice should be obtained if in doubt.

Participants will be male and female adults (n =54), aged 18-65 years. Exclusion criteria will include diabetes, uncontrolled hypertension (blood pressure > 150/90 on medication), history of cardiovascular disease, physically active and other significant illness that would prevent the participant to undertake physical activity.

Participants will undergo baseline measurements, and after they will be randomised into two conditions: a control group (continue usual lifestyle behaviour), resistance exercise group (RE group). After that, all participants will undertake 12 weeks of intervention or usual lifestyle before post-intervention measurements. Also, participants will be assessed at 4 weeks and 8 weeks during the intervention for some of the variables. Assessments will include anthropometric measures (body weight, height and waist circumference); body composition (% fat mass and % free fat mass); muscle strength (grip strength and 1RM for leg press, bench press and lat pull down), muscle endurance (for leg press, bench press and lat pulldown) and muscle thickness (vastus lateralis).

Participants in the control group will be asked to continue with their lifestyle behaviour and not to increase the amount of their physical activity during the study. The exercise intervention group (RE group) will undergo a 12-week home-based resistance exercise training. It will include 6 exercises (press-ups, squats, squat jumps, plank, upright row and seated row). Participants will perform one exercise for one minute each day for 6 days a week, aiming for the maximum number of repetitions. An overview of the study protocol is shown in Figure 1.

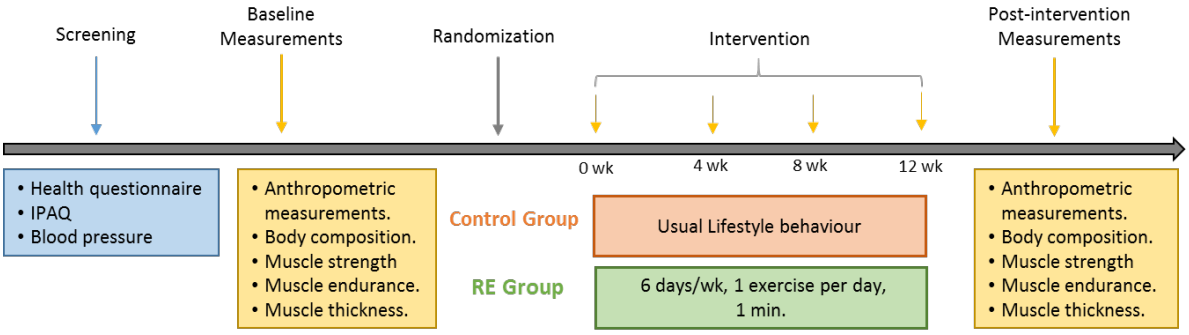


Figure 1. Overview of study protocol

Assessments

I. Screening measurements:

1) Health questionnaire:

(undertaken at 1 time-point; screening)

Participants will be asked to fill a health questionnaire to determine if they are suitable to participate in the study.

2) IPAQ:

(undertaken at 1 time-point; screening)

Participants will be asked to fill the International Physical Activity Questionnaire to determine their physical levels and to know if they are suitable for the study.

3) Blood pressure:

(undertaken at 1 time-point; screening)

Participants rest blood pressure will be assessed after 10 min lying on a bed. Systolic blood pressure and diastolic blood pressure will be measured to determine if they are suitable to participate in the study.

II. Baseline and Post intervention measurements:

1) Measurement of body composition

(undertaken at 4 time-points; at 0, 4, 8 and 12 wk)

Participants' body compositions will be assessed with Bioelectrical Impedance Analysis (BIA) (% fat mass and % free fat mass). Participants will be asked to not engage in physical activity for 8 hrs prior the measurement, to drink 500 ml of water the night before and 2 hrs prior the measurement, to void their bladder before the measurement and to have a solid meal as the last meal before the assessment. This measurement will be taken at the same time of the day for each participant for baseline, 4wk, 8wk and post intervention measurements. Height, weight and waist circumference will be also measured.

2) Muscle strength assessment:

(undertaken at 4 time-points; 0, 4, 8 and 12 wk)

Participants muscle strength will be assessed with 2 methods: grip strength and 1-RM test for bench press, leg press and lat pull down. Participants will have a warm-up of 10 min, with 20 repetitions with light weight and will be taught the correct technique. Weight will be gradually increased until one repetition can be done with the heaviest weight, full range of motion and correct technique. There will be rest intervals of 1-2 min between repetitions.

3) Muscle endurance:

(undertaken at 4 time-points; at 0, 4, 8 and 12 wk)

Muscle endurance will be assessed for bench press, leg press and lateral pull down exercises. Participants will use 50% of their initial 1RM and they will perform the maximum number of repetitions until momentary failure with the correct technique.

4) Muscle thickness:

(undertaken at 2 time-points; at 0 wk and 12 wk)

Muscle thickness will be assessed in vastus lateralis with a Telemed LS 128 CEXT-1Z Beamformer ultrasound. For the vastus lateralis, trochanterion and tibiale laterale land marking will be used to determine the midpoint of the thigh. For baseline measurements, participants will be asked to refrain from any exercise 3 days prior to the measurement and they will be measured 3 days after the exercise intervention. For all measurements participants will be asked to be normally hydrated 24 hrs before the assessment.

Intervention

1) Control group

The control group will be asked to keep their lifestyle behaviour and not to increase their physical activity levels during the study period.

1) Exercise intervention (RE group)

The exercise group will engage in a home-based resistance exercise intervention for 12 weeks. They will perform 6 exercises (press-ups, squats, squat jumps, plank, upright row and seated row) for one minute, aiming for the maximum number of repetitions. Participants will perform one exercise per day, for 6 days a week. One resistance band will be used for some of the exercises. They will be asked to fill an exercise diary for the intervention duration and will have a reminder of the exercises technique (See "Exercise Diary" document attached).

Sample size and power calculation

A previous investigation has reported an 8.7 kg increase for muscle strength for bench press after a resistance exercise training (14). With a 9.9 kg SD for change in muscle strength (14), power of 80% and an alpha of 0.05, groups of 22 participants will be needed. Considering 20% of drop out during the study, we propose to recruit 27 participants per group with a total of 54 participants.

(14) Radaelli R, Fleck SJ, Leite T, Leite RD, Pinto RS, Fernandes L, et al. Dose-Response of 1, 3, and 5 Sets of Resistance Exercise on Strength, Local Muscular Endurance, and Hypertrophy. J Strength Cond Res [Internet]. 2015;29(5). Available from: https://journals.lww.com/nsca-jscr/Fulltext/2015/05000/Dose_Response_of_1,_3,_and_5_Sets_of_Resistance.25.aspx

3. How will potential participants in the study be (i) identified, (ii) approached and (iii) recruited? Give details for cases and controls separately, if appropriate

You should explain how a person becomes identified as a potential participant and then an enrolled participant. If the initial approach uses a poster, social media or email then the materials should be submitted for review.

i. **Identification:** Volunteers will be recruited by posters, personal contact, email and local advertising in Glasgow. Advertisement will be posted at Universities sites and on internal University mailings and websites. Leaflets and posters will be placed around the University campus and in various locations throughout Glasgow.

ii. **Approach:** Study volunteers will be approached by email or telephone.

iii. **Recruitment:** Participants will initially be contacted by phone or email and will be screened at visit 1 according to inclusion and exclusion criteria. Prior to visit 1, participants will be sent the documents (Participant information sheet and Consent Form) by email, to have the opportunity to read them. During the first visit participants will be given a detailed explanation of the study, including risk factors and benefits. They will be given a study information sheet and a consent form, which they can read in detail at their convenience, make questions about the study and to sign the consent if they want to participate. After signing the consent form they will complete a "Health Questionnaire", the IPAQ and their blood pressure will be measured to see if they are suitable to participate in the study according to inclusion and exclusion criteria (screening procedure) (See "Health questionnaire" and "IPAQ" documents attached). Contact details of the participants will be asked, to ensure contact during the study period.

4. Describe the research procedures as they affect the research participants and any other parties involved. It should be clear exactly (i) what will happen to the research participant, (ii) how many times and (iii) in what order. If your research involves administration of a substance, for example saline, topical anaesthetic etc. then please give full details on the substance and manufacturer. Reference to an existing standardised operating procedure is acceptable.

Volunteers will be asked to attend the laboratory on **4/5** occasions:

Screening, visit 1 – Participants will be asked to come for a brief screening procedure, to determine if they are suitable for the study. An explanation of study including screening with inclusion/exclusion criteria. The volunteer information sheet and written informed consent will be given and obtained. A health questionnaire (See Health questionnaire document attached), the IPAQ will be undertaken (See IPAQ questionnaire attached) and blood pressure will be measured to ensure that the participant is suitable for the study. If the participant is suitable to participate, the baseline measurements will follow. Contact details of the participants will be asked, to ensure contact with the participants during the study period. This part of session 1 will take 20 min.

Baseline measurements, visit 1 – On a second visit, body composition, muscle thickness, muscle strength and muscle endurance measurements will be assessed. Participants will be asked to come to the laboratory facilities after an overnight fast. The session will take 2 hrs.

Exercise session demonstration (0 wk), visit 2 – On a second session, participants randomized to the RE group will be taught all the exercises, the correct way to perform them and how to use the resistance bands. An exercise diary (paper format) will be provided which will be have pictures of the exercises and a table to record the training (See "Exercise diary" document attached). In addition, a video with a demonstration of each exercise will be provided (See "Exercises demonstration" video attached). Participants will be taught on how to fill the exercise diary. The session will take 30-45 min.

Exercise intervention (week 1 to week 12) – Participants in the exercise group will be asked to follow a home-based for 12 weeks. They will perform 6 exercises (press-ups, squats, squat jumps, plank, upright row and seated row) for one minute, aiming for the maximum number of repetitions. Participants will perform one exercise per day, for 6 days a week. One resistance band will be used for some of the exercises (upright row and seated row). Participants can perform the exercises in their homes or any other place of their choice.

Intervention Exercise diary record (week 1 to week 12) – Participants in the resistance exercise group will be asked to fill an exercise diary for the length of the intervention (12 weeks) (See "Exercise Diary" document attached). It will distributed in paper format during the exercise session demonstration.

Intervention measurements (4wk and 8wk), visits 3 and 4 – Body composition, muscle strength and muscle endurance measurements will be taken. Participants will be asked to come to the laboratory facilities after an overnight fast. The sessions will take around 30 min each.

Post intervention measurements (12wk), visit 5 - Anthropometric measurements, body composition, muscle thickness, muscle strength and muscle endurance measurements will

be assessed. Participants will be asked to come to the laboratory facilities after an overnight fast. The session will take 2 hrs.

5. What are the ethical considerations involved in this proposal? You may wish, for example, to comment on issues to do with consent, confidentiality, risk to participants, etc.

Consent and participation
Participants will voluntarily consent to the study, and will be told that they can withdraw from the study anytime they want without consequence or need to provide a reason.

Exercise testing and intervention
Preliminary screening will exclude any subjects with a history of cardiovascular problems and those known to exhibit major risk factors for CHD. Exercise will be at maximal level at some points during the study and there is a possibility that the subject could suffer from acute muscle soreness. Participants in the control group will be offered to undergo the exercise intervention after the study period.

Anonymity and confidentiality
The information obtained will be anonymised and individual information will not be passed on to anyone outside the research members. Each participant will be given a number to ensure anonymity for the results analysis.

Data retention
In case of withdrawal at any state of the study, data obtained from participants will be kept by the researchers.
Data from volunteers that have been excluded from the study during the screening procedure will not be stored by the researches and will be destroyed.

6. Outline the reasons why the possible benefits to be gained from the project justify any risks or discomforts involved.

The risks and discomfort associated with participating in this study are minor and the beneficial effect outweighs the small existing risk of participating. Subjects will receive feedback on muscle strength gained throughout the experimental period, so will benefit from the study personally. The results of the proposed research will provide data on changes in muscle morphology and strength modulated by the resistance training. This information may be important in the design of future studies and ultimately developing resistance exercise guidelines. The risks associated with participating in this study are very small.

7. Who are the investigators (including assistants) who will conduct the research? What are their qualifications and experience?

Professor Jason Gill has >20 years of experience in conducting human metabolic and exercise studies.

Dr Stuart Gray has Dr Stuart Gray (PhD) a lecturer in exercise and metabolic health with 14 years of experience in conducting human metabolic and exercise studies.

María Fernanda Gabler is a PhD student under the supervision of Professor Jason Gill. She has been trained in exercise procedures under the MSc Sport and Exercise Science and Medicine 2017/2018 programme by the University of Glasgow. She has undergone first aid training including CPR.

Meghan McLoone is an MSc student under the supervision of Professor Jason Gill. She has been trained in exercise procedures under the MSc Sport and Exercise Science and Medicine 2018/2019 programme by the University of Glasgow.

8. Are arrangements for the provision of clinical facilities to handle emergencies necessary? If so, briefly describe the arrangements made.

The clinical research facility contains a defibrillator, emergency drugs and a telephone to contact emergency services, in the unlikely event of a problem arising. In the event of an emergency, the previously approved emergency protocols will be followed. All exercise tests will be supervised by at least two personnel experienced in the procedures involved (at least one will be CPR certified).

9. In cases where participants will be identified from information held by another party (e.g., a doctor or hospital), describe how you intend to obtain this information. Include, where appropriate, whether additional Research Ethics Committee approvals will be sought and gained (including overseas committees).

No applicable for this study

10. Specify whether participants will include students or others in a dependent relationship and, where possible, avoid recruiting students who might feel to be, or be construed to be, under obligation to volunteer for a project. This is most likely to be when a student is enrolled on a course where the investigator is a teacher. In these circumstances, the recruitment could be carried out by one of the other investigators or a suitably qualified third party.

If students are enrolled on a course or supervised by Professor Jason Gill, recruitment will be carried out by another member of the study team who is not directly involved with their studies. Participants will be under no obligation or incentive to volunteer for the study.

11. Specify whether the research will include children or participants with mental illness, physical disability or intellectual disability. If so, please explain the necessity of involving these individuals as research participants and include documentation of the suitability of those researchers who will be in contact with children or vulnerable adults (e.g., Disclosure Scotland or membership of the Protection of Vulnerable Groups Scheme).

The research/study will not include children or participants with mental illness, disability or handicap.

12. Will payment or other incentive, such as a gift or free services, be made to any research participant? If so, please specify, and state the level of payment to be made and/or the source of the funds/gift/free service to be used. Please explain the justification for offering an incentive.

No cash or exchange of funds will be offered.

13. Please give details of how consent is to be obtained and recorded. A copy of the proposed consent form, along with a separate information sheet, written in simple, non-technical language MUST ACCOMPANY THIS PROPOSAL FORM.

One of the study investigators listed on the study will seek informed written consent after an introductory session, which will involve participants receiving a 'Participant Information Sheet' to read and verbal explanation of the study in regard to the benefits, burdens and risks of the study with the opportunity to ask questions before providing written consent to participate.

14. Comment on any cultural, social or gender-based characteristics of the participants that have affected the design of the project or may affect its conduct.
In this study, the design has not been affected by any cultural, social or gender-based characteristics.

15. Please state (i) who will have access to the data, (ii) how the data will be stored, how will access be restricted, and (iii) what measures will be adopted to maintain the confidentiality of the research participants and to comply with data protection requirements.

For studies where participant responses are recorded and transcribed at a later date, give details of storage and transcription. Please give some detail on how long data will be stored for and where. You should clarify how identifiable, anonymised research data and consent forms will be stored.

i) Only the named investigators will have full access to the data obtained. The information obtained will be anonymised and identifiable data will not be passed on to anyone outside the study group. Anonymised data, only coded with a participant information number, with all identifying information removed, will be shared with collaborators to maximise the life-time value of the data generated for human health, in line with best practice for data sharing
ii) Data will be stored on personal computers of the named investigators on the University server. Access will be restricted by password-protection and data stored for 10 years.
iii) Data will be anonymised with subjects being identified by a number rather than a name. Personal data including linkage of subject name and number will be held in a locked filing cabinet in the BHF Glasgow clinical research centre or as

password−protected files saved on the University server, known only to the named investigators.

Please tick to confirm that all relevant research data generated during and after the study will be collected and held in compliance with the General Data Protection Regulation (May 2018). [X]

Please tick to confirm that you have completed a data protection impact assessment form if required. [X]

If this is not required, please specify why not;

For guidance in this matter, please refer to the University Data Protection Office webpages:
https://www.gla.ac.uk/myglasgow/dpfoioffice/gdpr/

In regard to (ii) above, please clarify (tick one) how the data will be stored:

[ ] **(a) in a fully anonymised form (link to participants broken),**

[ ] **(b) in a linked anonymised form (data +/- samples linked to participant identification number but participant not identifiable to researchers), or**

[x] **(c) in a form in which the participant could be identifiable to researcher.**

If data are stored in linked anonymised form, please state who will have access to the code and personal information about the participant.

The data will be held securely for a period of ten years after the completion of the research project, or for longer if specified by the research funder or sponsor, in accordance with the University's Code of Good Practice in Research. (https://www.gla.ac.uk/research/strategy/ourpolicies/) Please tick and give further details below [ ]

16. To your knowledge, will the intended group of research participants be involved in other research? If so, please justify.
The study participants will not be involved in other research.

17. Proposed starting date: 01-05-2019

Expected completion date: 30-04-2020

18. Please state location(s) where the project will be carried out, including all overseas laboratories, hospitals and other relevant locations.
Sir James Black Building and British Heart Foundation Glasgow Cardiovascular Research Centre at the University of Glasgow. The training programme will take place wherever is convenient for participants.

19. Please state briefly any precautions being taken to protect the health and safety of researchers and others associated with the project (as distinct from the research participants), e.g., where blood samples are being taken, home visits.
Not applicable for this study

20. Please state all relevant sources of funding or support for this study.
The work is funded by a PhD Scholarship to Ms Gabler from Beca Chile CONICYT.

21a). Are there any conflicts of interest related to this project for any member of the research team? This includes, but is not restricted to, financial or commercial interests in the findings. If so, please explain these in detail and justify the role of the research team. For each member of the research team please complete a declaration of conflicts of interest below.

Researcher Name: __ Jason Gill _____ conflict of interest No
If yes, please detail below

Researcher Name: ___ Stuart Gray _____ conflict of interest No
If yes, please detail below

Researcher Name: ___ María Fernanda Gabler _____ conflict of interest No
If yes, please detail below

Researcher Name: ___Meghan McLoone _____ conflict of interest No
If yes, please detail below

21b). If there are any conflicts of interest, please describe these in detail and justify conducting the proposed study.

Not applicable

22. How do you intend to disseminate the findings of this research?
Please include details of how the study participants will be notified of the study finding. If they are not to be informed, please justify.

The results will form part of María Fernanda Gabler's PhD thesis and Meghan McLoone MSc dissertation project. An associated paper, presentation and a poster will be made. In addition, we plan to present the findings in a peer-reviewed scientific journal.

I confirm that have read the University of Glasgow's Data Protection Policy.
https://www.gla.ac.uk/myglasgow/dpfoioffice/

Please initial box | X

Name _ Maria Fernanda Gabler Trisotti _____ Date _03-04-2019_
(Proposer of research)
Please type your name on the line above.

For student projects:

I confirm that I have read and contributed to this submission and believe that the methods proposed and ethical issues discussed are appropriate.

I confirm that the student will have the time and resources to complete this project.

Name __Jason Gill _____ Date __03-04-2019_
(Supervisor of student)
Please type your name on the line above.

Please upload the completed and signed form, along with other required documents by logging in to the Research Ethics System at - https://frontdoor.spa.gla.ac.uk/login/

Appendix B: Approval Letter

Dear Professor Jason Gill

MVLS College Ethics Committee
Project Title: *The ONE Study: Effect of one minute of resistance exercise per day on muscular strength*
200180137

The College Ethics Committee has reviewed your application and has agreed that there is no objection on ethical grounds to the proposed study.

We are happy therefore to approve the project, subject to the following conditions.

- Project end date as stipulated in original application.
- The data should be held securely for a period of ten years after the completion of the research project, or for longer if specified by the research funder or sponsor, in accordance with the University's Code of Good Practice in Research: (http://www.gla.ac.uk/media/media_227599_en.pdf)
- The research should be carried out only on the sites, and/or groups defined in the application.
- Any proposed changes in the protocol should be submitted for reassessment, except when it is necessary to change the protocol to eliminate hazard to the subjects or where the change involves only the administrative aspects of the project. The Ethics Committee should be informed of any such changes.
- For projects requiring the use of an online questionnaire, the University has an Online Surveys account for research. To request access, see the University's application procedure at https://www.gla.ac.uk/research/strategy/ourpolicies/useofonlinesurveystoolforresearch/ .
- You should submit a short end of study report to the Ethics Committee within 3 months of completion.

Yours sincerely

Terry Quinn
FESO, MD, FRCP, BSc (hons), MBChB (hons)
Senior Lecturer / Honorary Consultant

College of Medicine, Veterinary & Life Sciences
Institute of Cardiovascular and Medical Sciences
New Lister Building, Glasgow Royal Infirmary
Glasgow
G31 2ER
terry.quinn@glasgow.gla.ac.uk
Tel – 0141 201 8519

The University of Glasgow, charity number SC004401

Dr Terry Quinn

Appendix C: Approved Amendment

University of Glasgow | College of Medical, Veterinary & Life Sciences

College of Medical, Veterinary & Life Sciences Ethics Committee for Non-Clinical Research Involving Human Participants

APPLICATION FORM FOR ETHICAL APPROVAL

NOTES:
THIS APPLICATION FORM SHOULD BE TYPED NOT HAND WRITTEN.

ALL QUESTIONS MUST BE ANSWERED. "NOT APPLICABLE" IS A SATISFACTORY ANSWER WHERE APPROPRIATE.

The primary remit of this committee is the review of non-clinical research. However, clinical research involving humans, their tissue or data that falls outwith the remit of the NHS Research Ethics Service will also be reviewed by the MVLS committee. If your project involves NHS facilities, or is clinical research, then you must ensure that NHS REC review is not needed before applying to the MVLS REC. The review of the MVLS REC does not obviate the need for NHS review.

Please note – it is now a requirement for a Data Protection Impact Assessment (DPIA) to be completed where processes are likely to involve high-risk personal data. This is likely to be the case for many research projects. If so, you must complete this before submission for ethical review. For research involving personal data, you should give participants a Privacy Notice as well as a Participant Information sheet.

Information on DPIAs and Privacy Notices
https://www.gla.ac.uk/myglasgow/dpfoioffice/gdpr/dpia/
https://www.gla.ac.uk/myglasgow/dpfoioffice/gdpr/privacy%20notices/

Information on the General Data Protection Regulation (GDPR)
https://www.gla.ac.uk/myglasgow/dpfoioffice/

Information on Research Data Management
https://www.gla.ac.uk/myglasgow/datamanagement/

University of Glasgow policy on surveys of students for research purposes
https://www.gla.ac.uk/myglasgow/senateoffice/policies/studentengagement/studentsurveys/policyonstudentsurveys/

Project Title:

The ONE Study: Effect of one minute of resistance exercise per day on muscular strength

Has this application been previously submitted to this or any other ethics committee?
No

If 'Yes', please state the title and reference number.

Is this project from a commercial source, or funded by a research grant of any kind?
No

If 'Yes', has it been referred to Research Support Office?
Has it been allocated a project Number?
Give details and ensure that this is stated on the Informed Consent Form.

Insurance Coverage and Restrictions:

****Please Note: The Insurance restrictions set out below relate to research of a clinical nature. Non clinical research is not subject to restriction and no additional insurance is required****

The University insurance cover is restricted under specific circumstances, including, but not limited to the following -

- **work involving the use of research participants outside Great Britain, Northern Ireland, the Channel Islands or the Isle of Man**
- **the use of hazardous materials**
- **non CE marked medical devices**
- **molecules or compounds developed and manufactured at the University of Glasgow**
- **number of participants in excess of 5000**
- **work involving research participants known to be pregnant at the time of the project**

All such projects must be referred to Research Support Office and coverage confirmed before ethical approval is sought. Please contact Dr Debra Stuart in the University's Research Governance Office: debra.stuart@glasgow.ac.uk

Please tick here if this project has been referred to the Research Support Office to confirm adequate insurance coverage. ☐

Please tick here if the project includes a technique involving incision, piercing of skin, insertion of a device or object, ingestion of medicines or food substances. ☐

Please tick here if the project involves work on human participants that will be conducted within the Imaging Centre of Excellence (ICE) ☐

Date of submission:
29 Novemeber 2019

Name of all person(s) submitting research proposal:
Professor Jason Gill
Dr Stuart Gray
María Fernanda Gabler Trisotti
Meghan McLoone
Professor Cindy Gray
Marisa Nishio

Position(s) held:

Professor of Cardiometabolic Health	JG
Lecturer in Exercise and Metabolic Health	SG
PhD Student Cardiovascular Sciences (Research)	MFG
MSc Sport and Exercise Science and Medicine	MM
Professor of Health and Behaviour	CG
MSc in Global Health	MN

School/Group/Institute/Centre:
Institute of Cardiovascular and Medical Sciences (JG, SG and MFG)

Address for correspondence relating to this submission:
BHF Glasgow Cardiovascular Research Centre, University of Glasgow, Institute of Cardiovascular and Medical Sciences, College of Medical, Veterinary and Life Sciences, Glasgow, G12 8TA

Email address: Jason.Gill@glasgow.ac.uk
Stuart.Gray@glasgow.ac.uk

m.glabler-trisotti.1@research.gla.ac.uk
xxxxxxxx@student.gla.ac.uk
Cindy.Gray@glasgow.ac.uk
xxxxxxxx@student.gla.ac.uk

Name of Principal Researcher (if different from above, e.g., Student's Supervisor):
Jason Gill

Position held:

Undergraduate student project:
No If 'Yes', please state degree being undertaken:

Postgraduate student project:
Yes If 'Yes', please state degree being undertaken:

PhD Cardiovascular Sciences (Research)
MSc Sport and Exercise Science and Medicine

For postgraduate student projects, please state whether this a research (PGR) or taught (PGT) degree:

PGR and PGT

1. Describe the purposes of the research proposed. Please include the background and scientific justification for the research. Why is this an area of importance? Please try to describe why the research is novel and experimental.

We do not need a comprehensive review of the topic area: a short summary that is sufficient for the reviewers to understand the study is sufficient. Bullet points and references to more detailed texts are both acceptable.

A resistance training programme can lead to a variety of health benefits including significant increases in muscle size and strength (1). Other potential health benefits of resistance training include reduction of body fat, increased metabolic rate, improve insulin sensitivity, blood glucose tolerance and blood lipid profiles (2). Home-based exercise programmes with the use of elastic resistance bands are becoming increasingly more popular and could may well be used as an alternative to resistance training for patients with prescribed exercise programmes as they are portable and cost effective (3). Several studies have revealed elastic resistance band training and conventional resistance training provide similar increases in muscle activation when relative loadings were matched (4–6), however there is a lack of studies on sedentary population.

The current physical activity guidelines for England and Scotland recommend undertaking muscle strengthening activities involving major muscle groups two days a week or more, and to undertake at least 150 minutes per week of moderate intensity physical activity (or 75 minutes per week of vigorous intensity physical activity) (7). However, in England, while 66% of men and 58% of women over met the guidelines for aerobic exercise, only the 31% of men and 23% of women achieved the guidelines for both aerobic and muscle-strengthening exercise in 2016 (8). In Scotland, 67% of men and 58% of women met the aerobic exercise guidelines in 2012, but only 27% of adults met the guidelines for resistance exercise, 30% men and 23% of women (9). This may be because performing resistance exercise may be more burdensome than aerobic exercise which can more easily be incorporated into daily activities. Thus, identifying approaches to minimise the burden of performing resistance exercise and identifying the minimal amount of resistance training which can provide benefits is a key issue which could help more people to undertake muscle strengthening exercises.

Evidence from meta-analyses suggests that while exercising each major muscle group two or more times per week appears to be optimal to maximise strength gains, substantial increase in strength are observed with a single session of exercise per week (10,11). There is also evidence that a single set of exercise per muscle group is sufficient to induce substantial strength changes provided if exercise is performed to failure (12). As a lack of time can often is a common barrier to exercise adoption (13), it is important to develop an approach to undertake resistance training with minimal time commitment. One approach is to split a typical single session of resistance exercise involving several exercises across different muscle groups into separate 1-minute micro-sessions where a different muscle group is exercised on each day. This may be a more convenient way to undertake resistance exercise for some people. The purposes of this study are therefore (1) to determine the effects of one-minute-per-day home-based resistance exercise training on muscular strength and (2) to determine participants' views and experiences of the intervention.

1. Saric J, Lisica D, Orlic I, Grgic J, Krieger JW, Vuk S, et al. Resistance Training Frequencies of 3 and 6 Times Per Week Produce Similar Muscular Adaptations in

Resistance-Trained Men. J Strength Cond Res [Internet]. 2018 Oct;1. Available from: https://journals.lww.com/nsca-jscr/Fulltext/publishahead/Resistance_Training_Frequencies_of_3_and_6_Times.95086.aspx

2. Kraemer WJ, Ratamess NA, French DN. Resistance training for health and performance. Curr Sports Med Rep [Internet]. 2002;1(3):165–71. Available from: https://doi.org/10.1007/s11932-002-0017-7
3. Iversen VM, Mork PJ, Vasseljen O, Bergquist R, Fimland MS. Multiple-joint exercises using elastic resistance bands vs. conventional resistance-training equipment: A cross-over study. Eur J Sport Sci [Internet]. 2017;17(8):973–82. Available from: https://doi.org/10.1080/17461391.2017.1337229
4. Aboodarda SJ, Hamid MSA, Che Muhamed AM, Ibrahim F, Thompson M. Resultant muscle torque and electromyographic activity during high intensity elastic resistance and free weight exercises. Eur J Sport Sci. 2013;13(2):155–63.
5. Aboodarda SJ, Shariff MAH, Muhamed AMC, Ibrahim F, Yusof A. Electromyographic activity and applied load during high intensity elastic resistance and nautilus machine exercises. J Hum Kinet. 2011;30(1):5–12.
6. Andersen CH, Mortensen OS, Poulsen OM, Zebis MK, Andersen LL, Bjornlund IBT. Muscle Activation and Perceived Loading During Rehabilitation Exercises: Comparison of Dumbbells and Elastic Resistance. Phys Ther. 2010;90(4):538–49.
7. World Health Organization. Global Recommendations on Physical Activity for Health [Internet]. 2011 [cited 2019 Mar 28]. p. 1. Available from: https://www.who.int/dietphysicalactivity/physical-activity-recommendations-18-64years.pdf?ua=1
8. Scholes S. Health Survey for England 2016 Physical activity in adults [Internet]. 2017. 20 p. Available from: https://files.digital.nhs.uk/publication/m/3/hse16-adult-phy-act.pdf
9. Bromley C, Dowling S, Gray L, Hinchliffe S, Hughes T, Leyland A, et al. The Scottish Health Survey [Internet]. Vol. 1, The Scottish Health Survey. 2012. Available from: www.scotland.gov.uk
10. Grgic J, Schoenfeld BJ, Davies TB, Lazinica B, Krieger JW, Pedisic Z. Effect of Resistance Training Frequency on Gains in Muscular Strength: A Systematic Review and Meta-Analysis. Sport Med [Internet]. 2018;48(5):1207–20. Available from: https://doi.org/10.1007/s40279-018-0872-x
11. Gentil P, Bottaro M, Giessing J, Steele J, Fisher J, Campos MH, et al. Effects of equal-volume resistance training with different training frequencies in muscle size and strength in trained men. PeerJ. 2018;6:e5020.
12. Ismail AD, Aba Alkhayl FF, Wilson J, Johnston L, Gill JMR, Gray SR. The effect of short duration resistance training on insulin sensitivity and muscle adaptations in overweight men. Exp Physiol [Internet]. 2019;(October 2018):2–7. Available from: http://doi.wiley.com/10.1113/EP087435
13. Trost SG, Owen N, Bauman AE, Sallis JF, Brown W. Correlates of adults' participation in physical activity: review and update. Med Sci Sport Exerc. 2002;34(12):1996–2001.
14. Wight D, Wimbush E, Jepson R, Doi L. Six steps in quality intervention development (6SQuID). J Epidemiol Community Health. 2016;70(5):520.
15. Yardley L, Morrison L, Bradbury K, Muller I. The person-based approach to intervention development: application to digital health-related behavior change interventions. J Med Internet Res. 2015;17(1):e30.

16. Radaelli R, Fleck SJ, Leite T, Leite RD, Pinto RS, Fernandes L, et al. Dose-Response of 1, 3, and 5 Sets of Resistance Exercise on Strength, Local Muscular Endurance, and Hypertrophy. J Strength Cond Res [Internet]. 2015;29(5). Available from: https://journals.lww.com/nsca-jscr/Fulltext/2015/05000/Dose_Response_of_1,_3,_and_5_Sets_of_Resistance.25.aspx

2. Describe the design of the study and methods to be used. If multiple methods are to be used, please describe them each in turn. Include details of the study sample size and how you decided this. Statistical advice should be obtained if in doubt.

Participants will be male and female adults (n =54), aged 18-65 years. Exclusion criteria will include diabetes, uncontrolled hypertension (blood pressure > 150/90 on medication), history of cardiovascular disease, to do at least 60 min of vigorous intensity physical activity and other significant illness that would prevent the participant to undertake physical activity.

Participants will undergo baseline measurements, and after they will be randomised into two conditions: a control group (continue usual lifestyle behaviour), resistance exercise group (RE group). After that, all participants will undertake 12 weeks of intervention or usual lifestyle before post-intervention measurements. Also, participants will be assessed at 4 weeks and 8 weeks during the intervention for some of the variables. Assessments will include anthropometric measures (body weight, height and waist circumference); body composition (% fat mass and % free fat mass); muscle strength (grip strength and 1RM for leg press, bench press and lat pull down), muscle endurance (for leg press, bench press and lat pulldown) and muscle thickness (vastus lateralis). A subsample of intervention group participants (n~12) will be recruited during or after the intervention to take part in a single qualitative interview about their views and experiences of the intervention. Purposive sampling will be undertaken to include a range of views: men/women/younger/older.

Participants in the control group will be asked to continue with their lifestyle behaviour and not to increase the amount of their physical activity during the study. The exercise intervention group (RE group) will undergo a 12-week home-based resistance exercise training. It will include 6 exercises (press-ups, squats, squat jumps, plank, upright row and seated row). Participants will perform one exercise for one minute each day for 6 days a week, aiming for the maximum number of repetitions. An overview of the study protocol is shown in Figure 1.

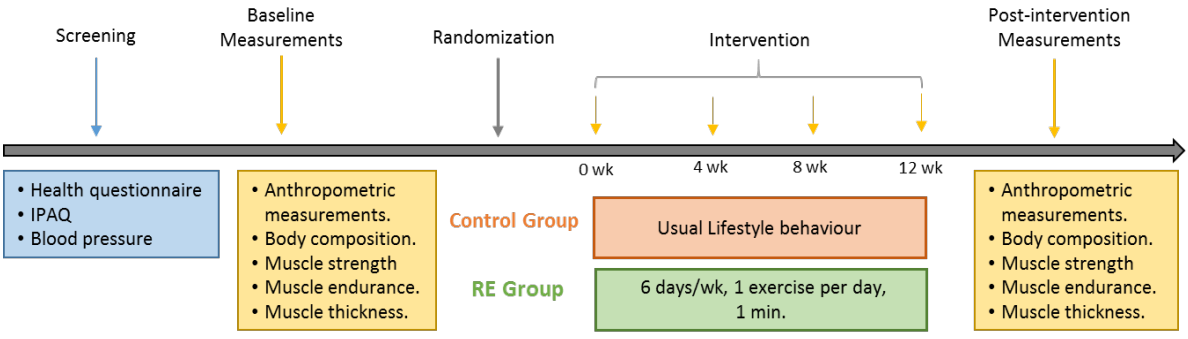


Figure 1. Overview of study protocol

Assessments

III. Screening measurements:

4) Health questionnaire:

(undertaken at 1 time-point; screening)

Participants will be asked to fill a health questionnaire to determine if they are suitable to participate in the study.

5) IPAQ:

(undertaken at 1 time-point; screening)

Participants will be asked to fill the International Physical Activity Questionnaire to determine their physical levels and to know if they are suitable for the study.

6) Blood pressure:

(undertaken at 1 time-point; screening)

Participants rest blood pressure will be assessed after 10 min lying on a bed. Systolic blood pressure and diastolic blood pressure will be measured to determine if they are suitable to participate in the study.

IV. Baseline and Post intervention measurements:

1) Measurement of body composition

(undertaken at 4 time-points; at 0, 4, 8 and 12 wk)

Participants' body compositions will be assessed with Bioelectrical Impedance Analysis (BIA) (% fat mass and % free fat mass). Participants will be asked to not engage in physical activity for 8 hrs prior the measurement, to drink 500 ml of water the night before and again 2 hrs before the measurement and not to consume solid food for at least 2 hrs before the measurement. This measurement will be taken at the same time of the day for each participant for baseline, 4wk, 8wk and post intervention measurements. Height, weight and waist circumference will be also measured.

2) Muscle strength assessment:

(undertaken at 4 time-points; 0, 4, 8 and 12 wk)

Participants muscle strength will be assessed with 2 methods: grip strength and 1-RM test for bench press, leg press and lat pull down. Participants will have a warm-up of 10 min, with 20 repetitions with light weight and will be taught the correct technique. Weight will be gradually increased until one repetition can be done with the heaviest weight, full range of motion and correct technique. There will be rest intervals of 1-2 min between repetitions.

3) Muscle endurance:

(undertaken at 4 time-points; at 0, 4, 8 and 12 wk)

Muscle endurance will be assessed for bench press, leg press and lateral pull down exercises. Participants will use 50% of their initial 1RM and they will perform the maximum number of repetitions until momentary failure with the correct technique.

4) Muscle thickness:

(undertaken at 2 time-points; at 0 wk and 12 wk)

Muscle thickness will be assessed in vastus lateralis with a Telemed LS 128 CEXT-1Z Beamformer ultrasound. For the vastus lateralis, trochanterion and tibiale laterale land marking will be used to determine the midpoint of the thigh. For baseline measurements, participants will be asked to refrain from any exercise 3 days prior to the measurement and they will be measured 3 days after the exercise intervention. For all measurements, participants will be asked to be normally hydrated 24 hrs before the assessment.

5) Post intervention interviews:

(undertaken at one timepoint)

Participants will undergo in-depth "Think Aloud" interviews (14,15) in their homes (lasting around 60 minutes) to understand barriers, facilitators and the ways in which they incorporate the programme into their daily routine. The interview findings will be used to inform the intervention theory of change and any refinements required to the core components.

Intervention

1) Control group

The control group will be asked to keep their lifestyle behaviour and not to increase their physical activity levels during the study period.

1) Exercise intervention (RE group)

The exercise group will engage in a home-based resistance exercise intervention for 12 weeks. They will perform 6 exercises (press-ups, squats, squat jumps, plank, upright row and seated row) for one minute, aiming for the maximum number of repetitions. Participants will perform one exercise per day, for 6 days a week. One resistance band will be used for some of the exercises. They will be asked to fill an exercise diary for the intervention duration and will have a reminder of the exercises technique (See "Exercise Diary" document attached).

Sample size and power calculation

A previous investigation has reported an 8.7 kg increase for muscle strength for bench press after a resistance exercise training (16). With a 9.9 kg SD for change in muscle strength (16), power of 80% and an alpha of 0.05, groups of 22 participants will be needed. Considering 20% of drop out during the study, we propose to recruit 27 participants per group with a total of 54 participants.

In the qualitative study, we aim to recruit around 12 participants for in-depth think aloud interviews. Past experience suggests this number should allow us to reach data saturation. If this is not the case, we will continue recruitment until either data saturation has been reached or all willing intervention group participants have been interviewed. A decision on whether or not saturation has been reached will be taken by the whole supervisory and qualitative teams.

14. Wight D, Wimbush E, Jepson R, Doi L. Six steps in quality intervention development (6SQuID). J Epidemiol Community Health. 2016;70(5):520.
15. Yardley L, Morrison L, Bradbury K, Muller I. The person-based approach to intervention development: application to digital health-related behavior change interventions. J Med Internet Res. 2015;17(1):e30.
16. Radaelli R, Fleck SJ, Leite T, Leite RD, Pinto RS, Fernandes L, et al. Dose-Response of 1, 3, and 5 Sets of Resistance Exercise on Strength, Local Muscular Endurance, and Hypertrophy. J Strength Cond Res [Internet]. 2015;29(5). Available from: https://journals.lww.com/nsca-jscr/Fulltext/2015/05000/Dose_Response_of_1,_3,_and_5_Sets_of_Resistance.25.aspx

3. How will potential participants in the study be (i) identified, (ii) approached and (iii) recruited? Give details for cases and controls separately, if appropriate

You should explain how a person becomes identified as a potential participant and then an enrolled participant. If the initial approach uses a poster, social media or email then the materials should be submitted for review.

iv. **Identification:** Volunteers will be recruited by posters, personal contact, email and local advertising in Glasgow. Advertisement will be posted at Universities sites and on internal University mailings and websites, and local newspapers. Leaflets and posters will be placed around the University campus and in various locations throughout Glasgow.

v. **Approach:** Study volunteers will be approached by email or telephone.
Participants from the exercise group will be approached during the intervention or after it by the research team to ask them if they would be willing to take part in a qualitative interview about their experiences of the intervention.

vi. **Recruitment:** Participants will initially be contacted by phone or email and will be screened at visit 1 according to inclusion and exclusion criteria. Prior to visit 1, participants will be sent the documents (Participant information sheet and Consent Form) by email, to have the opportunity to read them. During the first visit participants will be given a detailed explanation of the study, including risk factors and benefits. They will be given a study information sheet and a consent form, which they can read in detail at their convenience, make questions about the study and to sign the consent if they want to participate. After signing the consent form they will complete a "Health Questionnaire", the IPAQ and their blood pressure will be measured to see if they are suitable to participate in the study according to inclusion and exclusion criteria (screening procedure) (See "Health questionnaire" and "IPAQ" documents attached). Contact details of the participants will be asked, to ensure contact during the study period.
Participants in the exercise group will be given a Qualitative Interview Information Form and, once they have read it, asked if they would be willing (if chosen) to take part in an interview. A subsample of those who agree will be selected for interview using purposive sampling (men/women/younger/older) to reflect a range of experiences. Those selected will be phoned to arrange a time for the qualitative intern who will be conducting the interviews to visit and interview each participant at home. Before the interview starts, each participant will be asked if they have any questions about the interview, and once these have been answered, asked to sign a second consent form (Attached, see Interview Consent Form).

4. Describe the research procedures as they affect the research participants and any other parties involved. It should be clear exactly (i) what will happen to the research participant, (ii) how many times and (iii) in what order. If your research involves administration of a substance, for example saline, topical anaesthetic etc. then please give full details on the substance and manufacturer. Reference to an existing standardised operating procedure is acceptable.

Volunteers will be asked to attend the laboratory on **4/5** occasions:

Screening, visit 1 – Participants will be asked to come for a brief screening procedure, to determine if they are suitable for the study. An explanation of study including screening with inclusion/exclusion criteria. The volunteer information sheet and written informed consent will be given and obtained. A health questionnaire (See Health questionnaire document attached), the IPAQ will be undertaken (See IPAQ questionnaire attached) and blood pressure will be measured to ensure that the participant is suitable for the study. If the participant is suitable to participate, the baseline measurements will follow. Contact details of the participants will be asked, to ensure contact with the participants during the study period. This part of session 1 will take 20 min.

Baseline measurements, visit 1 – On a second visit, body composition, muscle thickness, muscle strength and muscle endurance measurements will be assessed. Participants will be asked to come to the laboratory facilities after an overnight fast. The session will take 2 hrs.

Exercise session demonstration (0 wk), visit 2 – On a second session, participants randomized to the RE group will be taught all the exercises, the correct way to perform them and how to use the resistance bands. An exercise diary (paper format) will be provided which will be have pictures of the exercises and a table to record the training (See "Exercise diary" document attached). In addition, a video with a demonstration of each exercise will be provided (See "Exercises demonstration" video attached). Participants will be taught on how to fill the exercise diary. The session will take 30-45 min.

Exercise intervention (week 1 to week 12) – Participants in the exercise group will be asked to follow a home-based for 12 weeks. They will perform 6 exercises (press-ups, squats, squat jumps, plank, upright row and seated row) for one minute, aiming for the maximum number of repetitions. Participants will perform one exercise per day, for 6 days a week. One resistance band will be used for some of the exercises (upright row and seated row). Participants can perform the exercises in their homes or any other place of their choice.

Intervention Exercise diary record (week 1 to week 12) – Participants in the resistance exercise group will be asked to fill an exercise diary for the length of the intervention (12 weeks) (See "Exercise Diary" document attached). It will distributed in paper format during the exercise session demonstration.

Intervention measurements (4wk and 8wk), visits 3 and 4 – Body composition, muscle strength and muscle endurance measurements will be taken. Participants will be asked to come to the laboratory facilities after an overnight fast. The sessions will take around 30 min each.

Post intervention measurements (12wk), visit 5 - Anthropometric measurements, body composition, muscle thickness, muscle strength and muscle endurance measurements will

be assessed. Participants will be asked to come to the laboratory facilities after an overnight fast. The session will take 2 hrs.

Interview (during or after intervention) – Participants in the exercise group that volunteer, are selected and consent to be interviewed will be visited by the qualitative intern researcher in their own homes on one occasion. Each interview will take about 60 minutes and participants will be asked to demonstrate and talk the interviewer through their exercise programme, describe how the fit the exercises into their normal routine, and what has helped/prevented them from doing so.

5. What are the ethical considerations involved in this proposal? You may wish, for example, to comment on issues to do with consent, confidentiality, risk to participants, etc.

Consent and participation
Participants will voluntarily consent to the study, and will be told that they can withdraw from the study anytime they want without consequence or need to provide a reason.

Exercise testing and intervention
Preliminary screening will exclude any subjects with a history of cardiovascular problems and those known to exhibit major risk factors for CHD. Exercise will be at maximal level at some points during the study and there is a possibility that the subject could suffer from acute muscle soreness. Participants in the control group will be offered to undergo the exercise intervention after the study period.

Anonymity and confidentiality
The information obtained will be anonymised and individual information will not be passed on to anyone outside the research members. Each participant will be given a number to ensure anonymity for the results analysis.

Data retention
In case of withdrawal at any state of the study, data obtained from participants will be kept by the researchers.
Data from volunteers that have been excluded from the study during the screening procedure will not be stored by the researches and will be destroyed.

6. Outline the reasons why the possible benefits to be gained from the project justify any risks or discomforts involved.

The risks and discomfort associated with participating in this study are minor and the beneficial effect outweighs the small existing risk of participating. Subjects will receive feedback on muscle strength gained throughout the experimental period, so will benefit from the study personally. The results of the proposed research will provide data on changes in muscle morphology and strength modulated by the resistance training. This information may be important in the design of future studies and ultimately developing resistance exercise guidelines. The risks associated with participating in this study are very small.

7. Who are the investigators (including assistants) who will conduct the research? What are their qualifications and experience?

Professor Jason Gill has >20 years of experience in conducting human metabolic and exercise studies.

Dr Stuart Gray has Dr Stuart Gray (PhD) a lecturer in exercise and metabolic health with 14 years of experience in conducting human metabolic and exercise studies.

María Fernanda Gabler is a PhD student under the supervision of Professor Jason Gill. She has been trained in exercise procedures under the MSc Sport and Exercise Science and Medicine 2017/2018 programme by the University of Glasgow. She has undergone first aid training including CPR.

Meghan McLoone is an MSc student under the supervision of Professor Jason Gill. She has been trained in exercise procedures under the MSc Sport and Exercise Science and Medicine 2018/2019 programme by the University of Glasgow.

Professor Cindy Gray has over 12 years experience in using qualitative methods to inform the development and optimisation of health behaviour change interventions (including physical activity/exercise programmes)

Marisa Nishio is an MSc in Global Health student under the supervision of Professor Cindy Gray.

8. Are arrangements for the provision of clinical facilities to handle emergencies necessary? If so, briefly describe the arrangements made.

The clinical research facility contains a defibrillator, emergency drugs and a telephone to contact emergency services, in the unlikely event of a problem arising. In the event of an emergency, the previously approved emergency protocols will be followed. All exercise tests will be supervised by at least two personnel experienced in the procedures involved (at least one will be CPR certified).

9. In cases where participants will be identified from information held by another party (e.g., a doctor or hospital), describe how you intend to obtain this information. Include, where appropriate, whether additional Research Ethics Committee approvals will be sought and gained (including overseas committees).
No applicable for this study

10. Specify whether participants will include students or others in a dependent relationship and, where possible, avoid recruiting students who might feel to be, or be construed to be, under obligation to volunteer for a project. This is most likely to be when a student is enrolled on a course where the investigator is a teacher. In these circumstances, the recruitment could be carried out by one of the other investigators or a suitably qualified third party.

If students are enrolled on a course or supervised by Professor Jason Gill, recruitment will be carried out by another member of the study team who is not directly involved with their studies. Participants will be under no obligation or incentive to volunteer for the study.

11. Specify whether the research will include children or participants with mental illness, physical disability or intellectual disability. If so, please explain the necessity of involving these individuals as research participants and include documentation of the suitability of those researchers who will be in contact with children or vulnerable adults (e.g., Disclosure Scotland or membership of the Protection of Vulnerable Groups Scheme).

The research/study will not include children or participants with mental illness, disability or handicap.

12. Will payment or other incentive, such as a gift or free services, be made to any research participant? If so, please specify, and state the level of payment to be made and/or the source of the funds/gift/free service to be used. Please explain the justification for offering an incentive.

We realise that 12 weeks of intervention and 4 visits is a big commitment. Therefore, in order to get more volunteers and as an appreciation token for their commitment for the study we will give each participant that finishes the study an Amazon voucher of £20 (including the participants that have already finishes the trial).

13. Please give details of how consent is to be obtained and recorded. A copy of the proposed consent form, along with a separate information sheet, written in simple, non-technical language MUST ACCOMPANY THIS PROPOSAL FORM.

One of the study investigators listed on the study will seek informed written consent after an introductory session, which will involve participants receiving a 'Participant Information Sheet' to read and verbal explanation of the study in regard to the benefits, burdens and risks of the study with the opportunity to ask questions before providing written consent to participate.

For the qualitative study one of the study investigators will seek a second written consent after an introductory session, which will involve participants receiving a second 'Participant Information Sheet' to read and verbal explanation of the study in regard to the benefits, burdens and risks of the study with the opportunity to ask questions before providing written consent to participate.

14. Comment on any cultural, social or gender-based characteristics of the participants that have affected the design of the project or may affect its conduct.

In this study, the design has not been affected by any cultural, social or gender-based characteristics.

15. Please state (i) who will have access to the data, (ii) how the data will be stored, how will access be restricted, and (iii) what measures will be adopted to maintain the confidentiality of the research participants and to comply with data protection requirements.

For studies where participant responses are recorded and transcribed at a later date, give details of storage and transcription. Please give some detail on how long data will be stored for and where. You should clarify how identifiable, anonymised research data and consent forms will be stored.

iv) Only the named investigators will have full access to the data obtained. The information obtained will be anonymised and identifiable data will not be passed on to anyone outside the study group. Anonymised data, only coded with a participant information number, with all identifying information removed, will be shared with collaborators to maximise the life-time value of the data generated for human health, in line with best practice for data sharing

v) Data will be stored on personal computers of the named investigators on the University server. Access will be restricted by password-protection and data stored for 10 years.

vi) Data will be anonymised with subjects being identified by a number rather than a name. Personal data including linkage of subject name and number will be held in a locked filing cabinet in the BHF Glasgow clinical research centre or as password−protected files saved on the University server, known only to the named investigators.

Please tick to confirm that all relevant research data generated during and after the study will be collected and held in compliance with the General Data Protection Regulation (May 2018). [X]

Please tick to confirm that you have completed a data protection impact assessment form if required. [X]

If this is not required, please specify why not;

For guidance in this matter, please refer to the University Data Protection Office webpages:
https://www.gla.ac.uk/myglasgow/dpfoioffice/gdpr/

In regard to (ii) above, please clarify (tick one) how the data will be stored:

[ ] **(a) in a fully anonymised form (link to participants broken),**

☐ **(b) in a linked anonymised form (data +/- samples linked to participant identification number but participant not identifiable to researchers), or**

☒ **(c) in a form in which the participant could be identifiable to researcher.**

If data are stored in linked anonymised form, please state who will have access to the code and personal information about the participant.

The data will be held securely for a period of ten years after the completion of the research project, or for longer if specified by the research funder or sponsor, in accordance with the University's Code of Good Practice in Research. (https://www.gla.ac.uk/research/strategy/ourpolicies/) Please tick and give further details below ☐

16. To your knowledge, will the intended group of research participants be involved in other research? If so, please justify.
The study participants will not be involved in other research.

17. Proposed starting date: 01-05-2019

Expected completion date: 30-04-2020

18. Please state location(s) where the project will be carried out, including all overseas laboratories, hospitals and other relevant locations.
Sir James Black Building and British Heart Foundation Glasgow Cardiovascular Research Centre at the University of Glasgow. The training programme will take place wherever is convenient for participants.
The interview will be held at the participants homes.

19. Please state briefly any precautions being taken to protect the health and safety of researchers and others associated with the project (as distinct from the research participants), e.g., where blood samples are being taken, home visits.
Not applicable for this study

20. Please state all relevant sources of funding or support for this study.
The work is funded by a PhD Scholarship to Ms Gabler from Beca Chile CONICYT and research funds from the College of Social Sciences, University of Glasgow granted to Professor Cindy Gray.

21a). Are there any conflicts of interest related to this project for any member of the research team? This includes, but is not restricted to, financial or commercial interests in the findings. If so, please explain these in detail and justify the role of the research team. For each member of the research team please complete a declaration of conflicts of interest below.

Researcher Name: __ Jason Gill _____ conflict of interest No
If yes, please detail below

Researcher Name: ___ Stuart Gray _____ conflict of interest No
If yes, please detail below

Researcher Name: ___ María Fernanda Gabler _____ conflict of interest No
If yes, please detail below

Researcher Name: ___Meghan McLoone _____ conflict of interest No
If yes, please detail below
Researcher Name: ___Cindy Gray_____ conflict of interest No
If yes, please detail below
Researcher Name: ___Marisa Nishio_____ conflict of interest No

21b). If there are any conflicts of interest, please describe these in detail and justify conducting the proposed study.

Not applicable

22. How do you intend to disseminate the findings of this research?
Please include details of how the study participants will be notified of the study finding. If they are not to be informed, please justify.

The results will form part of María Fernanda Gabler's PhD thesis and Meghan McLoone MSc dissertation project. An associated paper, presentation and a poster will be made. In addition, we plan to present the findings in a peer-reviewed scientific journal.

I confirm that have read the University of Glasgow's Data Protection Policy.
https://www.gla.ac.uk/myglasgow/dpfoioffice/

Please initial box [X]

Name _ Maria Fernanda Gabler Trisotti _____ Date _03-04-2019_

(Proposer of research)
Please type your name on the line above.

For student projects:

I confirm that I have read and contributed to this submission and believe that the methods proposed and ethical issues discussed are appropriate.

I confirm that the student will have the time and resources to complete this project.

Name __Jason Gill _____ Date __03-04-2019_
(Supervisor of student)
Please type your name on the line above.

Please upload the completed and signed form, along with other required documents by logging in to the Research Ethics System at - https://frontdoor.spa.gla.ac.uk/login/

Appendix D: Consent form ONE Study

University of Glasgow | College of Medical, Veterinary & Life Sciences

Centre Number:

Project Number:

Participant Identification Number for this trial:

Title of Project: **The ONE Study: Effect of one minute of resistance exercise per day on muscular strength**

Name of Researcher(s): Maria Fernanda Gabler Trisotti, Meghan McLoone, Stuart Gray and Jason Gill.

CONSENT FORM

	Please initial box
I confirm that I have read and understood the Participant Information Sheet version 1.1 dated 29/03/2019.	☐
I confirm that I have read and understood the Privacy Notice version 1 dated 09/04/2019.	☐
I have had the opportunity to think about the information and ask questions, and understand the answers I have been given.	☐
I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my legal rights being affected.	☐
I confirm that I agree to the way my data will be collected and processed and that data will be stored for up to 10 years in University archiving facilities in accordance with relevant Data Protection policies and regulations.	☐
I understand that all data and information I provide will be kept confidential and will be seen only by study researchers and regulators whose job it is to check the work of researchers.	☐
I agree that my name, contact details and data described in the information sheet will be kept for the purposes of this research project.	☐

I understand that if I withdraw from the study, my data collected up to that point will be retained and used for the remainder of the study. ☐

I agree to take part in the study. ☐

_____	_____	_____
Name of participant	**Date**	**Signature**
_____	_____	_____
Name of Person taking consent (if different from researcher)	**Date**	**Signature**
_____	_____	_____
Researcher	**Date**	**Signature**

(1 copy for participant; 1 copy for researcher)

Appendix E: Participant Information ONE Study

University of Glasgow | College of Medical, Veterinary & Life Sciences

The ONE Study: Effect of one minute of resistance exercise per day on muscular strength

PARTICIPANT INFORMATION SHEET

You are being invited to take part in a research study but before you decide whether to take part, it is important that you fully understand why the research is being carried out and what it will involve. This document is designed to help you decide whether you would like to participate. Please take time to read the following information carefully and discuss it with your friends and family. If anything is not clear or if you would like more information, please contact a member of the research team whose details are included at the bottom of the information sheet. If you decide to take part in this study, you will be given a copy of this Participant Information Sheet and the signed consent form to keep.

What is the purpose of the study?

Resistance exercise (e.g. lifting weights or using resistance bands) produces several health benefits and increases muscle mass and strength. Current physical activity guidelines recommend that adults do at least 150 minutes of moderate intensity aerobic physical activity (or 75 minutes of vigorous intensity) and weight lifting activities on two or more days per week. Only a third of the population meet the physical activity guidelines. Therefore, finding a way of doing resistance exercise that is time efficient may increase the number of people that achieve the guidelines. The purpose of this study is to determine the effects of a one-minute a day home-based resistance exercise training on muscle strength.

Why have I been invited to participate?

You have been invited to take part in this study because you are a healthy adult aged between 18 and 65 years who is currently inactive and may benefit from a programme of resistance exercise. A total of 54 participants will be included in our study.

Do I have to take part?

No, it is up to you to decide whether or not to take part. Participation in this study is completely voluntarily. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part, you are still free to withdraw at any time and without giving a reason. If you are a student and decide not to participate will not affect your grades in any way.

What will happen to me if I take part?

You will be involved in a research study in which you will be randomly assigned (by a computer) to one of two groups. One group (exercise) will undergo a 12-week home-

based resistance exercise programme. The other (control) group will be asked to maintain the usual lifestyle for the duration of the study. If you are assigned to the control group, you will be given the opportunity to undertake the home-based resistance exercise programme after you have completed the study. All participants will be asked to come to the laboratory five or six times during the research period (two or three times before the study intervention and then again 4, 8 and 12 weeks after the start of the intervention).

All participants will undertake the following measures:

a) Screening procedures:

Before enrolling in the study, you will be asked to attend for a visit in which we will:

- Provide an opportunity to read the participant information sheet.
- Provide an opportunity for you to ask questions about the study.
- Sign the consent form in case you decide to participate in the study.
- Complete a health questionnaire regarding your personal details, family and personal medical history.
- Complete the "International Physical Activity Questionnaire" to measure your physical activity levels.
- Measure your blood pressure.

These screening procedures will enable us to determine whether you fall into the group of people we wish to study and will also ensure that it is safe for you to participate. This will take around 15-20 minutes.

b) Experimental measurements:

Following the screening procedures, if you decide to participate in the study we will make some measurements. We will ask you to wear sports clothes (shorts and a shirt) for this visit.

We will take the following measurements:

- <u>Anthropometric measurements:</u>
  We will measure your height, weight and your waist circumference. You will be asked to remove your shoes and to wear only one thin layer of clothes. For you height you will be asked to stand still and your height will be measured. For you weight you will be asked to remove any objects you have with you. You will be asked to stand still on an electronic scale and your weight will be recorded. For your waist circumference you will be asked to stand, to pull your shirt up to your chest your and to cross your arms on your chest. A tape will be put around your waist and your circumference will be measured. These three measurements will be repeated three times each. This will take around 10 minutes. These measurements will also be taken at 4, 8 and 12 weeks.

- <u>Body composition</u>
  We will measure your body composition (i.e. the amount of fat in your body) by bioelectrical impedance analysis, which you will be asked to stand on a scale that will measure the electrical flow through your tissues. This is not harmful,

and you will not feel anything. This will take around 5 minutes. For this measurement, will ask that you do not do exercise 8 hrs before, that the night before you drink 500 ml of water and again 2 hrs before, to have a solid meal as the last meal before the day of the measurement and to go to the toilet before the measurement. These measurements will also be made 4, 8 and 12 weeks.

- Muscle Strength and Endurance Measurements:
  On the same visit, your muscle strength will be measured with two methods. First grip strength will be measured with a dynamometer. You will be asked to sit upright and place your forearms on armrests, with your feet flat on the floor. You will be asked to hold a dynamometer with your thumb facing upward and then squeeze the handle of the dynamometer as hard as you can for 3 seconds. This will be repeated 3 times on each hand, alternating them. We will also measure your 1-RM (maximum weight that you can lift in one repetition) for leg press, bench press and lat pull down. You will start with a warm-up. Then the weight will gradually increase until you can only do only one repetition with complete movement and the correct technique. These tests will take around 40 minutes in total.

  On the same visit, your muscle endurance will be measured for leg press, bench press and lateral pull down. You will have to do as many repetitions as possible until you cannot do more with half of the weight you previously lifted for the muscle strength test. These tests will take around 45-60 minutes in total.

- Thigh Muscle Thickness measurements:
  On the same visit, we will measure the thickness of the muscle on the outside of your thigh (vastus lateralis) using an ultrasound device. We will ask you to wear shorts for this measurement. You will be asked to lie on an examination couch and we will apply some gel to your both left and right thigh. We will then use a small handheld ultrasound device to measure the thickness of your muscles. This will take around 20-30 minutes. This will be taken once more at the end of the study.

Participants randomly assigned to the exercise group will also undertake the following:

c) Home-based resistance exercise programme:

- Exercise session demonstration:
  If you are assigned to the exercise group, you will be asked to come to the laboratory for an exercise session. You will be taught all the exercises and be instructed on how often you will perform them, for how long and how to record your session in an exercise diary that will be given to you. An exercise diary with the exercise pictures and a table to record the exercises for the training will be given to you during this session. This will take around 30-45 minutes.

- Home-based resistance exercise training programme:
  You will be asked to do a resistance exercise programme for 12-weeks at your home or any other place you choose. You will be asked to perform one exercise per day, for one minute, on six days a week, with a total of six exercises. The exercises that you will perform are press-ups, squats, seated row, plank, squat

jumps and upright row. For some exercises, you will require a resistance band, which will be given to you during the exercise session demonstration. You will be asked to fill an exercise diary of your training, which will also have the exercise pictures demonstration for you to remember the technique of each exercise.

The following table explains which measurements will be taken in on which time point and number of visit and how long each visit is going take.

What will happen at this visit	Week 0 (visit 1) 2.5 hours	Week 0 (visit 2) 30-45 min	Week 4 (visit 3) 30 min	Week 8 (visit 4) 30 min	Week 13 (visit 5) 2 hours
Consent process	•				
Blood pressure	•				
International Physical Activity questionnaire (IPAQ)	•				
Anthropometric measurements	•				•
Body composition measurements	•		•	•	•
Muscle strength measurements	•		•	•	•
Muscle endurance measurement	•		•	•	•
Muscle thickness measurement	•				•
Exercise session demonstration (exercise group only)		•			

What do I have to do?

If you are assigned to the control group will ask that you continue to have your usual lifestyle and not to increase your levels of physical activity during the period of the study. If you are assigned to the exercise programme we will ask that, other than undertaking the home-based resistance exercise programme, you continue with your usual lifestyle and do not to increase your levels of other aspects physical activity during the period of the study. After the study period, participants in the control group will be offered the opportunity to undergo the exercise intervention.

What are the possible disadvantages and risks of taking part?

Exercise has a very small risk in healthy adults, although exercise at maximal capacity could carry a very small risk of inducing myocardial ischaemia (“heart attack”). The screening procedure helps to minimise that risk. The primary symptom of myocardial ischaemia is chest pain on exertion. If you experience any unusual sensations in your

chest, feel unwell or do not want to continue for any other reason during exercise you should cease exercising immediately.

You may also feel some muscle soreness after the muscle strength and endurance measurements and after the first few sessions of exercise training programme.

What are the possible benefits of taking part?
This study will help increase understanding about the minimum amount of resistance exercise needed to increase muscular strength and endurance. The information gained during the study will allow us to give you feedback about your own muscle strength and endurance and body composition.

Will my taking part in this study be kept confidential?
All information which is collected about you, or responses that you provide, during the course of the research, will be kept strictly confidential. You will be identified by an ID number, and any information about you will have your name and address removed so that you cannot be recognised from it. Any data in paper form will be stored in locked cabinets in rooms with restricted access at the University of Glasgow. All data in electronic format will be stored on secure password–protected computers. No one outside of the research team or appropriate governance staff will be able to find out your name, or any other information which could identify you.

What will happen to my data?
Researchers from the University of Glasgow collect, store and process all personal information in accordance with the General Data Protection Regulation (2018). If you withdraw from the study, your data that has been collected at to that point will be retained and used by the researchers. The data will be stored in archiving facilities in line with the University of Glasgow retention policy of up to 10 years. After this period, further retention may be agreed or your data will be securely destroyed in accordance with the relevant standard procedures.

What will happen to the results of the research study?
The results will be coded (for anonymity) and analysed by the research team before being reported in research reports. The results will form part of María Fernanda Gabler's PhD thesis and Meghan McLoone's MSc dissertation project. Associated papers, presentations, and posters will be made of the findings. In addition, the results may be published in a peer-reviewed scientific journal, however, you will not be identified by name in any publications. You will be informed about the results of the study and a copy of the published results will be sent to you upon request by the research team.

Who is organising and funding the research?
The work is organised by the Prof Jason Gill, Dr Stuart Gray, Ms María Fernanda Gabler and Ms Meghan McLoone in the Institute of Cardiovascular and Medical Sciences in the University of Glasgow. The work is funded by a PhD Scholarship to Ms Gabler from Beca Chile CONICYT.

Who has reviewed the study?
To protect your safety, rights, wellbeing and dignity, all research by the University of Glasgow is looked at by an independent group of people. This study has been reviewed

and approved by the College of Medical Veterinary and Life Sciences Ethics Committee at the University of Glasgow.

Contact for Further Information
Any questions about the procedures used in this study are encouraged. If you have any doubts or questions, please ask for further explanations by contacting one of the investigators below:

Maria Fernanda Gabler Trisotti
Email: m.gabler-trisotti.1@research.gla.ac.uk
Tel: 0141 3307615

Professor Jason Gill
Email: jason.gill@glasgow.ac.uk
Tel: 0141 3302916

Independent Contact information:

Carlos Celis-Morales
Email: carlos.celis@glasgow.ac.uk
Tel: 0141 330 4201

Thank you for reading the Participant Information Sheet.

Appendix F: Health questionnaire ONE Study

University of Glasgow

The ONE Study Health Questionnaire

Participant Name:

Date of birth:

Date:

It is important that volunteers participating in research studies are currently in good health and have had no significant medical problems in the past. This is to ensure (i) their own continuing well-being and (ii) to avoid the possibility of individual health issues confounding study outcomes.

Please complete this brief questionnaire to confirm fitness to participate:

1. At present, do you have any health problem for which you are:

(a) on medication, prescribed or otherwise	yes [ ]	no [ ]
(b) attending your general practitioner	yes [ ]	no [ ]
(c) on a hospital waiting list	yes [ ]	no [ ]

3. **Have** you ever had any of the following symptoms to a significant degree ***at rest or during exercise***? That is, have you had to consult a physician relating to any of the following?

	Rest	*Exercise*
Breathlessness	NO / YES	NO / YES
Chest Pain	NO / YES	NO / YES
Dizzy Fits/Fainting	NO / YES	NO / YES
Heart Murmurs	NO / YES	NO / YES
Palpitations	NO / YES	NO / YES
Tightness in chest, jaw or arm	NO / YES	NO / YES
Other*	NO / YES	

*(*Please specify*) ……

Muscle or joint injury:
Do you have/or have had any muscle or joint injury which could affect your safety in performing exercise ***(e.g. cycling or running),*** strength testing or strength training?
NO/YES

4**.** **Have you ever** had any of the following:

(a) Convulsions/epilepsy	yes [ ]	no [ ]
(b) Asthma	yes [ ]	no [ ]
(c) Eczema	yes [ ]	no [ ]
(d) Diabetes	yes [ ]	no [ ]
(e) A blood disorder	yes [ ]	no [ ]
(g) Digestive problems	yes [ ]	no [ ]
(h) Hearing problems	yes [ ]	no [ ]
(i) Disturbance of balance/co-ordination	yes [ ]	no [ ]
(j) Numbness in hands or feet	yes [ ]	no [ ]
(k) Disturbance of vision	yes [ ]	no [ ]
(l) Thyroid problems	yes [ ]	no [ ]
(m) Kidney or liver problems	yes [ ]	no [ ]
(n) Heart problems	yes [ ]	no [ ]
(o) Any other health problems	yes [ ]	no [ ]

5. **Have any of your family (parents, grandparents, brothers, sisters, children, aunts, uncles, cousins)** ever had any of the following: (if yes please give details including age of first diagnosis)

(a) Any heart problems	yes [ ]	no [ ]
(b) Diabetes	yes [ ]	no [ ]
(c) Stroke	yes [ ]	no [ ]
(d) Any other family illnesses	yes [ ]	no [ ]

If YES to any question, please describe briefly, including listing of current medication (e.g. to confirm whether problem was short-lived, insignificant or well controlled.) (Use a separate sheet if necessary)

……

……

……

……

Signature: _____ Date: _____

Appendix G: International Physical Activity Questionnaire (IPAQ)

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** and **moderate** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal.

PART 1: JOB-RELATED PHYSICAL ACTIVITY

The first section is about your work. This includes paid jobs, farming, volunteer work, course work, and any other unpaid work that you did outside your home. Do not include unpaid work you might do around your home, like housework, yard work, general maintenance, and caring for your family. These are asked in Part 3.

1. Do you currently have a job or do any unpaid work outside your home?

   ☐ Yes

   ☐ No → ***Skip to PART 2: TRANSPORTATION***

The next questions are about all the physical activity you did in the **last 7 days** as part of your paid or unpaid work. This does not include traveling to and from work.

2. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, heavy construction, or climbing up stairs **as part of your work**? Think about only those physical activities that you did for at least 10 minutes at a time.

   _____ **days per week**

   ☐ No vigorous job-related physical activity → ***Skip to question 4***

3. How much time did you usually spend on one of those days doing **vigorous** physical activities as part of your work?

   _____ **hours per day**
   _____ **minutes per day**

4. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads **as part of your work**? Please do not include walking.

   _____ **days per week**

   ☐ No moderate job-related physical activity → ***Skip to question 6***

5. How much time did you usually spend on one of those days doing **moderate** physical activities as part of your work?

_____ **hours per day**
_____ **minutes per day**

6. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **as part of your work**? Please do not count any walking you did to travel to or from work.

_____ **days per week**

☐ No job-related walking → ***Skip to PART 2: TRANSPORTATION***

7. How much time did you usually spend on one of those days **walking** as part of your work?

_____ **hours per day**
_____ **minutes per day**

PART 2: TRANSPORTATION PHYSICAL ACTIVITY

These questions are about how you traveled from place to place, including to places like work, stores, movies, and so on.

8. During the **last 7 days**, on how many days did you **travel in a motor vehicle** like a train, bus, car, or tram?

_____ **days per week**

☐ No traveling in a motor vehicle → ***Skip to question 10***

9. How much time did you usually spend on one of those days **traveling** in a train, bus, car, tram, or other kind of motor vehicle?

_____ **hours per day**
_____ **minutes per day**

Now think only about the **bicycling** and **walking** you might have done to travel to and from work, to do errands, or to go from place to place.

10. During the **last 7 days**, on how many days did you **bicycle** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐ No bicycling from place to place → ***Skip to question 12***

11. How much time did you usually spend on one of those days to **bicycle** from place to place?

_____ **hours per day**
_____ **minutes per day**

12. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐ No walking from place to place → ***Skip to PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY***

13. How much time did you usually spend on one of those days **walking** from place to place?

_____ **hours per day**
_____ **minutes per day**

PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY

This section is about some of the physical activities you might have done in the **last 7 days** in and around your home, like housework, gardening, yard work, general maintenance work, and caring for your family.

14. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, chopping wood, shoveling snow, or digging **in the garden or yard**?

_____ **days per week**

☐ No vigorous activity in garden or yard → ***Skip to question 16***

15. How much time did you usually spend on one of those days doing **vigorous** physical activities in the garden or yard?

_____ **hours per day**
_____ **minutes per day**

16. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, sweeping, washing windows, and raking **in the garden or yard**?

_____ **days per week**

☐ No moderate activity in garden or yard → ***Skip to question 18***

17. How much time did you usually spend on one of those days doing **moderate** physical activities in the garden or yard?

_____ **hours per day**
_____ **minutes per day**

18. Once again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, washing windows, scrubbing floors and sweeping **inside your home**?

_____ **days per week**

☐ No moderate activity inside home → ***Skip to PART 4: RECREATION, SPORT AND LEISURE-TIME PHYSICAL ACTIVITY***

19. How much time did you usually spend on one of those days doing **moderate** physical activities inside your home?

_____ **hours per day**
_____ **minutes per day**

PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY

This section is about all the physical activities that you did in the **last 7 days** solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned.

20. Not counting any walking you have already mentioned, during the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **in your leisure time**?

_____ **days per week**

☐ No walking in leisure time → ***Skip to question 22***

21. How much time did you usually spend on one of those days **walking** in your leisure time?

_____ **hours per day**
_____ **minutes per day**

22. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like aerobics, running, fast bicycling, or fast swimming **in your leisure time**?

_____ **days per week**

☐ No vigorous activity in leisure time → ***Skip to question 24***

23. How much time did you usually spend on one of those days doing **vigorous** physical activities in your leisure time?

_____ **hours per day**
_____ **minutes per day**

24. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like bicycling at a regular pace, swimming at a regular pace, and doubles tennis **in your leisure time**?

_____ **days per week**

☐ No moderate activity in leisure time → ***Skip to PART 5: TIME SPENT SITTING***

25. How much time did you usually spend on one of those days doing **moderate** physical activities in your leisure time?
_____ **hours per day**
_____ **minutes per day**

PART 5: TIME SPENT SITTING

The last questions are about the time you spend sitting while at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television. Do not include any time spent sitting in a motor vehicle that you have already told me about.

26. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekday**?

_____ **hours per day**
_____ **minutes per day**

27. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekend day**?

_____ **hours per day**
_____ **minutes per day**

This is the end of the questionnaire, thank you for participating.

Appendix H: Exercise Diary

Visits

1. **Screening:** Date: _____

   Completed: ☐ YES ☐NO

2. **Baseline measurements:** Date: _____

   Completed: ☐ YES ☐NO

3. **Exercise Session Demonstration:** Date: _____

   Completed: ☐ YES ☐NO

4. **Week 4 measurements:** Date: _____

   Completed: ☐ YES ☐NO

5. **Week 8 measurements:** Date: _____

   Completed: ☐ YES ☐NO

6. **Post intervention measurements:** Date: _____

   Completed: ☐ YES ☐NO

University of Glasgow

Exercise Diary

ID: _____

Instructions:

1. There are **6 exercises** in total: **press-ups, squats, upright row, squat jumps, seated row and plank.**
2. Do as **many repetitions as you can** for **1 minute**. For the **"plank",** aim to **maintain** the position for **1 minute**, if it is not possible maintain it as long as you can.
3. For "**upright row**" and "**seated row**" you will need a **resistance elastic band**, which will be given to you.
4. You can do the exercises in any **order** you want
5. You have **one rest day per week**, in which you do not need to exercise. We suggest that you take the last day of the week, but you can choose any day you wish.
6. Please **record the number of repetitions** you were able to do for each exercise each day. For the **"Plank"** please **record the amount of time (in seconds)** you were able to maintain it.

The following table shows an **example** on how to **record** the exercise sessions:

Week	**Day 1**		**Day 2**		**Day 3**	
Example	Date	20/05/19	Date	21/05/19	Date	22/05/19
	Exercise	Press-up	Exercise	Squat	Exercise	Plank
	Reps	15	Reps	20	Seconds	30

Exercise Examples

Squats

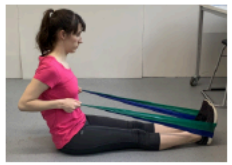

①


②

a. Feet shoulder width apart.
b. Drive through the heels and squeeze glutes when standing tall.
c. Inhale on the way down, exhale while driving up.

Seated Row


①


②

a. Begin in seated position, keep core tight. Grasp band with palms facing in.
b. Pull band into stomach
c. Squeeze shoulder blades back and pause.
d. Slowly return to starting position.

Press Up


①


②

a. Position on the floor on all fours (feet or knees) with hands slightly wider than shoulder width.
b. Maintain on all fours, place hips forwards so most of the weight is on the hands.
c. Bend elbows down and lower chest towards the floor.
d. Keep your body straight while going down.
e. Push back to beginning position.

Week	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6	
1	Date		Date		Date		Date		Date		Date	
	Exercise		Exercise		Exercise		Exercise		Exercise		Exercise	
	Reps		Reps		Reps		Reps		Reps		Reps	
2	Date		Date		Date		Date		Date		Date	
	Exercise		Exercise		Exercise		Exercise		Exercise		Exercise	
	Reps		Reps		Reps		Reps		Reps		Reps	
3	Date		Date		Date		Date		Date		Date	
	Exercise		Exercise		Exercise		Exercise		Exercise		Exercise	
	Reps		Reps		Reps		Reps		Reps		Reps	
4	Date		Date		Date		Date		Date		Date	
	Exercise		Exercise		Exercise		Exercise		Exercise		Exercise	
	Reps		Reps		Reps		Reps		Reps		Reps	
5	Date		Date		Date		Date		Date		Date	
	Exercise		Exercise		Exercise		Exercise		Exercise		Exercise	
	Reps		Reps		Reps		Reps		Reps		Reps	
6	Date		Date		Date		Date		Date		Date	
	Exercise		Exercise		Exercise		Exercise		Exercise		Exercise	
	Reps		Reps		Reps		Reps		Reps		Reps	
7	Date		Date		Date		Date		Date		Date	
	Exercise		Exercise		Exercise		Exercise		Exercise		Exercise	
	Reps		Reps		Reps		Reps		Reps		Reps	
8	Date		Date		Date		Date		Date		Date	
	Exercise		Exercise		Exercise		Exercise		Exercise		Exercise	
	Reps		Reps		Reps		Reps		Reps		Reps	
9	Date		Date		Date		Date		Date		Date	
	Exercise		Exercise		Exercise		Exercise		Exercise		Exercise	
	Reps		Reps		Reps		Reps		Reps		Reps	
10	Date		Date		Date		Date		Date		Date	
	Exercise		Exercise		Exercise		Exercise		Exercise		Exercise	
	Reps		Reps		Reps		Reps		Reps		Reps	
11	Date		Date		Date		Date		Date		Date	
	Exercise		Exercise		Exercise		Exercise		Exercise		Exercise	
	Reps		Reps		Reps		Reps		Reps		Reps	
12	Date		Date		Date		Date		Date		Date	
	Exercise		Exercise		Exercise		Exercise		Exercise		Exercise	
	Reps		Reps		Reps		Reps		Reps		Reps	

Plank

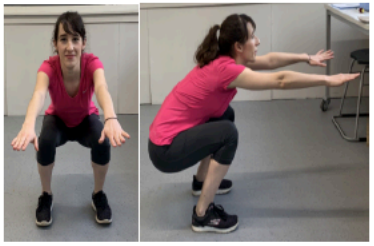
a. Begin in press up position, put forearms into the ground instead of hands.
b. Keep core tight and squeeze the glutes.
c. Keep a neutral neck and spine.

Upright Row


① ②

a. Stand upright with feet shoulder width apart and slight bend in the knees
b. Hold bands and pull up towards chest
c. Slowly return to starting position.

Squat Jump




① ②

a. Start with feet shoulder width apart.
b. Begin with doing a regular squat, then engage care and jump up.
c. Land with soft knees back into the squat.

Appendix I: Topic Guide Interviews

ONE Study Interviews Indicative Topic Guide

Please note the questions will be finalised after piloting.
After checking that the participant is still happy to take part in the study and has no further questions, ask them to sign the consent form. Then start the interview.

Participation in the ONE study

1. Please can you tell me why you took part in the ONE study
2. What did you think of the exercises you were asked to do?
3. Talk me through how you did the exercises – prompt which did you do each day? Did this change over the period of the study?
4. What helped you to do the exercises? What got in the way of your doing them?
5. Which exercises did you find easy to do – why? Which did you find more difficult to do – why?
6. We want to understand how people managed to fit the exercises into their everyday life. Can you show me how/where you did each one (get the participant to talk about the exercise and how they are finding it as they do each one).

After they have finished demonstrating the exercises:

Impact of programme

1. What changes have you noticed in yourself as a result of doing the programme? (prompt for both positive and negative changes)

Optimising the programme

1. What would you say was good about the programme? What was not so good?
2. We know this was not the perfect version of the programme – what changes would you suggest we should make for next time?

Future recruitment

1. How would you describe the programme if you were telling other people about it?
2. Who do you think it would appeal too, if we wanted to get more people involved?

Appendix J: Code book Thematic analysis

ONE Study Qualitative Interviews themes definitions

1. **PA before the study:** Anything the participants say about the PA they did before the study.

2. **Reasons for joining study:** Anything that motivated the participants to participate in the study, including expectations of what it would involve, what they would achieve from it.

3. **Instruction and learning:** participants' perceptions of regarding the instructions received from the research team regarding the exercises, the resistance bands, exercise diary (including videos). Including how they learned how to do the exercises (video, mirror, experiential learning, previous experience).

4. **Programme of daily life and planning:** Participants' descriptions of how they do the exercises into their daily life (including clothes, shoes, exercise mat, bands) and any planning they do (morning, afternoon, place in which do the exercise etc).

5. **Perceptions of the programme:** Participants opinions, feelings and ideas regarding the study exercise programme.

6. **Self-monitoring:** Everything related to the devices monitoring their self-presentations including the exercise diary/phone/timer and how participants monitored their performance during the study programme.

7. **Impact of the programme:** Participants' references to the results they have experienced from taking part in the exercise programme, including physical, mental and behavioural changes.

8. **Motivators for PA:** Beliefs, perceptions, knowledge and anything that motivates the participants to perform physical activity.

9. **Barriers and facilitators:** Anything that: a) stops or is an impediment to, or b) eases, helps, simplifies and promotes the participants to perform physical activity.

10. **Health:** Anything participants say about their health.

11. **Suggestions for the programme:** Participants suggestions to improve/change the programme or adapt it for other populations.

12. **'Selling the programme':** Participants' description of the programme for other potential participants.

13. **Other:** Anything that seems relevant but does not seem to belong to 1-12.

Appendix K: REFLEX approved proposal

University of Glasgow | College of Medical, Veterinary & Life Sciences

College of Medical, Veterinary & Life Sciences Ethics Committee for Non-Clinical Research Involving Human Participants

APPLICATION FORM FOR ETHICAL APPROVAL

NOTES:
THIS APPLICATION FORM SHOULD BE TYPED NOT HAND WRITTEN.

ALL QUESTIONS MUST BE ANSWERED. "NOT APPLICABLE" IS A SATISFACTORY ANSWER WHERE APPROPRIATE.

The primary remit of this committee is the review of non-clinical research. However, clinical research involving humans, their tissue or data that falls outwith the remit of the NHS Research Ethics Service will also be reviewed by the MVLS committee. If your project involves NHS facilities, or is clinical research, then you must ensure that NHS REC review is not needed before applying to the MVLS REC. The review of the MVLS REC does not obviate the need for NHS review.

Please note – it is now a requirement for a Data Protection Impact Assessment (DPIA) to be completed where processes are likely to involve high-risk personal data. This is likely to be the case for many research projects. If so, you must complete this before submission for ethical review. For research involving personal data, you should give participants a Privacy Notice as well as a Participant Information sheet.

Information on DPIAs and Privacy Notices
https://www.gla.ac.uk/myglasgow/dpfoioffice/gdpr/dpia/
https://www.gla.ac.uk/myglasgow/dpfoioffice/gdpr/privacy%20notices/

Information on the General Data Protection Regulation (GDPR)
https://www.gla.ac.uk/myglasgow/dpfoioffice/

Information on Research Data Management
https://www.gla.ac.uk/myglasgow/datamanagement/

University of Glasgow policy on surveys of students for research purposes
https://www.gla.ac.uk/myglasgow/senateoffice/policies/studentengagement/studentsurveys/policyonstudentsurveys/

Project Title:

Effect of a home-based REsistance exercise vs a home-based FLEXbility exercise programme on muscular endurance and flexibility in healthy adults (REFLEX).

Has this application been previously submitted to this or any other ethics committee? No

If 'Yes', please state the title and reference number.

Is this project from a commercial source, or funded by a research grant of any kind?
No

If 'Yes', has it been referred to Research Support Office?
Has it been allocated a project Number?
Give details and ensure that this is stated on the Informed Consent Form.

Insurance Coverage and Restrictions:
Please Note: The Insurance restrictions set out below relate to research of a clinical nature. Non clinical research is not subject to restriction and no additional insurance is required

The University insurance cover is restricted under specific circumstances, including, but not limited to the following -

- **work involving the use of research participants outside Great Britain, Northern Ireland, the Channel Islands or the Isle of Man**
- **the use of hazardous materials**
- **non CE marked medical devices**
- **molecules or compounds developed and manufactured at the University of Glasgow**
- **number of participants in excess of 5000**
- **work involving research participants known to be pregnant at the time of the project**

All such projects must be referred to Research Support Office and coverage confirmed before ethical approval is sought. Please contact Dr Debra Stuart in the University's Research Governance Office: debra.stuart@glasgow.ac.uk

Please tick here if this project has been referred to the Research Support Office to confirm adequate insurance coverage.

Please tick here if the project includes a technique involving incision, piercing of skin, insertion of a device or object, ingestion of medicines or food substances. ☐

Please tick here if the project involves work on human participants that will be conducted within the Imaging Centre of Excellence (ICE) ☐

Date of submission:
20 July 2020

Name of all person(s) submitting research proposal:
Professor Jason Gill
Dr Stuart Gray
Prof Cindy Gray
María Fernanda Gabler Trisotti
Ayan Merchant
Hesham Alfeheid
Phillip McBride

Position(s) held:

Professor of Cardiometabolic Health	JG
Lecturer in Exercise and Metabolic Health	SG
Interdisciplinary Professor of Health and Behaviour	CG
PhD Student Cardiovascular Sciences (Research)	MFG
PhD Student Cardiovascular Sciences (Research)	AM
PhD Student Cardiovascular Sciences (Research)	HA
PhD Student Health Science	PM

School/Group/Institute/Centre:
Institute of Cardiovascular and Medical Sciences (JG, SG, MFG, AM and HA)

Institute of Health and Wellbeing (CG)
University of Leicester (PM)

Address for correspondence relating to this submission:
BHF Glasgow Cardiovascular Research Centre, University of Glasgow, Institute of Cardiovascular and Medical Sciences, College of Medical, Veterinary and Life Sciences, Glasgow, G12 8TA

Email address: Jason.Gill@glasgow.ac.uk
Stuart.Gray@glasgow.ac.uk
…….. Cindy.Gray@glasgow.ac.uk
m.glabler-trisotti.1@research.gla.ac.uk
a.merchant.1@research.gla.ac.uk
h.alfeheid.1@research.gla.ac.uk
pm381@le.ac.uk

Name of Principal Researcher (if different from above, e.g., Student's Supervisor):
Jason Gill

Position held:
Professor of Cardiometabolic Health

Undergraduate student project:
No If 'Yes', please state degree being undertaken:

Postgraduate student project:
Yes If 'Yes', please state degree being undertaken:

PhD Cardiovascular Sciences (Research)

For postgraduate student projects, please state whether this a research (PGR) or taught (PGT) degree:

PGR

1. Describe the purposes of the research proposed. Please include the background and scientific justification for the research. Why is this an area of importance? Please try to describe why the research is novel and experimental.

We do not need a comprehensive review of the topic area: a short summary that is sufficient for the reviewers to understand the study is sufficient. Bullet points and references to more detailed texts are both acceptable.

Studies have shown that regular resistance training can lead to a variety of health benefits including increases in muscle size and strength, reductions on body fat, increased metabolic rate, glycaemic control, decreased blood pressure and improved blood lipid profiles (1–3). Because of this, national and international physical activity guidelines recommend undertaking muscle strengthening activities involving major muscle groups two days a week or more, alongside at least 150 minutes per week of moderate intensity physical activity (or 75 minutes per week of vigorous intensity physical activity)(4,5). However, in the UK, while about two-thirds of men and almost three-fifths of women over met the guidelines for aerobic exercise, less than a third of men and a quarter of women achieve the guidelines for muscle-strengthening exercise in 2016 (6,7).

Why participation in muscle-strengthening exercise is low is not clear but people identify several barriers including the lack of time (8,9), the effort involved (8,9), lack of purpose, pain due to injury, negative experiences of prescriptive exercise, apathy (10), illness, injury inclement weather and work commitment (11). In addition, some women have expressed a worry of looking 'manly' or 'bulking up' if they undertake resistance exercise (12). A further potential barrier is lack of access to a gym with appropriate equipment to perform resistance exercise, or dislike of a gym setting. Thus, identifying approaches to find a safe, enjoyable and accessible programme that minimises the burden of performing resistance exercise, and identifying a minimal amount of resistance training which can provide benefits is a key issue which could help more people to undertake muscle strengthening exercises.

The dose-response relationship between volume of resistance exercise and gains in muscle size and strength recommended by the ACSM for optimal benefits is two to three times per week. However, the largest gains are seen between undertaking zero and one session per week, with decreasing gains beyond this (13). Substantial increases in strength (~20%) have been observed with a single session of exercise per week if it is performed to momentary failure; in this context, the specific load does not appear to influence the magnitude of the adaptations (14). Furthermore, it has been found that the frequency of resistance exercise does not influence the magnitude of change in strength or hypertrophy if the volume of exercise (sets per week) is equated (15,16).
Thus, a single set of exercise per muscle group per week appears to be an effective dose for adaptation, and programmes using this approach could potentially address the barrier of a lack of time. However this in itself, does not necessarily help overcome the need for access to a gym facility with strength training equipment. Developing protocols that can be performed at home may help with this. Most of the evidence in the literature for home-based resistance exercise comes from studies in older (>65 years) adults (17) but there is limited evidence in younger (18-64 years) volunteers.

One approach to overcome barriers of daily time commitment and access to specialised facilities/equipment is to carry out a resistance exercise programme with low time commitment and performed at home with minimal equipment. This may be a more convenient way to undertake resistance exercise and improve long term adherence. We first attempted to study in this in our ongoing ONE study (MVLS ethics approval number 200180137). Preliminary quantitative data of the ONE Study (with n =17 completed out target n of 54) shows that one minute of resistance exercise per day produces a trend increase in muscle endurance after 12 weeks. Preliminary qualitative data shows that participants enjoyed the programme, but would prefer to have more flexibility in how the exercises were distributed throughout the week, a greater choice of exercises, and the potential to undertake more than this minimum prescription. The current study aims to extend the ONE study in light of these qualitative insights, and to deliver the intervention completely online (via an app), given current social distancing restrictions. This will also help trial the online delivery platform for future widescale implementation. We plan to deliver this as a randomised control trial (RCT) with a comparison group undertaking a flexibility exercise programme (which would be expected to improve flexibility but not muscular endurance).

The main aim of this study is to compare the effects of an app-based home-based resistance exercise programme vs a home-based flexibility programme on muscular endurance (number of press-ups, bodyweight squats and crunches achieved, assessed online during a zoom call) and flexibility (sit and reach, assessed online during a zoom call) in healthy adults. Secondary aims are a) to determine participants' adherence to both exercise programmes, b) to determine participants' choice of weekly exercise volume (compared to minimum prescription) in both exercise programmes c) to determine participants' distribution of exercise throughout the week in both exercise programmes d) to determine the effects of a exercise programmes on well-being, and finally e) to determine participants' perceptions, feelings, thoughts, enjoyment, tolerance and acceptability of both exercise programmes.

This study is being undertaken in collaboration with BBC Scotland for a programme called "The Truth About Getting Fit at Home" and a subset of participants will feature on the programme.

1. Saric J, Lisica D, Orlic I, Grgic J, Krieger JW, Vuk S, et al. Resistance Training Frequencies of 3 and 6 Times Per Week Produce Similar Muscular Adaptations in Resistance-Trained Men. J Strength Cond Res [Internet]. 2018 Oct;1. Available from: https://journals.lww.com/nsca-jscr/Fulltext/publishahead/Resistance_Training_Frequencies_of_3_and_6_Times.95086.aspx
2. Kraemer WJ, Ratamess NA, French DN. Resistance training for health and performance. Curr Sports Med Rep [Internet]. 2002;1(3):165–71. Available from: https://doi.org/10.1007/s11932-002-0017-7
3. Ashton RE, Tew GA, Aning JJ, Gilbert SE, Lewis L, Saxton JM. Effects of short-term, medium-term and long-term resistance exercise training on cardiometabolic health outcomes in adults: Systematic review with meta-analysis. Br J Sports Med. 2020;54(6):341–8.
4. World Health Organization. Global Recommendations on Physical Activity for Health [Internet]. 2011 [cited 2019 Mar 28]. p. 1. Available from: https://www.who.int/dietphysicalactivity/physical-activity-recommendations-18-

64years.pdf?ua=1
5. PCSFN. Physical Activity Guidelines for Americans [Internet]. 2019 [cited 2020 Jul 3]. Available from: https://www.hhs.gov/fitness/be-active/physical-activity-guidelines-for-americans/index.html#:~:text=For substantial health benefits%2C adults,or an equivalent combination of
6. Scholes S. Health Survey for England 2016 Physical activity in adults [Internet]. 2017. 20 p. Available from: https://files.digital.nhs.uk/publication/m/3/hse16-adult-phy-act.pdf
7. Bromley C, Dowling S, Gray L, Hinchliffe S, Hughes T, Leyland A, et al. The Scottish Health Survey [Internet]. Vol. 1, The Scottish Health Survey. 2012. Available from: www.scotland.gov.uk
8. Hurley KS, Flippin KJ, Blom LC, Bolin JE, Hoover DL, Judge LW. Practices, Perceived Benefits, and Barriers to Resistance Training Among Women Enrolled in College. Int J Exerc Sci [Internet]. 2018;11(5):226–38. Available from: http://www.ncbi.nlm.nih.gov/pubmed/29795737%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC5955292
9. Trost SG, Owen N, Bauman AE, Sallis JF, Brown W. Correlates of adults' participation in physical activity: review and update. Med Sci Sport Exerc. 2002;34(12):1996–2001.
10. Hancox JE, Van Der Wardt V, Pollock K, Booth V, Vedhara K, Harwood RH. Factors influencing adherence to home-based strength and balance exercises among older adults with mild cognitive impairment and early dementia: Promoting activity, independence and stability in early dementia (praised). PLoS One. 2019;14(5):1–19.
11. Tulloch H, Sweet SN, Fortier M, Capstick G, Kenny GP, Sigal RJ. Exercise facilitators and barriers from adoption to maintenance in the diabetes aerobic and resistance exercise trial. Can J Diabetes [Internet]. 2013;37(6):367–74. Available from: http://dx.doi.org/10.1016/j.jcjd.2013.09.002
12. Dworkin SL. A woman's place is in the ... cardiovascular room?? Gender relations, the body, and the gym. In: Athletic intruders: ethnographic research on women, culture and exercise. Albany: State University of New York Press; 2003. p. 131–58.
13. Westcott W. ACSM STRENGTH TRAINING GUIDELINES. ACSMs Health Fit J [Internet]. 2009 Jul;13(4):14–22. Available from: http://insights.ovid.com/crossref?an=00135124-200907000-00007
14. Ismail AD, Aba Alkhayl FF, Wilson J, Johnston L, Gill JMR, Gray SR. The effect of short duration resistance training on insulin sensitivity and muscle adaptations in overweight men. Exp Physiol [Internet]. 2019;(October 2018):2–7. Available from: http://doi.wiley.com/10.1113/EP087435
15. Gentil P, Bottaro M, Giessing J, Steele J, Fisher J, Campos MH, et al. Effects of equal-volume resistance training with different training frequencies in muscle size and strength in trained men. PeerJ. 2018;6:e5020.
16. Grgic J, Schoenfeld BJ, Davies TB, Lazinica B, Krieger JW, Pedisic Z. Effect of Resistance Training Frequency on Gains in Muscular Strength: A Systematic Review and Meta-Analysis. Sport Med [Internet]. 2018;48(5):1207–20. Available from: https://doi.org/10.1007/s40279-018-0872-x
17. Kis O, Buch A, Stern N, Moran DS. Minimally supervised home-based resistance training and muscle function in older adults: A meta-analysis. Arch Gerontol Geriatr [Internet]. 2019;84(March):103909. Available from: https://doi.org/10.1016/j.archger.2019.103909
18. ACSM. ACSM's Guidelines for Exercise Testing and Prescrption. 10th Editi. Wolters Kluwer; 2016.

19. Radaelli R, Fleck SJ, Leite T, Leite RD, Pinto RS, Fernandes L, et al. Dose-Response of 1, 3, and 5 Sets of Resistance Exercise on Strength, Local Muscular Endurance, and Hypertrophy. J Strength Cond Res [Internet]. 2015;29(5). Available from: https://journals.lww.com/nsca-jscr/Fulltext/2015/05000/Dose_Response_of_1,_3,_and_5_Sets_of_Resistance.25.aspx
20. Ritchie J, Lewis J, McNaughton Nicolls C, Ormston R, editors. Qualitative Research Practice: A Guide for Social Science Students and Researchers. 2014th ed. Sage; 2003.

2. Describe the design of the study and methods to be used. If multiple methods are to be used, please describe them each in turn. Include details of the study sample size and how you decided this. Statistical advice should be obtained if in doubt.

The study design is an RCT with two groups, a flexibility exercise group (which will be the comparison group), and a resistance exercise group. Mixed methods will be used.
Participants will be male and female, aged between 18-64 years old, who perform ≤ 30 min a week of aerobic vigorous physical activity (compendium of physical activities) and do not to perform any kind of resistance exercise. Exclusion criteria will include failure of the Physical Activity Readiness Questionnaire Plus (PAR-Q+), performing 30 minutes or more of vigorous intensity exercise from the IPAQ, having a job that compromises manual labour, a history of cardiovascular disease, diabetes and any other illness that would prevent the participation in a resistance exercise or flexibility exercise programme.
After screening, participants will undergo baseline measurements (online), and after that they will be randomised into two conditions: a flexibility exercise group (comparison group) and a resistance exercise group. Participants will then undertake a 12-week flexibility or resistance exercise intervention. Baseline measurements will be repeated after 6 and 12 weeks. Assessments will include muscle endurance, adherence, quality of life and participants perceptions, feelings and thoughts of the intervention.

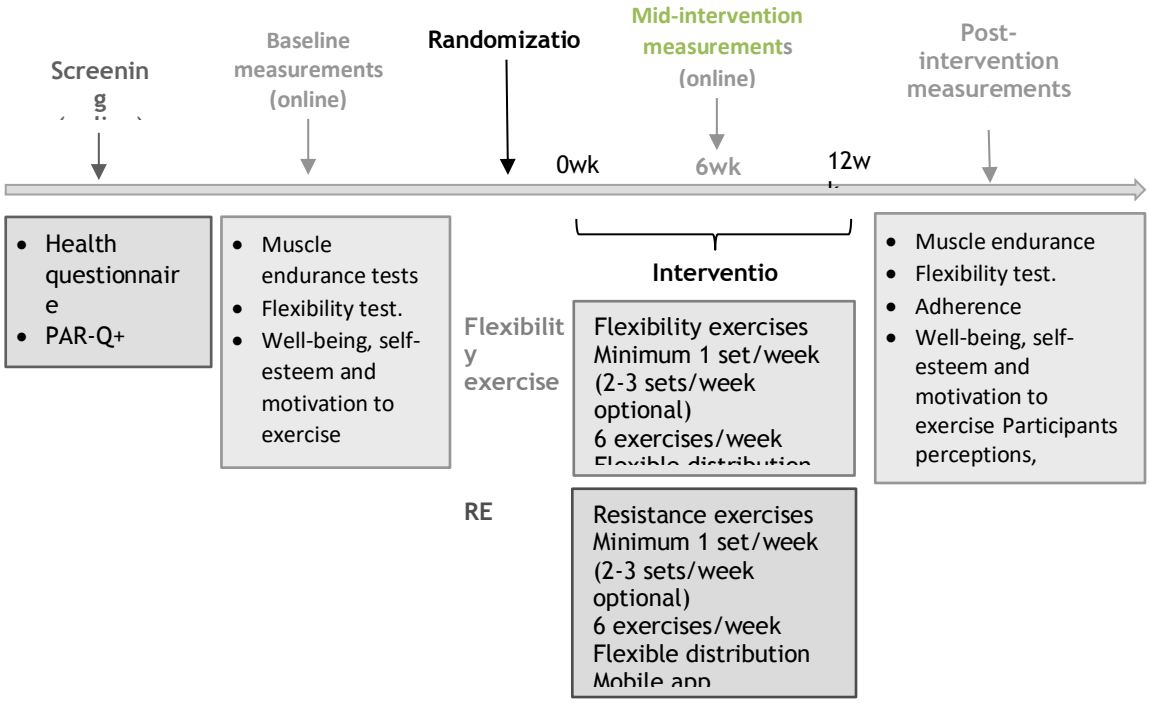


Figure 1. Overview of study protocol.

Assessments

V. Screening measurements (appendix 1):

7) Health questionnaire:

(undertaken at 1 time-point; screening)

Participants will be asked to fill a health questionnaire to determine if they are suitable to participate in the study.

8) PAR-Q+:

(undertaken at 1 time-point; screening)

Participants will be asked to fill the Physical Activity Readiness Questionnaire Plus to determine their safety to undertake physical activity.

9) IPAQ-SF:

Participants will be asked to fill the International Physical Activity Questionnaire (short form) to determine their level of physical activity. We will ask an additional question to determine if participants are participating in any resistance exercise.

VI. Baseline, 6 weeks and post-intervention measurements:

1) Muscle endurance:

(undertaken at 0, 6-weeks and 12 weeks)

Muscular endurance with be measured at baseline, 6 weeks and 12 weeks. Three measured will be used: i) maximum number of press-ups (on feet for men, on knees for women) in time with a metronome @ 40 reps per min; ii) maximum number of bodyweight squats (@ 40 squats per min) ; iii) maximum number of crunches (@ 20 reps per min). All tests will measure maximum number of repetitions until exhaustion (fatigue). Number of press-ups will be the primary outcome, the other measures will be secondary outcomes. The measurement will be via zoom, with the participant and research team member blinded to the intervention group on each end of the videocall.

2) Flexibility

(undertaken at 0, 6-weeks and 12 weeks)

Flexibility will be assessed via a sit-and-reach test, via zoom at baseline, 6 and 12 weeks. This will be a secondary outcome.

3) Adherence:

Participants will record all of their exercise sessions as they complete them using an online app. Adherence will be assessed at 12 weeks from the in-app data using the following outcomes:

- Percentage of the minimum number of exercise sets prescribed undertaken.
- Percentage of participants that drop-out from the study. Drop out considered as: a) participants who no longer record their exercises on the app, but complete the outcome measurements; and b) participants who neither record their exercises nor complete the outcome measurements.

4) Choice of exercise volume and progression (as assessed at 12 weeks from the in-app data)**:**

- Number of sets of exercise undertaken relative to minimum prescribed dose during each week of the intervention.

5) Choice of distribution of exercise throughout the week (as assessed at 12 weeks from the in-app data)**:**

- Distribution of participants undertaking their exercise different numbers of days of week throughout the intervention period.

6) Well-being, self-esteem and motivation to exercise questionnaires
(undertaken at 0, 6 weeks and 12 weeks)

Well-being will be assessed using the Cantril Ladder, WEMWBS questionnaire and subjective vitality scale. Self-esteem will be assessed using Rosenberg's self-esteem questionnaire, and motivation to exercise will be assessed using the adapted Behavioural Regulations in Exercise Questionnaire (BREQ-2) questionnaire. The questionnaires will be delivered through the app.

7) Participants' perceptions, feelings, thoughts, enjoyment, tolerance and acceptability of a home-based resistance exercise programme
(after the intervention period)

Semi-structured online interviews (each lasting 30-60 minutes) will be conducted with a subset of participants in both exercise groups (n = 18-24 participants overall). The interviews will be conducted via Zoom or WhatsApp, both recently approved by the University for online data collection during the COVID 19 pandemic, and depending on people preferences. A topic guide will be used to guide discussions – indicative questions are provided in appendix 3.

Intervention

All participants will be asked to follow a 12-week home-based exercise programme. Participants will be asked to perform a minimum amount of resistance or flexibility exercise of 1 set/week for each of six exercises and will have the opportunity to increase their volume of exercise to 2 sets or 3 sets/week per exercise if it is their choice. In addition, participants will be able to distribute the exercises during the week according to their preference (all in one day or spread over several days of the week, etc.). Participants will be encouraged to have a minimum of one day of rest per week. If participants choose to increase to 2 or 3 sets/week some examples will be given to distribute the exercises throughout the week including:

a) Two or three sets of the same exercise per day with a minimum of one minute of rest between sets.

b) One set of two or three different exercises per day.

c) Four or six sets per day of 4 different or 3 different exercises (3 sessions a week) with 4 days of rest.

1) **Flexibility exercise group (FE [comparison] group).**

The flexibility exercise group will be asked to perform 6 flexibility exercises per week (2 different for legs, 1 shoulder and arms, 1 chest, 1 back and 1 core). Participants will be able to choose from a bank of flexibility of exercises to perform. Participants will perform passive static stretching exercises (appendix 4). They will be asked to stretch to the point of feeling tightness or slight discomfort, to hold the stretch for 30 seconds (each side), and repeat that twice (in total 60 seconds of stretching per side) according to the ACSM's guidelines for flexibility exercises (18).

2) **Resistance exercise intervention (RE group)**

Participants in the resistance exercise group will be asked to perform a total of 6 exercises per week (2 different leg exercises, 1 shoulder exercise, 1 chest exercise, 1 back exercise and 1 core exercise, Appendix 4). Participants will have the opportunity to choose the exercise they want to perform from a bank of exercises that will be provided. Each exercise will have several levels. At the beginning of the exercise programme, participants will be asked to choose a level in which they are able to perform between 6-20 repetitions. During each exercise session in the programme, they will be asked to complete as many repetitions as possible. If the participant is able to perform >20 repetitions, they will be able to progress to the next exercise level. For the plank, participants will progress to the next level of difficulty once they can maintain the posture for 60 seconds. Participants will receive a complete set of resistance bands (4 bands of different tensions) to perform the band exercises.

Video and written instructions for all exercises (flexibility and resistance) will be delivered via an app which will be free and only available for study participants. Participants will have access only to the bank of exercise for their intervention arm (i.e. flexibility or resistance). Participants will be asked to record each exercise session they perform during the 12-week exercise programme, recording type of exercise, level, number of repetitions or time (for plank exercises) achieved and Rating of Perceived Exertion on a scale of 1-10 (RPE). The app will send participants reminders about the exercise schedule and targets. Participants will also be able to access their own records in the app, and the investigators will be able to access all data inputted into the app via the 'back end'. For all data in the app, participants will be only identified by a study number and no identifiable personal information will be recorded.

Once the study period is over, all participants will have access to all exercises through the app (flexibility and resistance exercises) and the exercise diary. The data after the study period will not be collected and will not be used by the research team.

Sample size and power calculation

There are limited published data available evaluating the effects of resistance exercise on muscular endurance. A previous investigation has reported an 8.7 kg increase for muscle strength for bench press after a resistance exercise training, with a 9.9 kg SD for change in muscle strength (19); thus with power of 90% and an alpha of 0.05, groups of 29 participants will be needed. Considering 20% of drop out during the study, we propose to recruit 36 participants per group with a total of 72 participants. Preliminary data from 7 participants from the ONE Study showed a difference of 8.5 repetitions for press-up endurance (over primary outcome) pre to post-intervention with a SD of 7.06 in baseline press-up endurance. While this low n means that we are not confident to use these data in our power calculation, these data suggest that we would require 16 participants per group to detect this difference with 90% power and alpha 0.05. Our power calculation using muscular strength as the outcome is likely therefore to be conservative.

Data analysis

The primary outcome for the study will be change in number of press-ups from baseline to 12-weeks. Secondary outcomes will be change in number of press-ups from 0-6 weeks and 6-12 weeks; and changes in number of bodyweight squats, crunches, distance achieved in the sit-and-reach test and change in well-being between all timepoints. Differences between groups in these measures will be assessed by 2-way ANOVA (group x time) with repeated measures on the time factor. We will report descriptive data for adherence, volume and progression of exercise, and distribution of exercise throughout the week. A subset (likely n = ~10) of participants will feature on the BBC programme. We will perform sensitivity analyses to determine whether changes observed in these participants differed from the wider group.

Qualitative interviews data will be transcribed by an external company approved by the University of Glasgow (e.g. 1st Class Transcription Services). Anonymised transcripts will be analysed thematically using an adapted Framework approach (20) using NVivo 12 software to determine participants' perceptions, feelings, thoughts, enjoyment, tolerance and acceptability regarding both exercise programmes.

3. How will potential participants in the study be (i) identified, (ii) approached and (iii) recruited? Give details for cases and controls separately, if appropriate

You should explain how a person becomes identified as a potential participant and then an enrolled participant. If the initial approach uses a poster, social media or email then the materials should be submitted for review.

vii. **Identification:** Volunteers will be recruited via our study partners, the BBC, who will advertise the study online and via social media, and via the research team's personal contacts and snowballing. Interested parties will be directed to a weblink where they will input their level of physical activity and age. If participants do not meet initial inclusion criteria (i.e. age 18-64, <30 min/week vigorous physical activity, no resistance exercise), they will receive an automated message thanking them for their interest but saying they are not eligible. If they do meet these inclusion criteria, they will be asked to input their contact details.

viii. **Approach:** After an initial expression of interest and eligibility check, study volunteers will be approached by email or telephone, and they will be sent the PIS and consent form via email. Following this, an appointment will be made for a video call (Zoom or WhatsApp) for detailed screening (health history questionnaire, PAR-Q+ and IPAQ) and an opportunity to ask questions.

ix. **Recruitment:** Participants will initially be contacted by phone, email or a video call and will be screened on an online visit 1 (via Zoom or WhatsApp) according to inclusion and exclusion criteria. During the first visit participants will be given a detailed explanation of the study, including risks and benefits. They will be given a study information sheet and a consent form, which they can read in detail at their convenience and ask questions about the study. Verbal consent will be requested during the Zoom/WhatsApp call and will be recorded and stored at the university servers. After giving verbal consent, the researcher will share the screen on the Zoom video call to show the participant the screening questionnaires. The researcher and the participant will then complete a "Health Questionnaire", PAR-Q+ and IPAQ-SF assess the participant's eligibility for the study (See "Health questionnaire", "PAR-Q+" and "IPAQ-SF" documents attached). If the participant is suitable for the study, address details will be requested, to enable postage of the study materials (resistance bands for the resistance exercise group).

4. Describe the research procedures as they affect the research participants and any other parties involved. It should be clear exactly (i) what will happen to the research participant, (ii) how many times and (iii) in what order. If your research involves administration of a substance, for example saline, topical anaesthetic etc. then please give full details on the substance and manufacturer. Reference to an existing standardised operating procedure is acceptable.

Volunteers will be asked to attend online visits on four/five occasions.

Screening, online visit 1 – Participants will be asked to attend an online visit via Zoom for a brief screening procedure, to determine if they are suitable for the study. An explanation of study including screening with inclusion/exclusion criteria. The volunteer information sheet and written informed consent will be given. Verbal consent will be obtained. After consent is given screening procedure will proceed as described above (Section 3). This part of session 1 will take 30 min.

Baseline measurements, online visit 2 – On another online visit, if the participant is suitable for the study the researcher will send a web link, the "study link" and a unique code to log in to take the following measurements. A well-being questionnaire (WEMWBS) will be accessed and completed via the link. After that muscle endurance tests will be assessed. These measurements will be made by a researcher blinded to the group allocation of the participant. Participants will be asked to perform four tests (push-ups test, sit ups test, squat test and sit-and-reach) with two minutes of rest between them. The tests will be performed in that order for all participants. Participants will have access to videos and sound signals (with the specific cadence for each test) with instructions for the tests via the link. The participants will be asked to put their camera in a specific position for each test. The session will take 30 min and it will be recorded for verification purposes.

Exercise intervention (week 1 to week 12) – The exercise intervention will follow as the description above (Section 2).

Intervention Exercise diary record (week 1 to week 12) – All participants in the study will be asked to fill an exercise diary for the duration of the intervention (12 weeks) using the study app provided by the research team.

Mid-intervention measurements (6-week), online visit 3 – A well-being questionnaire (WEMWBS) will be accessed via the link. After that muscle endurance tests will be assessed by a researcher blinded to the group allocation. Participants will be asked to perform four tests (push-ups test, sit ups test, squat test and sit-and-reach) with two minutes of rest between them. The tests will be performed in that order for all participants. Participants will have access to videos and sound signals (with the specific cadence for each test) with instructions for the tests via the link. The participants will be asked to put their camera in a specific position for each test. The session will take 30 min and it will be recorded for verification purposes.

Post-intervention measurements (12-week), online visit 4 - A well-being questionnaire (WEMWBS) will be accessed via the link. After that muscle endurance tests will be assessed by a researcher blinded to the group allocation. Participants will be asked to perform four tests (push-ups test, sit ups test, squat test and sit-and-reach) with two minutes of rest between them. The tests will be performed in that order for all

participants. Participants will have access to videos and sound signals (with the specific cadence for each test) with instructions for the tests via the link. The participants will be asked to put their camera in a specific position for each test. The session will take 30 min and it will be recorded for verification purposes.

Qualitative Interviews (12-week), online visit 5 – A subgroup of participants will be asked to be interviewed online by a member of the research team. Each interview will take between 30 and 60 minutes and participants will be asked to demonstrate and talk the interviewer through their exercise programme (if possible), describe how they fit the exercise programme into their normal routine, and what has helped/prevented them from doing so (see attached interview guide).

5. What are the ethical considerations involved in this proposal? You may wish, for example, to comment on issues to do with consent, confidentiality, risk to participants, etc.

Consent and participation
Participants will voluntarily consent to the study and will be told that they can withdraw from the study anytime they want without consequence or need to provide a reason. Verbal consent will be taken, which will be recorded and stored in the University of Glasgow's servers.

Exercise testing and intervention
Preliminary screening will exclude any subjects that fail the PAR-Q+, do > 30 min of vigorous physical activity, do any resistance exercise, any participant with a history of cardiovascular problems and those known to exhibit major risk factors for CHD. Exercise will be at maximal level at some points during the study and there is a possibility that the subject could suffer from acute muscle soreness. Participants in the flexibility exercise group will have access to the resistance exercise intervention (videos and instructions) after completion of the study period. Participants in the resistance exercise group will have access to the flexibility exercises after the study period.

Anonymity and confidentiality
The information obtained will be anonymised and individual information will not be passed on to anyone outside the research members. Each participant will be given a number to ensure anonymity for the results analysis. Participants will be asked to log on to the app with their ID number and unique code. All data stored from the app will therefore contain no personal identifiable information with participants only identified by a study ID. Personal identifiable data will be obtained by a member of the research team and will be stored in a different document protected by a password. This document will be stored in the University of Glasgow's servers. Only members of the research team (MFGT, JG, CG, SG) will have access to personal identifiable data.

Data retention
In case of withdrawal at any state of the study, data obtained from participants will be kept by the researchers. Data from volunteers that have been excluded from the study during the screening procedure will not be stored by the researches and will be destroyed.

6. Outline the reasons why the possible benefits to be gained from the project justify

any risks or discomforts involved.

The risks and discomfort associated with participating in this study are minor and the beneficial effect outweighs the small existing risk of participating. Subjects will receive feedback on muscle endurance gained throughout the experimental period, so will benefit from the study personally. The results of the proposed research will provide data on changes in muscle endurance modulated by the resistance training, information about the programme adherence, participants' feelings, thoughts and perceptions of a home-based resistance exercise delivered via the study app. This information may be important in the design of future studies and ultimately developing resistance exercise guidelines. The risks associated with participating in this study are very small.

7. Who are the investigators (including assistants) who will conduct the research? What are their qualifications and experience?

Professor Jason Gill has ~25 years of experience in conducting human metabolic and exercise studies.

Dr Stuart Gray (PhD) is a lecturer in exercise and metabolic health with over 15 years of experience in conducting human metabolic and exercise studies.

Professor Cindy Gray has over 12 years of experience in using qualitative methods, including conducting telephone/online interviews, to inform the development and optimisation of health behaviour change interventions (including physical activity/exercise programmes).

María Fernanda Gabler is a PhD student under the supervision of Professor Gill, Professor Gray and Dr Gray. She has been trained in exercise procedures under the MSc Sport and Exercise Science and Medicine 2017/2018 programme by the University of Glasgow and this work as an extension of her first PhD study (ONE Study, MVLS ethics approval number 200180137).

Ayan Merchant, Hesham Alfeheid, Philip McBride are PhD students who will be responsible for the blinded measurements of muscular endurance and flexibility over Zoom. They will be trained in these procedures by Maria Fernanda Gabler. Hesham and Philip both have an MSc Sport and Exercise Science and Medicine.

8. Are arrangements for the provision of clinical facilities to handle emergencies necessary? If so, briefly describe the arrangements made.

Not applicable for this study. Participants will be performing all activities at their home or at a place of their choice.

9. In cases where participants will be identified from information held by another party (e.g., a doctor or hospital), describe how you intend to obtain this information. Include, where appropriate, whether additional Research Ethics Committee approvals will be sought and gained (including overseas committees).

Not applicable for this study

10. Specify whether participants will include students or others in a dependent relationship and, where possible, avoid recruiting students who might feel to be, or be construed to be, under obligation to volunteer for a project. This is most likely to be when a student is enrolled on a course where the investigator is a teacher. In these circumstances, the recruitment could be carried out by one of the other investigators or a suitably qualified third party.

If students are enrolled on a course or supervised by Professor Gill, Professor Gray and Dr Gray, recruitment will be carried out by another member of the study team who is not directly involved with their studies. Participants will be under no obligation or incentive to volunteer for the study.

11. Specify whether the research will include children or participants with mental illness, physical disability or intellectual disability. If so, please explain the necessity of involving these individuals as research participants and include documentation of the suitability of those researchers who will be in contact with children or vulnerable adults (e.g., Disclosure Scotland or membership of the Protection of Vulnerable Groups Scheme).

The research/study will not include children. Participants will need to be able to access the intervention materials and upload data online and to participant in assessments via videocall. They will also need to be physically able to perform the prescribed exercises. If they are able to achieve this, then participants with mental illness, physical disability or intellectual disability may be included.

12. Will payment or other incentive, such as a gift or free services, be made to any research participant? If so, please specify, and state the level of payment to be made and/or the source of the funds/gift/free service to be used. Please explain the justification for offering an incentive.

No cash or exchange of funds will be offered.

13. Please give details of how consent is to be obtained and recorded. A copy of the proposed consent form, along with a separate information sheet, written in simple, non-technical language MUST ACCOMPANY THIS PROPOSAL FORM.

Participants will be sent the “Participant information sheet” and “Consent form” with at least 24hrs prior to the first online session. One of the study investigators listed on the study will seek verbal consent after an introductory session, which will involve a review of the PIS and a verbal explanation of the study in regard to the benefits, burdens and risks of the study with the opportunity to ask questions before providing verbal consent to participate which will be recorded and stored on the university servers.

14. Comment on any cultural, social or gender-based characteristics of the participants that have affected the design of the project or may affect its conduct.
In this study, the design has not been affected by any cultural, social or gender-based characteristics.

15. Please state (i) who will have access to the data, (ii) how the data will be stored, how will access be restricted, and (iii) what measures will be adopted to maintain the confidentiality of the research participants and to comply with data protection requirements.

For studies where participant responses are recorded and transcribed at a later date, give details of storage and transcription. Please give some detail on how long data will be stored for and where. You should clarify how identifiable, anonymised research data and consent forms will be stored.

vii) Only the named investigators will have full access to the data obtained. The information obtained will be anonymised and identifiable data will not be stored through the study link and will not be passed on to anyone outside the study group. Anonymised data, only coded with a participant information number, with all identifying information removed, will be shared with collaborators to maximise the life-time value of the data generated for human health, in line with best practice for data sharing

viii) Anonymised data from the app will be stored on a secure external server. All files containing identifiable data will only be stored on University servers in password protected files separate from the study data. Access will be restricted by password-protection and data stored for 10 years.

ix) Data will be anonymised with subjects being identified by a number rather than a name. Personal data including linkage of subject name and number will be held in a locked filing cabinet in the BHF Glasgow clinical research centre or as password−protected files saved on the University server, known only to the named investigators.

x) Recorded measurement sessions will be stored in password protected files saved on the University server, only know to named investigators.

Please tick to confirm that all relevant research data generated during and after the study will be collected and held in compliance with the General Data Protection Regulation (May 2018). [X]

Please tick to confirm that you have completed a data protection impact assessment form if required. [X]

If this is not required, please specify why not;

For guidance in this matter, please refer to the University Data Protection Office webpages:
https://www.gla.ac.uk/myglasgow/dpfoioffice/gdpr/

In regard to (ii) above, please clarify (tick one) how the data will be stored:

☐ **(a) in a fully anonymised form (link to participants broken),**

☐ **(b) in a linked anonymised form (data +/- samples linked to participant identification number but participant not identifiable to researchers), or**

X (c) in a form in which the participant could be identifiable to researcher.

If data are stored in linked anonymised form, please state who will have access to the code and personal information about the participant.

The data will be held securely for a period of ten years after the completion of the research project, or for longer if specified by the research funder or sponsor, in accordance with the University's Code of Good Practice in Research. (https://www.gla.ac.uk/research/strategy/ourpolicies/) Please tick and give further details below

Data will be stored for 10 years on University servers

16. To your knowledge, will the intended group of research participants be involved in other research? If so, please justify.
The study participants will not be involved in other research while they are undertaking this study.

17. Proposed starting date: 10-08-2020

Expected completion date: 09-08-2021

18. Please state location(s) where the project will be carried out, including all overseas laboratories, hospitals and other relevant locations.
The intervention will be conducted remotely with participants in their homes or another location at their convenience.

19. Please state briefly any precautions being taken to protect the health and safety of researchers and others associated with the project (as distinct from the research participants), e.g., where blood samples are being taken, home visits.
Not applicable for this study

20. Please state all relevant sources of funding or support for this study.
The work is funded by a PhD Scholarship to Ms Gabler from Beca Chile CONICYT and the BBC.

21a). Are there any conflicts of interest related to this project for any member of the research team? This includes, but is not restricted to, financial or commercial interests in the findings. If so, please explain these in detail and justify the role of the research team. For each member of the research team please complete a declaration of conflicts of interest below.

Researcher Name: __ Jason Gill _____ conflict of interest
No

Researcher Name: ___ Stuart Gray _____ conflict of interest
No

Researcher Name: ___Cindy Gray _____ conflict of interest
No

Researcher Name: ___ María Fernanda Gabler _____ conflict of interest
No

Researcher Name: ___ Ayan Merchant _____ conflict of interest
No

Researcher Name: ___ Hesham Alfeheid _____ conflict of interest
No

Researcher Name: ___ Phillip McBride _____ conflict of interest
No

21b). If there are any conflicts of interest, please describe these in detail and justify conducting the proposed study.

Not applicable

22. How do you intend to disseminate the findings of this research?
Please include details of how the study participants will be notified of the study finding. If they are not to be informed, please justify.

The results will form part of María Fernanda Gabler's PhD thesis. An associated paper, presentation and a poster will be made. In addition, we plan to present the findings in a peer-reviewed scientific journal. Results of the subgroup of participants recorded for the BBC will be disseminated on a BBC TV programme.

I confirm that have read the University of Glasgow's Data Protection Policy.
https://www.gla.ac.uk/myglasgow/dpfoioffice/

Please initial box | X |

Name _ Maria Fernanda Gabler Trisotti _____ Date _20-07-2020_
(Proposer of research)
Please type your name on the line above.

For student projects:

I confirm that I have read and contributed to this submission and believe that the methods proposed and ethical issues discussed are appropriate.

I confirm that the student will have the time and resources to complete this project.

Name __Jason Gill _____ Date __20-07-2020_
(Supervisor of student)
Please type your name on the line above.

Please upload the completed and signed form, along with other required documents by logging in to the Research Ethics System at - https://frontdoor.spa.gla.ac.uk/login/

Appendix L: REFLEX approval letter

University of Glasgow

5th August 2020

MVLS College Ethics Committee

Project Title: Effect of a home-based REsistance exercise vs a home-based FLEXbility exercise programme on muscular endurance and flexibility in healthy adults (REFLEX)

Project No: 200190188

Dear Professor Gill,

The College Ethics Committee has reviewed your application and has agreed that there is no objection on ethical grounds to the proposed study. It is happy therefore to approve the project.

- Project end date: As stated in application.
- The data should be held securely for a period of ten years after the completion of the research project, or for longer if specified by the research funder or sponsor, in accordance with the University's Code of Good Practice in Research: (http://www.gla.ac.uk/media/media_227599_en.pdf)
- The research should be carried out only on the sites, and/or with the groups defined in the application.
- Any proposed changes in the protocol should be submitted for reassessment, except when it is necessary to change the protocol to eliminate hazard to the subjects or where the change involves only the administrative aspects of the project. The Ethics Committee should be informed of any such changes.
- You should submit a short end of study report to the Ethics Committee within 3 months of completion.

Yours sincerely,

Jesse Dawson
MD, BSc (Hons), FRCP, FESO
Professor of Stroke Medicine
Consultant Physician
Clinical Lead Scottish Stroke Research Network / NRS Stroke Research Champion
Chair MVLS Research Ethics Committee

Institute of Cardiovascular and Medical Sciences
College of Medical, Veterinary & Life Sciences
University of Glasgow
Room M0.05
Office Block
Queen Elizabeth University Hospital
Glasgow
G51 4TF

jesse.dawson@glasgow.ac.uk

Appendix M: REFLEX Amendment 1

University of Glasgow | College of Medical, Veterinary & Life Sciences

College of Medical, Veterinary & Life Sciences Ethics Committee for Non-Clinical Research Involving Human Participants

APPLICATION FORM FOR ETHICAL APPROVAL

NOTES:
THIS APPLICATION FORM SHOULD BE TYPED NOT HAND WRITTEN.

ALL QUESTIONS MUST BE ANSWERED. "NOT APPLICABLE" IS A SATISFACTORY ANSWER WHERE APPROPRIATE.

The primary remit of this committee is the review of non-clinical research. However, clinical research involving humans, their tissue or data that falls outwith the remit of the NHS Research Ethics Service will also be reviewed by the MVLS committee. If your project involves NHS facilities, or is clinical research, then you must ensure that NHS REC review is not needed before applying to the MVLS REC. The review of the MVLS REC does not obviate the need for NHS review.

Please note – it is now a requirement for a Data Protection Impact Assessment (DPIA) to be completed where processes are likely to involve high-risk personal data. This is likely to be the case for many research projects. If so, you must complete this before submission for ethical review. For research involving personal data, you should give participants a Privacy Notice as well as a Participant Information sheet.

Information on DPIAs and Privacy Notices
https://www.gla.ac.uk/myglasgow/dpfoioffice/gdpr/dpia/
https://www.gla.ac.uk/myglasgow/dpfoioffice/gdpr/privacy%20notices/

Information on the General Data Protection Regulation (GDPR)
https://www.gla.ac.uk/myglasgow/dpfoioffice/

Information on Research Data Management
https://www.gla.ac.uk/myglasgow/datamanagement/

University of Glasgow policy on surveys of students for research purposes
https://www.gla.ac.uk/myglasgow/senateoffice/policies/studentengagement/studentsurveys/policyonstudentsurveys/

Project Title:

Effect of a home-based REsistance exercise vs a home-based FLEXbility exercise programme on muscular endurance and flexibility in healthy adults (REFLEX).

Has this application been previously submitted to this or any other ethics committee? No

If 'Yes', please state the title and reference number.

Is this project from a commercial source, or funded by a research grant of any kind?
No

If 'Yes', has it been referred to Research Support Office?
Has it been allocated a project Number?
Give details and ensure that this is stated on the Informed Consent Form.

Insurance Coverage and Restrictions:
Please Note: The Insurance restrictions set out below relate to research of a clinical nature. Non clinical research is not subject to restriction and no additional insurance is required

The University insurance cover is restricted under specific circumstances, including, but not limited to the following -

- **work involving the use of research participants outside Great Britain, Northern Ireland, the Channel Islands or the Isle of Man**
- **the use of hazardous materials**
- **non CE marked medical devices**
- **molecules or compounds developed and manufactured at the University of Glasgow**
- **number of participants in excess of 5000**
- **work involving research participants known to be pregnant at the time of the project**

All such projects must be referred to Research Support Office and coverage confirmed before ethical approval is sought. Please contact Dr Debra Stuart in the University's Research Governance Office: debra.stuart@glasgow.ac.uk

Please tick here if this project has been referred to the Research Support Office to confirm adequate insurance coverage.

Please tick here if the project includes a technique involving incision, piercing of skin, insertion of a device or object, ingestion of medicines or food substances. ☐

Please tick here if the project involves work on human participants that will be conducted within the Imaging Centre of Excellence (ICE) ☐

Date of submission:
20 July 2020

Name of all person(s) submitting research proposal:
Professor Jason Gill
Dr Stuart Gray
Prof Cindy Gray
María Fernanda Gabler Trisotti
Ayan Merchant
Hesham Alfeheid
Phillip McBride

Position(s) held:

Professor of Cardiometabolic Health	JG
Lecturer in Exercise and Metabolic Health	SG
Interdisciplinary Professor of Health and Behaviour	CG
PhD Student Cardiovascular Sciences (Research)	MFG
PhD Student Cardiovascular Sciences (Research)	AM
PhD Student Cardiovascular Sciences (Research)	HA
PhD Student Health Science	PM

School/Group/Institute/Centre:
Institute of Cardiovascular and Medical Sciences (JG, SG, MFG, AM and HA)

Institute of Health and Wellbeing (CG)
University of Leicester (PM)

Address for correspondence relating to this submission:
BHF Glasgow Cardiovascular Research Centre, University of Glasgow, Institute of Cardiovascular and Medical Sciences, College of Medical, Veterinary and Life Sciences, Glasgow, G12 8TA

Email address: Jason.Gill@glasgow.ac.uk
Stuart.Gray@glasgow.ac.uk
…….. Cindy.Gray@glasgow.ac.uk
m.glabler-trisotti.1@research.gla.ac.uk
a.merchant.1@research.gla.ac.uk
h.alfeheid.1@research.gla.ac.uk
pm381@le.ac.uk

Name of Principal Researcher (if different from above, e.g., Student's Supervisor):
Jason Gill

Position held:
Professor of Cardiometabolic Health

Undergraduate student project:
No If 'Yes', please state degree being undertaken:

Postgraduate student project:
Yes If 'Yes', please state degree being undertaken:

PhD Cardiovascular Sciences (Research)

For postgraduate student projects, please state whether this a research (PGR) or taught (PGT) degree:

PGR

1. Describe the purposes of the research proposed. Please include the background and scientific justification for the research. Why is this an area of importance? Please try to describe why the research is novel and experimental.

We do not need a comprehensive review of the topic area: a short summary that is sufficient for the reviewers to understand the study is sufficient. Bullet points and references to more detailed texts are both acceptable.

Studies have shown that regular resistance training can lead to a variety of health benefits including increases in muscle size and strength, reductions on body fat, increased metabolic rate, glycaemic control, decreased blood pressure and improved blood lipid profiles (1–3). Because of this, national and international physical activity guidelines recommend undertaking muscle strengthening activities involving major muscle groups two days a week or more, alongside at least 150 minutes per week of moderate intensity physical activity (or 75 minutes per week of vigorous intensity physical activity)(4,5). However, in the UK, while about two-thirds of men and almost three-fifths of women over met the guidelines for aerobic exercise, less than a third of men and a quarter of women achieve the guidelines for muscle-strengthening exercise in 2016 (6,7).

Why participation in muscle-strengthening exercise is low is not clear but people identify several barriers including the lack of time (8,9), the effort involved (8,9), lack of purpose, pain due to injury, negative experiences of prescriptive exercise, apathy (10), illness, injury inclement weather and work commitment (11). In addition, some women have expressed a worry of looking 'manly' or 'bulking up' if they undertake resistance exercise (12). A further potential barrier is lack of access to a gym with appropriate equipment to perform resistance exercise, or dislike of a gym setting. Thus, identifying approaches to find a safe, enjoyable and accessible programme that minimises the burden of performing resistance exercise, and identifying a minimal amount of resistance training which can provide benefits is a key issue which could help more people to undertake muscle strengthening exercises.

The dose-response relationship between volume of resistance exercise and gains in muscle size and strength recommended by the ACSM for optimal benefits is two to three times per week. However, the largest gains are seen between undertaking zero and one session per week, with decreasing gains beyond this (13). Substantial increases in strength (~20%) have been observed with a single session of exercise per week if it is performed to momentary failure; in this context, the specific load does not appear to influence the magnitude of the adaptations (14). Furthermore, it has been found that the frequency of resistance exercise does not influence the magnitude of change in strength or hypertrophy if the volume of exercise (sets per week) is equated (15,16).
Thus, a single set of exercise per muscle group per week appears to be an effective dose for adaptation, and programmes using this approach could potentially address the barrier of a lack of time. However this in itself, does not necessarily help overcome the need for access to a gym facility with strength training equipment. Developing protocols that can be performed at home may help with this. Most of the evidence in the literature for home-based resistance exercise comes from studies in older (>65 years) adults (17) but there is limited evidence in younger (18-64 years) volunteers.

One approach to overcome barriers of daily time commitment and access to specialised facilities/equipment is to carry out a resistance exercise programme with low time commitment and performed at home with minimal equipment. This may be a more convenient way to undertake resistance exercise and improve long term adherence. We first attempted to study in this in our ongoing ONE study (MVLS ethics approval number 200180137). Preliminary quantitative data of the ONE Study (with n =17 completed out target n of 54) shows that one minute of resistance exercise per day produces a trend increase in muscle endurance after 12 weeks. Preliminary qualitative data shows that participants enjoyed the programme, but would prefer to have more flexibility in how the exercises were distributed throughout the week, a greater choice of exercises, and the potential to undertake more than this minimum prescription. The current study aims to extend the ONE study in light of these qualitative insights, and to deliver the intervention completely online (via an app), given current social distancing restrictions. This will also help trial the online delivery platform for future widescale implementation. We plan to deliver this as a randomised control trial (RCT) with a comparison group undertaking a flexibility exercise programme (which would be expected to improve flexibility but not muscular endurance).

The main aim of this study is to compare the effects of an app-based home-based resistance exercise programme vs a home-based flexibility programme on muscular endurance (number of press-ups, bodyweight squats and crunches achieved, assessed online during a zoom call) and flexibility (sit and reach, assessed online during a zoom call) in healthy adults. Secondary aims are a) to determine participants' adherence to both exercise programmes, b) to determine participants' choice of weekly exercise volume (compared to minimum prescription) in both exercise programmes c) to determine participants' distribution of exercise throughout the week in both exercise programmes d) to determine the effects of a exercise programmes on well-being, and finally e) to determine participants' perceptions, feelings, thoughts, enjoyment, tolerance and acceptability of both exercise programmes.

This study is being undertaken in collaboration with BBC Scotland for a programme called "The Truth About Getting Fit at Home" and a subset of participants will feature on the programme.

1. Saric J, Lisica D, Orlic I, Grgic J, Krieger JW, Vuk S, et al. Resistance Training Frequencies of 3 and 6 Times Per Week Produce Similar Muscular Adaptations in Resistance-Trained Men. J Strength Cond Res [Internet]. 2018 Oct;1. Available from: https://journals.lww.com/nsca-jscr/Fulltext/publishahead/Resistance_Training_Frequencies_of_3_and_6_Times.95086.aspx
2. Kraemer WJ, Ratamess NA, French DN. Resistance training for health and performance. Curr Sports Med Rep [Internet]. 2002;1(3):165–71. Available from: https://doi.org/10.1007/s11932-002-0017-7
3. Ashton RE, Tew GA, Aning JJ, Gilbert SE, Lewis L, Saxton JM. Effects of short-term, medium-term and long-term resistance exercise training on cardiometabolic health outcomes in adults: Systematic review with meta-analysis. Br J Sports Med. 2020;54(6):341–8.
4. World Health Organization. Global Recommendations on Physical Activity for Health [Internet]. 2011 [cited 2019 Mar 28]. p. 1. Available from: https://www.who.int/dietphysicalactivity/physical-activity-recommendations-18-

64years.pdf?ua=1
5. PCSFN. Physical Activity Guidelines for Americans [Internet]. 2019 [cited 2020 Jul 3]. Available from: https://www.hhs.gov/fitness/be-active/physical-activity-guidelines-for-americans/index.html#:~:text=For substantial health benefits%2C adults,or an equivalent combination of
6. Scholes S. Health Survey for England 2016 Physical activity in adults [Internet]. 2017. 20 p. Available from: https://files.digital.nhs.uk/publication/m/3/hse16-adult-phy-act.pdf
7. Bromley C, Dowling S, Gray L, Hinchliffe S, Hughes T, Leyland A, et al. The Scottish Health Survey [Internet]. Vol. 1, The Scottish Health Survey. 2012. Available from: www.scotland.gov.uk
8. Hurley KS, Flippin KJ, Blom LC, Bolin JE, Hoover DL, Judge LW. Practices, Perceived Benefits, and Barriers to Resistance Training Among Women Enrolled in College. Int J Exerc Sci [Internet]. 2018;11(5):226–38. Available from: http://www.ncbi.nlm.nih.gov/pubmed/29795737%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC5955292
9. Trost SG, Owen N, Bauman AE, Sallis JF, Brown W. Correlates of adults' participation in physical activity: review and update. Med Sci Sport Exerc. 2002;34(12):1996–2001.
10. Hancox JE, Van Der Wardt V, Pollock K, Booth V, Vedhara K, Harwood RH. Factors influencing adherence to home-based strength and balance exercises among older adults with mild cognitive impairment and early dementia: Promoting activity, independence and stability in early dementia (praised). PLoS One. 2019;14(5):1–19.
11. Tulloch H, Sweet SN, Fortier M, Capstick G, Kenny GP, Sigal RJ. Exercise facilitators and barriers from adoption to maintenance in the diabetes aerobic and resistance exercise trial. Can J Diabetes [Internet]. 2013;37(6):367–74. Available from: http://dx.doi.org/10.1016/j.jcjd.2013.09.002
12. Dworkin SL. A woman's place is in the ... cardiovascular room?? Gender relations, the body, and the gym. In: Athletic intruders: ethnographic research on women, culture and exercise. Albany: State University of New York Press; 2003. p. 131–58.
13. Westcott W. ACSM STRENGTH TRAINING GUIDELINES. ACSMs Health Fit J [Internet]. 2009 Jul;13(4):14–22. Available from: http://insights.ovid.com/crossref?an=00135124-200907000-00007
14. Ismail AD, Aba Alkhayl FF, Wilson J, Johnston L, Gill JMR, Gray SR. The effect of short duration resistance training on insulin sensitivity and muscle adaptations in overweight men. Exp Physiol [Internet]. 2019;(October 2018):2–7. Available from: http://doi.wiley.com/10.1113/EP087435
15. Gentil P, Bottaro M, Giessing J, Steele J, Fisher J, Campos MH, et al. Effects of equal-volume resistance training with different training frequencies in muscle size and strength in trained men. PeerJ. 2018;6:e5020.
16. Grgic J, Schoenfeld BJ, Davies TB, Lazinica B, Krieger JW, Pedisic Z. Effect of Resistance Training Frequency on Gains in Muscular Strength: A Systematic Review and Meta-Analysis. Sport Med [Internet]. 2018;48(5):1207–20. Available from: https://doi.org/10.1007/s40279-018-0872-x
17. Kis O, Buch A, Stern N, Moran DS. Minimally supervised home-based resistance training and muscle function in older adults: A meta-analysis. Arch Gerontol Geriatr [Internet]. 2019;84(March):103909. Available from: https://doi.org/10.1016/j.archger.2019.103909
18. ACSM. ACSM's Guidelines for Exercise Testing and Prescrption. 10th Editi. Wolters Kluwer; 2016.

19. Radaelli R, Fleck SJ, Leite T, Leite RD, Pinto RS, Fernandes L, et al. Dose-Response of 1, 3, and 5 Sets of Resistance Exercise on Strength, Local Muscular Endurance, and Hypertrophy. J Strength Cond Res [Internet]. 2015;29(5). Available from: https://journals.lww.com/nsca-jscr/Fulltext/2015/05000/Dose_Response_of_1,_3,_and_5_Sets_of_Resistance.25.aspx
20. Ritchie J, Lewis J, McNaughton Nicolls C, Ormston R, editors. Qualitative Research Practice: A Guide for Social Science Students and Researchers. 2014th ed. Sage; 2003.

2. Describe the design of the study and methods to be used. If multiple methods are to be used, please describe them each in turn. Include details of the study sample size and how you decided this. Statistical advice should be obtained if in doubt.

The study design is an RCT with two groups, a flexibility exercise group (which will be the comparison group), and a resistance exercise group. Mixed methods will be used.
Participants will be male and female, aged between 18-64 years old, who perform ≤ 30 min a week of aerobic vigorous physical activity (compendium of physical activities) and do not to perform any kind of resistance exercise. Exclusion criteria will include failure of the Physical Activity Readiness Questionnaire Plus (PAR-Q+), performing 30 minutes or more of vigorous intensity exercise from the IPAQ, having a job that compromises manual labour, a history of cardiovascular disease, diabetes and any other illness that would prevent the participation in a resistance exercise or flexibility exercise programme.
After screening, participants will undergo baseline measurements (online), and after that they will be randomised into two conditions: a flexibility exercise group (comparison group) and a resistance exercise group. Participants will then undertake a 12-week flexibility or resistance exercise intervention. Baseline measurements will be repeated after 6 and 12 weeks. Assessments will include muscle endurance, adherence, quality of life and participants perceptions, feelings and thoughts of the intervention.

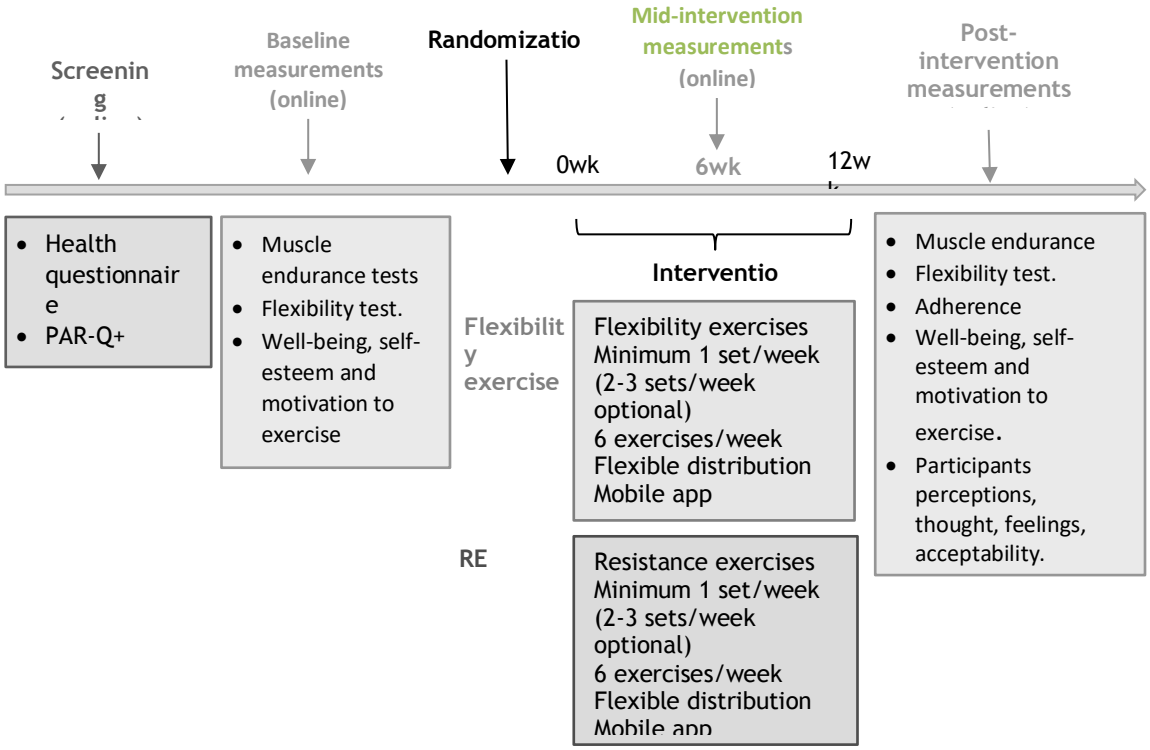


Figure 1. Overview of study protocol.

Assessments

VII. Screening measurements (appendix 1):

10) Health questionnaire:

(undertaken at 1 time-point; screening)

Participants will be asked to fill a health questionnaire to determine if they are suitable to participate in the study.

11) PAR-Q+:

(undertaken at 1 time-point; screening)

Participants will be asked to fill the Physical Activity Readiness Questionnaire Plus to determine their safety to undertake physical activity.

12) IPAQ-SF:

Participants will be asked to fill the International Physical Activity Questionnaire (short form) to determine their level of physical activity. We will ask an additional question to determine if participants are participating in any resistance exercise.

VIII. Baseline, 6 weeks and post-intervention measurements:

1) Muscle endurance:

(undertaken at 0, 6-weeks and 12 weeks)

Muscular endurance will be measured at baseline, 6 weeks and 12 weeks. Three tests will be used: i) Push up test: maximum number of press-ups (undertaken on feet, on knees, against a worktop or against a wall, depending on individual capacity); ii) Half-squat test: maximum time achieved in a half-squat against a wall (participant will have to maintain a squat position with 90 degree knee flexion and with their back against a wall as long as possible depending on their individual capacity); iii) Plank test: maximum time achieved on a plank (participant will have to maintain the plank position with forearms and feet as long as possible depending on their individual capacity). Number of press-ups will be the primary outcome, the other measures will be secondary outcomes. The measurement will be via zoom, with the participant and research team member blinded to the intervention group on each end of the videocall. See SOP attached.

2) Flexibility

(undertaken at 0, 6-weeks and 12 weeks)

Flexibility will be assessed via a sit-and-reach test, via zoom at baseline, 6 and 12 weeks. This will be a secondary outcome.

3) Adherence:

Participants will record all of their exercise sessions as they complete them using an online app. Adherence will be assessed at 12 weeks from the in-app data using the following outcomes:

- Percentage of the minimum number of exercise sets prescribed undertaken.
- Percentage of participants that drop-out from the study. Drop out considered as: a) participants who no longer record their exercises on the app, but complete the outcome measurements; and b) participants who neither record their exercises nor complete the outcome measurements.

4) Choice of exercise volume and progression (as assessed at 12 weeks from the in-app data)**:**

- Number of sets of exercise undertaken relative to minimum prescribed dose during each week of the intervention.

5) Choice of distribution of exercise throughout the week (as assessed at 12 weeks from the in-app data)**:**

- Distribution of participants undertaking their exercise different numbers of days of week throughout the intervention period.

6) Well-being, self-esteem and motivation to exercise questionnaires
(undertaken at 0, 6 weeks and 12 weeks)

Well-being will be assessed using the Cantril Ladder, WEMWBS questionnaire and subjective vitality scale. Self-esteem will be assessed using Rosenberg's self-esteem questionnaire, and motivation to exercise will be assessed using the adapted Behavioural Regulations in Exercise Questionnaire (BREQ-2) questionnaire. The questionnaires will be delivered through the app.

7) Participants' perceptions, feelings, thoughts, enjoyment, tolerance and acceptability of a home-based resistance exercise programme
(after the intervention period)

Semi-structured online interviews (each lasting 30-60 minutes) will be conducted with a subset of participants in both exercise groups (n = 18-24 participants overall). The interviews will be conducted via Zoom or WhatsApp, both recently approved by the University for online data collection during the COVID 19 pandemic, and depending on people preferences. A topic guide will be used to guide discussions – indicative questions are provided in appendix 3.

Intervention

All participants will be asked to follow a 12-week home-based exercise programme. Participants will be asked to perform a minimum amount of resistance or flexibility exercise of 1 set/week for each of six exercises and will have the opportunity to increase their volume of exercise to 2 sets or 3 sets/week per exercise if it is their choice. In addition, participants will be able to distribute the exercises during the week according to their preference (all in one day or spread over several days of the week, etc.). Participants will be encouraged to have a minimum of one day of rest per week. If participants choose to increase to 2 or 3 sets/week some examples will be given to distribute the exercises throughout the week including:

a) Two or three sets of the same exercise per day with a minimum of one minute of rest between sets.

b) One set of two or three different exercises per day.

c) Four or six sets per day of 4 different or 3 different exercises (3 sessions a week) with 4 days of rest.

3) Flexibility exercise group (FE [comparison] group).

The flexibility exercise group will be asked to perform 6 flexibility exercises per week (2 different for legs, 1 shoulder and arms, 1 chest, 1 back and 1 core). Participants will be able to choose from a bank of flexibility of exercises to perform. Participants will perform passive static stretching exercises (appendix 4). They will be asked to stretch to the point of feeling

tightness or slight discomfort, to hold the stretch for 30 seconds (each side), and repeat that twice (in total 60 seconds of stretching per side) according to the ACSM's guidelines for flexibility exercises (18).

4) Resistance exercise intervention (RE group)

Participants in the resistance exercise group will be asked to perform a total of 6 exercises per week (2 different leg exercises, 1 shoulder exercise, 1 chest exercise, 1 back exercise and 1 core exercise, Appendix 4). Participants will have the opportunity to choose the exercise they want to perform from a bank of exercises that will be provided. Each exercise will have several levels. At the beginning of the exercise programme, participants will be asked to choose a level in which they are able to perform between 6-20 repetitions. During each exercise session in the programme, they will be asked to complete as many repetitions as possible. If the participant is able to perform >20 repetitions, they will be able to progress to the next exercise level. For the plank, participants will progress to the next level of difficulty once they can maintain the posture for 60 seconds. Participants will receive a complete set of resistance bands (4 bands of different tensions) to perform the band exercises.

Video and written instructions for all exercises (flexibility and resistance) will be delivered via an app which will be free and only available for study participants. Participants will have access only to the bank of exercise for their intervention arm (i.e. flexibility or resistance). Participants will be asked to record each exercise session they perform during the 12-week exercise programme, recording type of exercise, level, number of repetitions or time (for plank exercises) achieved and Rating of Perceived Exertion on a scale of 1-10 (RPE). The app will send participants reminders about the exercise schedule and targets. Participants will also be able to access their own records in the app, and the investigators will be able to access all data inputted into the app via the 'back end'. For all data in the app, participants will be only identified by a study number and no identifiable personal information will be recorded.

Once the study period is over, all participants will have access to all exercises through the app (flexibility and resistance exercises) and the exercise diary. The data after the study period will not be collected and will not be used by the research team.

Sample size and power calculation

There are limited published data available evaluating the effects of resistance exercise on muscular endurance. A previous investigation has reported an 8.7 kg increase for muscle strength for bench press after a resistance exercise training, with a 9.9 kg SD for change in muscle strength (19); thus with power of 90% and an alpha of 0.05, groups of 29 participants will be needed. Considering 20% of drop out during the study, we propose to recruit 36 participants per group with a total of 72 participants. Preliminary data from 7 participants from the ONE Study showed a difference of 8.5 repetitions for press-up endurance (over primary outcome) pre to post-intervention with a SD of 7.06 in baseline press-up endurance. While this low n means that we are not confident to use these data in our power calculation, these data suggest that we would require 16 participants per group to detect this difference

with 90% power and alpha 0.05. Our power calculation using muscular strength as the outcome is likely therefore to be conservative.

Data analysis

The primary outcome for the study will be change in number of press-ups from baseline to 12-weeks. Secondary outcomes will be change in number of press-ups from 0-6 weeks and 6-12 weeks; and changes in time achieved on the half-squat test and plank test, distance achieved in the sit-and-reach test and change in well-being between all timepoints. Differences between groups in these measures will be assessed by 2-way ANOVA (group x time) with repeated measures on the time factor. We will report descriptive data for adherence, volume and progression of exercise, and distribution of exercise throughout the week. A subset (likely n = ~10) of participants will feature on the BBC programme. We will perform sensitivity analyses to determine whether changes observed in these participants differed from the wider group.

Qualitative interviews data will be transcribed by an external company approved by the University of Glasgow (e.g. 1st Class Transcription Services). Anonymised transcripts will be analysed thematically using an adapted Framework approach (20) using NVivo 12 software to determine participants' perceptions, feelings, thoughts, enjoyment, tolerance and acceptability regarding both exercise programmes.

3. How will potential participants in the study be (i) identified, (ii) approached and (iii) recruited? Give details for cases and controls separately, if appropriate

You should explain how a person becomes identified as a potential participant and then an enrolled participant. If the initial approach uses a poster, social media or email then the materials should be submitted for review.

x. **Identification:** Volunteers will be recruited via our study partners, the BBC, who will advertise the study online and via social media, and via the research team's personal contacts and snowballing. Interested parties will be directed to a weblink where they will input their level of physical activity and age. If participants do not meet initial inclusion criteria (i.e. age 18-64, <30 min/week vigorous physical activity, no resistance exercise), they will receive an automated message thanking them for their interest but saying they are not eligible. If they do meet these inclusion criteria, they will be asked to input their contact details.

xi. **Approach:** After an initial expression of interest and eligibility check, study volunteers will be approached by email or telephone, and they will be sent the PIS and consent form via email. Following this, an appointment will be made for a video call (Zoom or WhatsApp) for detailed screening (health history questionnaire, PAR-Q+ and IPAQ) and an opportunity to ask questions.

xii. **Recruitment:** Participants will initially be contacted by phone, email or a video call and will be screened on an online visit 1 (via Zoom or WhatsApp) according to inclusion and exclusion criteria. During the first visit participants will be given a detailed explanation of the study, including risks and benefits. They will be given a study information sheet and a consent form, which they can read in detail at their convenience and ask questions about the study. Verbal consent will be requested during the Zoom/WhatsApp call and will be recorded and stored at the university servers. After giving verbal consent, the researcher will share the screen on the Zoom video call to show the participant the screening questionnaires. The researcher and the participant will then complete a "Health Questionnaire", PAR-Q+ and IPAQ-SF assess the participant's eligibility for the study (See "Health questionnaire", "PAR-Q+" and "IPAQ-SF" documents attached). If the participant is suitable for the study, address details will be requested, to enable postage of the study materials (resistance bands for the resistance exercise group).

4. Describe the research procedures as they affect the research participants and any other parties involved. It should be clear exactly (i) what will happen to the research participant, (ii) how many times and (iii) in what order. If your research involves administration of a substance, for example saline, topical anaesthetic etc. then please give full details on the substance and manufacturer. Reference to an existing standardised operating procedure is acceptable.

Volunteers will be asked to attend online visits on four/five occasions.

Screening, online visit 1 – Participants will be asked to attend an online visit via Zoom for a brief screening procedure, to determine if they are suitable for the study. An explanation of study including screening with inclusion/exclusion criteria. The volunteer information sheet and written informed consent will be given. Verbal consent will be obtained. After consent is given screening procedure will proceed as described above (Section 3). This part of session 1 will take 30 min.

Baseline measurements, online visit 2 – On another online visit, if the participant is suitable for the study the researcher will send a web link, the "study link" and a unique code to log in to take the following measurements. A well-being questionnaire (WEMWBS) will be accessed and completed via the link. After that muscle endurance tests will be assessed. These measurements will be made by a researcher blinded to the group allocation of the participant. Participants will be asked to perform four tests (push-ups test, half-squat test, plank test and sit-and-reach) with two minutes of rest between them. The tests will be performed in that order for all participants. Participants will have access to videos and sound signals (with the specific cadence for each test) with instructions for the tests via the link. The participants will be asked to put their camera in a specific position for each test. The session will take 30 min and it will be recorded for verification purposes.

Exercise intervention (week 1 to week 12) – The exercise intervention will follow as the description above (Section 2).

Intervention Exercise diary record (week 1 to week 12) – All participants in the study will be asked to fill an exercise diary for the duration of the intervention (12 weeks) using the study app provided by the research team.

Mid-intervention measurements (6-week), online visit 3 – A well-being questionnaire (WEMWBS) will be accessed via the link. After that muscle endurance tests will be assessed by a researcher blinded to the group allocation. Participants will be asked to perform four tests (push-ups test, sit ups test, squat test and sit-and-reach) with two minutes of rest between them. The tests will be performed in that order for all participants. Participants will have access to videos and sound signals (with the specific cadence for each test) with instructions for the tests via the link. The participants will be asked to put their camera in a specific position for each test. The session will take 30 min and it will be recorded for verification purposes.

Post-intervention measurements (12-week), online visit 4 - A well-being questionnaire (WEMWBS) will be accessed via the link. After that muscle endurance tests will be assessed by a researcher blinded to the group allocation. Participants will be asked to perform four tests (push-ups test, sit ups test, squat test and sit-and-reach) with two minutes of rest between them. The tests will be performed in that order for all

participants. Participants will have access to videos and sound signals (with the specific cadence for each test) with instructions for the tests via the link. The participants will be asked to put their camera in a specific position for each test. The session will take 30 min and it will be recorded for verification purposes.

Qualitative Interviews (12-week), online visit 5 – A subgroup of participants will be asked to be interviewed online by a member of the research team. Each interview will take between 30 and 60 minutes and participants will be asked to demonstrate and talk the interviewer through their exercise programme (if possible), describe how they fit the exercise programme into their normal routine, and what has helped/prevented them from doing so (see attached interview guide).

5. What are the ethical considerations involved in this proposal? You may wish, for example, to comment on issues to do with consent, confidentiality, risk to participants, etc.

Consent and participation
Participants will voluntarily consent to the study and will be told that they can withdraw from the study anytime they want without consequence or need to provide a reason. Verbal consent will be taken, which will be recorded and stored in the University of Glasgow's servers.

Exercise testing and intervention
Preliminary screening will exclude any subjects that fail the PAR-Q+, do > 30 min of vigorous physical activity, do any resistance exercise, any participant with a history of cardiovascular problems and those known to exhibit major risk factors for CHD. Exercise will be at maximal level at some points during the study and there is a possibility that the subject could suffer from acute muscle soreness. Participants in the flexibility exercise group will have access to the resistance exercise intervention (videos and instructions) after completion of the study period. Participants in the resistance exercise group will have access to the flexibility exercises after the study period.

Anonymity and confidentiality
The information obtained will be anonymised and individual information will not be passed on to anyone outside the research members. Each participant will be given a number to ensure anonymity for the results analysis. Participants will be asked to log on to the app with their ID number and unique code. All data stored from the app will therefore contain no personal identifiable information with participants only identified by a study ID. Personal identifiable data will be obtained by a member of the research team and will be stored in a different document protected by a password. This document will be stored in the University of Glasgow's servers. Only members of the research team (MFGT, JG, CG, SG) will have access to personal identifiable data.

Data retention
In case of withdrawal at any state of the study, data obtained from participants will be kept by the researchers. Data from volunteers that have been excluded from the study during the screening procedure will not be stored by the researches and will be destroyed.

6. Outline the reasons why the possible benefits to be gained from the project justify

any risks or discomforts involved.

The risks and discomfort associated with participating in this study are minor and the beneficial effect outweighs the small existing risk of participating. Subjects will receive feedback on muscle endurance gained throughout the experimental period, so will benefit from the study personally. The results of the proposed research will provide data on changes in muscle endurance modulated by the resistance training, information about the programme adherence, participants' feelings, thoughts and perceptions of a home-based resistance exercise delivered via the study app. This information may be important in the design of future studies and ultimately developing resistance exercise guidelines. The risks associated with participating in this study are very small.

7. Who are the investigators (including assistants) who will conduct the research? What are their qualifications and experience?

Professor Jason Gill has ~25 years of experience in conducting human metabolic and exercise studies.

Dr Stuart Gray (PhD) is a lecturer in exercise and metabolic health with over 15 years of experience in conducting human metabolic and exercise studies.

Professor Cindy Gray has over 12 years of experience in using qualitative methods, including conducting telephone/online interviews, to inform the development and optimisation of health behaviour change interventions (including physical activity/exercise programmes).

María Fernanda Gabler is a PhD student under the supervision of Professor Gill, Professor Gray and Dr Gray. She has been trained in exercise procedures under the MSc Sport and Exercise Science and Medicine 2017/2018 programme by the University of Glasgow and this work as an extension of her first PhD study (ONE Study, MVLS ethics approval number 200180137).

Ayan Merchant, Hesham Alfeheid, Philip McBride are PhD students who will be responsible for the blinded measurements of muscular endurance and flexibility over Zoom. They will be trained in these procedures by Maria Fernanda Gabler. Hesham and Philip both have an MSc Sport and Exercise Science and Medicine.

8. Are arrangements for the provision of clinical facilities to handle emergencies necessary? If so, briefly describe the arrangements made.

Not applicable for this study. Participants will be performing all activities at their home or at a place of their choice.

9. In cases where participants will be identified from information held by another party (e.g., a doctor or hospital), describe how you intend to obtain this information. Include, where appropriate, whether additional Research Ethics Committee approvals will be sought and gained (including overseas committees).

Not applicable for this study

10. Specify whether participants will include students or others in a dependent relationship and, where possible, avoid recruiting students who might feel to be, or be construed to be, under obligation to volunteer for a project. This is most likely to be when a student is enrolled on a course where the investigator is a teacher. In these circumstances, the recruitment could be carried out by one of the other investigators or a suitably qualified third party.

If students are enrolled on a course or supervised by Professor Gill, Professor Gray and Dr Gray, recruitment will be carried out by another member of the study team who is not directly involved with their studies. Participants will be under no obligation or incentive to volunteer for the study.

11. Specify whether the research will include children or participants with mental illness, physical disability or intellectual disability. If so, please explain the necessity of involving these individuals as research participants and include documentation of the suitability of those researchers who will be in contact with children or vulnerable adults (e.g., Disclosure Scotland or membership of the Protection of Vulnerable Groups Scheme).

The research/study will not include children. Participants will need to be able to access the intervention materials and upload data online and to participant in assessments via videocall. They will also need to be physically able to perform the prescribed exercises. If they are able to achieve this, then participants with mental illness, physical disability or intellectual disability may be included.

12. Will payment or other incentive, such as a gift or free services, be made to any research participant? If so, please specify, and state the level of payment to be made and/or the source of the funds/gift/free service to be used. Please explain the justification for offering an incentive.

No cash or exchange of funds will be offered.

13. Please give details of how consent is to be obtained and recorded. A copy of the proposed consent form, along with a separate information sheet, written in simple, non-technical language MUST ACCOMPANY THIS PROPOSAL FORM.

Participants will be sent the “Participant information sheet” and “Consent form” with at least 24hrs prior to the first online session. One of the study investigators listed on the study will seek verbal consent after an introductory session, which will involve a review of the PIS and a verbal explanation of the study in regard to the benefits, burdens and risks of the study with the opportunity to ask questions before providing verbal consent to participate which will be recorded and stored on the university servers.

14. Comment on any cultural, social or gender-based characteristics of the participants that have affected the design of the project or may affect its conduct.
In this study, the design has not been affected by any cultural, social or gender-based characteristics.

15. Please state (i) who will have access to the data, (ii) how the data will be stored, how will access be restricted, and (iii) what measures will be adopted to maintain the confidentiality of the research participants and to comply with data protection requirements.

For studies where participant responses are recorded and transcribed at a later date, give details of storage and transcription. Please give some detail on how long data will be stored for and where. You should clarify how identifiable, anonymised research data and consent forms will be stored.

xi) Only the named investigators will have full access to the data obtained. The information obtained will be anonymised and identifiable data will not be stored through the study link and will not be passed on to anyone outside the study group. Anonymised data, only coded with a participant information number, with all identifying information removed, will be shared with collaborators to maximise the life-time value of the data generated for human health, in line with best practice for data sharing

xii) Anonymised data from the app will be stored on a secure external server. All files containing identifiable data will only be stored on University servers in password protected files separate from the study data. Access will be restricted by password-protection and data stored for 10 years.

xiii) Data will be anonymised with subjects being identified by a number rather than a name. Personal data including linkage of subject name and number will be held in a locked filing cabinet in the BHF Glasgow clinical research centre or as password−protected files saved on the University server, known only to the named investigators.

xiv) Recorded measurement sessions will be stored in password protected files saved on the University server, only know to named investigators.

Please tick to confirm that all relevant research data generated during and after the study will be collected and held in compliance with the General Data Protection Regulation (May 2018). [X]

Please tick to confirm that you have completed a data protection impact assessment form if required. [X]

If this is not required, please specify why not;

For guidance in this matter, please refer to the University Data Protection Office webpages:
https://www.gla.ac.uk/myglasgow/dpfoioffice/gdpr/

In regard to (ii) above, please clarify (tick one) how the data will be stored:

☐ **(a) in a fully anonymised form (link to participants broken),**

☐ **(b) in a linked anonymised form (data +/- samples linked to participant identification number but participant not identifiable to researchers), or**

X (c) in a form in which the participant could be identifiable to researcher.

If data are stored in linked anonymised form, please state who will have access to the code and personal information about the participant.

The data will be held securely for a period of ten years after the completion of the research project, or for longer if specified by the research funder or sponsor, in accordance with the University's Code of Good Practice in Research. (https://www.gla.ac.uk/research/strategy/ourpolicies/) Please tick and give further details below

Data will be stored for 10 years on University servers

16. To your knowledge, will the intended group of research participants be involved in other research? If so, please justify.
The study participants will not be involved in other research while they are undertaking this study.

17. Proposed starting date: 10-08-2020

Expected completion date: 31-12-2021

18. Please state location(s) where the project will be carried out, including all overseas laboratories, hospitals and other relevant locations.
The intervention will be conducted remotely with participants in their homes or another location at their convenience.

19. Please state briefly any precautions being taken to protect the health and safety of researchers and others associated with the project (as distinct from the research participants), e.g., where blood samples are being taken, home visits.
Not applicable for this study

20. Please state all relevant sources of funding or support for this study.
The work is funded by a PhD Scholarship to Ms Gabler from Beca Chile CONICYT and the BBC.

21a). Are there any conflicts of interest related to this project for any member of the research team? This includes, but is not restricted to, financial or commercial interests in the findings. If so, please explain these in detail and justify the role of the research team. For each member of the research team please complete a declaration of conflicts of interest below.

Researcher Name: __ Jason Gill _____ conflict of interest
No

Researcher Name: ___ Stuart Gray _____ conflict of interest
No

Researcher Name: ___Cindy Gray _____ conflict of interest
No

Researcher Name: ___ María Fernanda Gabler _____ conflict of interest
No

Researcher Name: ___ Ayan Merchant _____ conflict of interest
No

Researcher Name: ___ Hesham Alfeheid _____ conflict of interest
No

Researcher Name: ___ Phillip McBride _____ conflict of interest
No

21b). If there are any conflicts of interest, please describe these in detail and justify conducting the proposed study.

Not applicable

22. How do you intend to disseminate the findings of this research?
Please include details of how the study participants will be notified of the study finding. If they are not to be informed, please justify.

The results will form part of María Fernanda Gabler's PhD thesis. An associated paper, presentation and a poster will be made. In addition, we plan to present the findings in a peer-reviewed scientific journal. Results of the subgroup of participants recorded for the BBC will be disseminated on a BBC TV programme.

I confirm that have read the University of Glasgow's Data Protection Policy.
https://www.gla.ac.uk/myglasgow/dpfoioffice/

Please initial box	X

Name _ Maria Fernanda Gabler Trisotti _____ Date _20-07-2020_
(Proposer of research)
Please type your name on the line above.

For student projects:

I confirm that I have read and contributed to this submission and believe that the methods proposed and ethical issues discussed are appropriate.

I confirm that the student will have the time and resources to complete this project.

Name __Jason Gill _____ Date __20-07-2020_
(Supervisor of student)
Please type your name on the line above.

Please upload the completed and signed form, along with other required documents by logging in to the Research Ethics System at - https://frontdoor.spa.gla.ac.uk/login/

Appendix N: REFLEX Amendment 2

University of Glasgow | College of Medical, Veterinary & Life Sciences

Project Number:

Participant Identification Number for this trial:

Title of Project: **Effect of a home-based REsistance exercise vs a home-based FLEXbility exercise programme on muscular endurance and flexibility in healthy adults (REFLEX).**

For the consent process, this form will be shared on screen during a Zoom call between an investigator and participant. The questions read out loud to the participant, who will provide verbal responses. This verbal consent will be recorded and stored on a secure server. The researcher will tick the boxes below during the call an additional record.

Name of Researcher(s): Maria Fernanda Gabler Trisotti, Ayan Merchant, Hesham Alfeheid, Phillip McBride, Stuart Gray, Cindy Gray and Jason Gill.

CONSENT FORM

Version 3, 25/01/2021

Do you confirm that you have read and understood the Participant Information Sheet version 4 dated 25/01/2021?	☐
Do you confirm that you have read and understood the Privacy Notice version 1 dated 23/07/2020.	☐
Have you had the opportunity to think about the information and ask questions and do you understand the answers you have been given?	☐
Do you understand that your participation is voluntary and that you are free to withdraw at any time, without giving any reason, without your legal rights being affected?	☐
Do you confirm that you agree to the way your data will be collected and processed and that data will be stored for up to 10 years in University archiving facilities in accordance with relevant Data Protection policies and regulations?	☐

Do you understand that all data and information you provide will be kept confidential and will be seen only by study researchers and regulators whose job it is to check the work of researchers?	☐
Do you agree that your name, contact details and data described in the information sheet will be kept for the purposes of this research project?	☐
Do you understand that if you withdraw from the study, my data collected up to that point will be retained and used for the remainder of the study?	☐
Do you agree to your Zoom online assessment sessions to be recorded for verification purposes?	☐
Do you agree for an interview about your perceptions and experience of the study to be audio-recorded?	☐
Do you understand that the recorded interview will be transcribed word by word and the transcription stored for up to 10 years in University archiving facilities in accordance with Data Protection policies and regulations?	☐
Do agree to be contacted by the research team in around 6 months' time about taking part in another interview?	☐
Do you agree for the data you provide to be anonymously archived in the UK data archive or other approved archiving facilities, and that other researchers can have access to this data only if they have scientific and ethical approval, and agree to preserve the confidentiality of this information as set out in this form?	☐
Do you agree to take part in the study?	☐

_____ _____

Name of participant Date

_____ _____

Researcher Date

(1 copy for participant; 1 copy for researcher)

University of Glasgow | College of Medical, Veterinary & Life Sciences

Effect of a home-based REsistance exercise vs a home-based FLEXbility exercise programme on muscular endurance and flexibility in healthy adults (REFLEX).

PARTICIPANT INFORMATION SHEET
Version 4 (25/01/2021)

You are being invited to take part in a research study but before you decide whether to take part, it is important that you fully understand why the research is being carried out and what it will involve. This document is designed to help you decide whether you would like to participate. Please take time to read the following information carefully and discuss it with your friends and family. If anything is not clear or if you would like more information, please contact a member of the research team whose details are included at the bottom of the information sheet. If you decide to take part in this study, you will be given a copy of this Participant Information Sheet and the consent form to keep.

What is the purpose of the study?

Resistance exercise (e.g. lifting weights or using resistance bands) produces several health benefits and increases muscle mass, muscular strength and muscular endurance. Flexibility exercise improves joint flexibility (range of motion), postural stability and balance. Current physical activity guidelines recommend that adults do at least 150 minutes of moderate intensity aerobic physical activity (or 75 minutes of vigorous intensity) and weight-lifting activities on two or more days per week. Only a third of the population meet the physical activity guidelines. Therefore, finding a way of doing resistance exercise that is time efficient may increase the number of people that achieve the guidelines. The purpose of this study is to compare the effects of an app-based home-based resistance exercise programme vs a home-based flexibility programme on muscular endurance and flexibility in healthy adults.

Why have I been invited to participate?

You have been invited to take part in this study because you are a healthy adult aged between 18 and 64 years who does less than 30 min of vigorous physical activity per week, does not perform strength exercise and may benefit from a programme of resistance exercise. A total of 72 participants will be included in our study.

Do I have to take part?

No, it is up to you to decide whether or not to take part. Participation in this study is completely voluntarily. If you do decide to take part, you will be given this information sheet to keep and be asked to give verbal consent. If you decide to take part, you are still free to withdraw at any time and without giving a reason. If you are a student and decide not to participate will not affect your grades in any way.

What will happen to me if I take part?

You will be involved in a research study in which you will be randomly assigned (by a computer) to one of two groups. The resistance exercise group will undergo a 12-week home-based resistance exercise programme. The flexibility exercise group will be asked to follow a home-based flexibility exercise programme for 12-weeks. If you are assigned to the flexibility exercise group, you will be given the opportunity to undertake the home-based resistance exercise programme after you have completed the study. If you are randomly assigned to the resistance exercise group, you will have access to the flexibility exercise programme at the end of the study. A small group of participants will be asked to take part in an interview about their perception and experience about the exercise programme. A qualitative researcher will arrange an online interview (via Zoom or WhatsApp) and talk to you about your experiences of doing the study resistance exercise programme. You may be asked to demonstrate some of the exercises and talk about how you managed or did not manage to do them. The interview will last between 30 to 60 minutes. It will be audio recorded.
All participants will be asked to attend four or five online visits during the research period.

All participants will undertake the following measures:

d) Screening procedures:

Before enrolling in the study, you will be sent the Participant Information Sheet and the Consent form to read prior to the first online visit. During the first online visit we will:

- Explain what participation in the study involves and give you another opportunity to read the Participant Information Sheet.
- Provide an opportunity for you to ask questions about the study.
- As you to give verbal consent (which we will record) for your to participation in the study.
- Ask to complete the following questionnaires to determine if you fall into the group of people we wish to study and will also ensure that it is safe for you to participate:
    i. A health questionnaire regarding your personal details, family and personal medical history.
    ii. A "Physical Activity Readiness Questionnaire Plus (PARQ+)" to determine if it is safe for you to perform physical activity.
    iii. The "International Physical Activity Questionnaire (IPAQ)" to assess your current level of physical activity.

This visit will take around 30 minutes.

e) Experimental measurements:

Following the screening procedures and if you are eligible for the study, we will arrange a second online visit via Zoom with another member of the research team to perform an assessment of your muscular endurance and flexibility. You will also be sent a link to a study web app, in which you will be asked to log in with your ID number and password to complete questionnaires about your well-being, self-esteem and motivation to exercise.

During this Zoom session we will assess your muscle endurance with three tests: push-ups, plank and a half-squat; and your flexibility with a sit-and-reach test. You will be able to perform them at home and the researcher on the videocall will ask you to place your camera in a specific position for each test. You will be asked to perform the tests with a rest between

them in that specific order. You will be asked to until you cannot do them anymore (exhaustion or fatigue).

For the push-up test you will be asked to do as many push-ups you are able to do without pausing until you cannot do them anymore. You will perform a specific type push-up depending on your capacity, either: on your feet, on your knees, against a worktop and against a wall. If you are not able to perform two push-ups in a row with the correct technique, the test will end by the researcher and you will be told to stop. We will use the same type of push-up test for your measurements at each of the three times we perform this test in the study (e.g. if you do your first test with push-up against a worktop, all of your later push-up tests will be against a worktop, even if you are able to do push-ups on your knees by the end of the study). This is so we can make a direct comparison of any changes over the course of the study.

For the plank test you will be asked to lie on your stomach on the floor with your forearms and feet on the floor. You will be asked to lift your body on the air, keep it straight and hold the position as long as possible. If you are not able to keep the position the test will end by the researcher and you will be told to stop. The researcher will record the time you are able to hold the position.

For the half-squat test you will be asked to do a squat by resting your back on a wall. Your knees and legs need to be in 90 degrees and you will have your arms crossed on your chest. You will be askes to maintain the position as long as possible. If you are not able to hold the position, the test will end by the researcher and you will be told to stop. The researcher will record the time you are able to hold the position.

Your flexibility will be measured with the “sit-and-reach test”. You will be asked to sit down on the floor with your legs together and extended, and to reach to try to touch (or reach past) your toes. You will be asked to measure the distance of the tip of your fingers to the tip of your toes.

You will be able to access the tests videos with instructions on an email that will be sent to you. The researcher watching you will be counting the number of repetitions and the time achieved.

These tests will take around 30 minutes in total. These measurements will be repeated after 6 weeks and 12 weeks of the exercise programme. For the 6-week and 12-week measurements, it is very important that you do not tell the researcher taking your measurements which of the two exercise groups you were in, since this could influence the study results. All Zoom measurement sessions will be recorded for verification purposes. Only the research team will have access to them.

All participants will undertake the following:

You will be asked to follow an exercise programme for 12-weeks at your home or any other place of your choice. You will be asked to perform a minimum of 1 set/week for each of six exercises and will have the option to increase to 2 sets or 3 sets/week per exercise if you wish to do so. You will be able to distribute the exercise throughout the week as you please. For example, you can do all the exercises on a single day, or spread them over 3 days a week, 6

days a week, or any other choice as long as you do at least 1 set of each exercise per week. We encourage that you have at least one day of rest every week. The exercises that you do will depend on whether you have been randomly allocated to the flexibility exercise group or the resistance exercise group.

<u>For participants in the home-based flexibility exercise training programme:</u>
You will be asked to perform six stretching exercises per week (2 different leg exercises, 1 shoulders and arms, 1 chest, 1 back and 1 core). For each exercise you will be asked to stretch to the point of feeling tightness or slight discomfort, to hold the stretch for 30 seconds (each side) and repeat that twice (in total 60 seconds of stretching per side). You will have the opportunity to choose from a bank of flexibility exercises and will be able to access the exercise instruction videos via the web app. You will be asked to record on the web app each time you complete an exercise.

<u>For participants in the home-based resistance exercise training programme:</u>
You will be asked to perform 6 exercises per week (2 different leg exercises, 1 shoulder exercise, 1 chest exercise, 1 back exercise and 1 core exercise). You will be able to choose the exercise you want to do from a bank of resistance exercises that will be provided in the web app. Each exercise will have several levels. At the beginning of the programme you need to choose the level in which you are able to perform between 6-20 repetitions. During each exercise session during the programme you will be asked to complete as many repetitions of the exercise as possible. If you are able to perform more than 20 repetitions, you will be able to move to the next exercise level. For the plank exercise, you will be able to progress to the next exercise level once you are able to maintain the posture for 60 seconds. You will be able to access the instruction videos via the web app. You will be asked to record your exercise sessions on the web app, including the type of exercise, the level and number of repetitions (or duration) achieved. You will be able to see in the web app which exercises you still need to do for the week, the sets you have completed and the bonus sets (2-3 sets) you have completed for each exercise. You will also be able to see your progress throughout the study period.

For some exercises, you will require a resistance band. You will be sent, to an address of your choice, a set of 4 resistance bands with different levels of tension to enable you to do this.

Finally, a subgroup of participants will be asked to complete an online interview at the end of the exercise programme to help us understand more about your experiences of participation. For these participants, a qualitative researcher will contact you to arrange a time that is convenient for you for the online interview.

The following table explains which measurements will be taken in on which time point and number of visit and how long each visit is going take.

What will happen at this visit	**Week 0 (visit 1) 30 min**	**Week 0 (visit 2) 30 min**	**Week 6 (visit 2) 30 min**	**Week 12 (visit 3) 30 min**	**Post Week 12 (visit 4) 45 min**
Consent process	X				
PAR-Q	X				

IPAQ	X				
Health questionnaire	X				
Muscle endurance measurements		X	X	X	
Well-being, self-esteem and motivation questionnaires		X	X	X	
Qualitative Interview					X

What do I have to do?
If you are assigned to flexibility exercise group will ask that you follow the flexibility exercise programme and not to increase your levels of physical activity during the period of the study apart from this. If you are assigned to the resistance exercise programme we will ask that, other than undertaking the home-based resistance exercise programme, you continue with your usual lifestyle and do not to increase your levels of other aspects physical activity during the period of the study. After the study period, all participants will have access to all exercises (flexibility and resistance) via the web app. If you get selected, you could be asked to undertake an interview regarding perception and experience during the study period.

What are the possible disadvantages and risks of taking part?
Exercise has a very small risk in healthy adults, although exercise at maximal capacity could carry a very small risk of inducing myocardial ischaemia ("heart attack"). The screening procedure helps to minimise that risk. The primary symptom of myocardial ischaemia is chest pain on exertion. If you experience any unusual sensations in your chest, feel unwell or do not want to continue for any other reason during exercise you should cease exercising immediately. You may also feel some muscle soreness after the muscle endurance measurements and after the first few sessions of resistance exercise training programme.

What are the possible benefits of taking part?
This study will help increase understanding about the effect of the minimum amount of resistance and flexibility exercise needed to increase muscle endurance and flexibility, and to understand better peoples' behaviour and experiences about home-based exercise resistance and flexibility exercise programmes. The information gained during the study will allow us to give you feedback about your own muscle endurance and flexibility, and your well-being, as well as how these change in response to an exercise programme.

Will my taking part in this study be kept confidential?
All information which is collected about you, or responses that you provide, during the course of the research, will be kept strictly confidential. You will be identified by an ID number, and any information about you will have your name and address removed so that you cannot be recognised from it. Any data in paper form will be stored in locked cabinets in rooms with restricted access at the University of Glasgow. All data in electronic format will be encrypted and stored on secure password–protected computers. The zoom sessions recordings will be stored on the University of Glasgow servers and will be password protected. Only the research team will have access to them if needed. No one outside of the research team or

appropriate governance staff will be able to find out your name, or any other information which could identify you. Data will be anonymised and no personal data will be presented.

What will happen to my data?
Researchers from the University of Glasgow collect, store and process all personal information in accordance with the General Data Protection Regulation (2018). If you withdraw from the study, your data that has been collected at to that point will be retained and used by the researchers. The data will be stored in archiving facilities in line with the University of Glasgow retention policy of up to 10 years. After this period, further retention may be agreed or your data will be securely destroyed in accordance with the relevant standard procedures.

What will happen to the results of the research study?
The results will be coded (for anonymity) and analysed by the research team before being reported in research reports. The results will form part of María Fernanda Gabler's PhD thesis. Associated papers, presentations, and posters will be made of the findings. In addition, the results may be published in a peer-reviewed scientific journal, however, you will not be identified by name in any publications. You will be informed about the results of the study and a copy of the published results will be sent to you upon request by the research team.

Who is organising and funding the research?
The work is organised by the Prof Jason Gill, Dr Stuart Gray, Ms María Fernanda Gabler in the Institute of Cardiovascular and Medical Sciences and by Prof Cindy Gray in the Institute of Health and Wellbeing in the University of Glasgow. The work is funded by a PhD Scholarship to Ms Gabler from Beca Chile CONICYT.

Who has reviewed the study?
To protect your safety, rights, wellbeing and dignity, all research by the University of Glasgow is looked at by an independent group of people. This study has been reviewed and approved by the College of Medical Veterinary and Life Sciences Ethics Committee at the University of Glasgow.

Contact for Further Information
Any questions about the procedures used in this study are encouraged. If you have any doubts or questions, please ask for further explanations by contacting one of the investigators below:

Maria Fernanda Gabler Trisotti
Email: m.gabler-trisotti.1@research.gla.ac.uk
Tel: TBC

Professor Jason Gill
Email: jason.gill@glasgow.ac.uk

Independent Contact information:
Carlos Celis-Morales
Email: carlos.celis@glasgow.ac.uk
Tel: 0141 330 4201

Thank you for reading the Participant Information Sheet.

Appendix O: REFLEX Amendment 3

University of Glasgow | College of Medical, Veterinary & Life Sciences

College of Medical, Veterinary & Life Sciences Ethics Committee for Non-Clinical Research Involving Human Participants

APPLICATION FORM FOR ETHICAL APPROVAL

NOTES:
THIS APPLICATION FORM SHOULD BE TYPED NOT HAND WRITTEN.

ALL QUESTIONS MUST BE ANSWERED. "NOT APPLICABLE" IS A SATISFACTORY ANSWER WHERE APPROPRIATE.

The primary remit of this committee is the review of non-clinical research. However, clinical research involving humans, their tissue or data that falls outwith the remit of the NHS Research Ethics Service will also be reviewed by the MVLS committee. If your project involves NHS facilities, or is clinical research, then you must ensure that NHS REC review is not needed before applying to the MVLS REC. The review of the MVLS REC does not obviate the need for NHS review.

Please note – it is now a requirement for a Data Protection Impact Assessment (DPIA) to be completed where processes are likely to involve high-risk personal data. This is likely to be the case for many research projects. If so, you must complete this before submission for ethical review. For research involving personal data, you should give participants a Privacy Notice as well as a Participant Information sheet.

Information on DPIAs and Privacy Notices
https://www.gla.ac.uk/myglasgow/dpfoioffice/gdpr/dpia/
https://www.gla.ac.uk/myglasgow/dpfoioffice/gdpr/privacy%20notices/

Information on the General Data Protection Regulation (GDPR)
https://www.gla.ac.uk/myglasgow/dpfoioffice/

Information on Research Data Management
https://www.gla.ac.uk/myglasgow/datamanagement/

University of Glasgow policy on surveys of students for research purposes
https://www.gla.ac.uk/myglasgow/senateoffice/policies/studentengagement/studentsurveys/policyonstudentsurveys/

Project Title:

Effect of a home-based REsistance exercise vs a home-based FLEXbility exercise programme on muscular endurance and flexibility in healthy adults (REFLEX).

Has this application been previously submitted to this or any other ethics committee? No

If 'Yes', please state the title and reference number.

Is this project from a commercial source, or funded by a research grant of any kind?
No

If 'Yes', has it been referred to Research Support Office?
Has it been allocated a project Number?
Give details and ensure that this is stated on the Informed Consent Form.

Insurance Coverage and Restrictions:
Please Note: The Insurance restrictions set out below relate to research of a clinical nature. Non clinical research is not subject to restriction and no additional insurance is required

The University insurance cover is restricted under specific circumstances, including, but not limited to the following -

- **work involving the use of research participants outside Great Britain, Northern Ireland, the Channel Islands or the Isle of Man**
- **the use of hazardous materials**
- **non CE marked medical devices**
- **molecules or compounds developed and manufactured at the University of Glasgow**
- **number of participants in excess of 5000**
- **work involving research participants known to be pregnant at the time of the project**

All such projects must be referred to Research Support Office and coverage confirmed before ethical approval is sought. Please contact Dr Debra Stuart in the University's Research Governance Office: debra.stuart@glasgow.ac.uk

Please tick here if this project has been referred to the Research Support Office to confirm adequate insurance coverage.

Please tick here if the project includes a technique involving incision, piercing of skin, insertion of a device or object, ingestion of medicines or food substances. ☐

Please tick here if the project involves work on human participants that will be conducted within the Imaging Centre of Excellence (ICE) ☐

Date of submission:
20 July 2020

Name of all person(s) submitting research proposal:
Professor Jason Gill
Dr Stuart Gray
Prof Cindy Gray
María Fernanda Gabler Trisotti
Ayan Merchant
Hesham Alfeheid
Phillip McBride

Position(s) held:

Professor of Cardiometabolic Health	JG
Lecturer in Exercise and Metabolic Health	SG
Interdisciplinary Professor of Health and Behaviour	CG
PhD Student Cardiovascular Sciences (Research)	MFG
PhD Student Cardiovascular Sciences (Research)	AM
PhD Student Cardiovascular Sciences (Research)	HA
PhD Student Health Science	PM

School/Group/Institute/Centre:
Institute of Cardiovascular and Medical Sciences (JG, SG, MFG, AM and HA)

Institute of Health and Wellbeing (CG)
University of Leicester (PM)

Address for correspondence relating to this submission:
BHF Glasgow Cardiovascular Research Centre, University of Glasgow, Institute of Cardiovascular and Medical Sciences, College of Medical, Veterinary and Life Sciences, Glasgow, G12 8TA

Email address: Jason.Gill@glasgow.ac.uk
Stuart.Gray@glasgow.ac.uk
…….. Cindy.Gray@glasgow.ac.uk
m.glabler-trisotti.1@research.gla.ac.uk
a.merchant.1@research.gla.ac.uk
h.alfeheid.1@research.gla.ac.uk
pm381@le.ac.uk

Name of Principal Researcher (if different from above, e.g., Student's Supervisor):
Jason Gill

Position held:
Professor of Cardiometabolic Health

Undergraduate student project:
No If 'Yes', please state degree being undertaken:

Postgraduate student project:
Yes If 'Yes', please state degree being undertaken:

PhD Cardiovascular Sciences (Research)

For postgraduate student projects, please state whether this a research (PGR) or taught (PGT) degree:

PGR

1. Describe the purposes of the research proposed. Please include the background and scientific justification for the research. Why is this an area of importance? Please try to describe why the research is novel and experimental.

We do not need a comprehensive review of the topic area: a short summary that is sufficient for the reviewers to understand the study is sufficient. Bullet points and references to more detailed texts are both acceptable.

Studies have shown that regular resistance training can lead to a variety of health benefits including increases in muscle size and strength, reductions on body fat, increased metabolic rate, glycaemic control, decreased blood pressure and improved blood lipid profiles (1–3). Because of this, national and international physical activity guidelines recommend undertaking muscle strengthening activities involving major muscle groups two days a week or more, alongside at least 150 minutes per week of moderate intensity physical activity (or 75 minutes per week of vigorous intensity physical activity)(4,5). However, in the UK, while about two-thirds of men and almost three-fifths of women over met the guidelines for aerobic exercise, less than a third of men and a quarter of women achieve the guidelines for muscle-strengthening exercise in 2016 (6,7).

Why participation in muscle-strengthening exercise is low is not clear but people identify several barriers including the lack of time (8,9), the effort involved (8,9), lack of purpose, pain due to injury, negative experiences of prescriptive exercise, apathy (10), illness, injury inclement weather and work commitment (11). In addition, some women have expressed a worry of looking 'manly' or 'bulking up' if they undertake resistance exercise (12). A further potential barrier is lack of access to a gym with appropriate equipment to perform resistance exercise, or dislike of a gym setting. Thus, identifying approaches to find a safe, enjoyable and accessible programme that minimises the burden of performing resistance exercise, and identifying a minimal amount of resistance training which can provide benefits is a key issue which could help more people to undertake muscle strengthening exercises.

The dose-response relationship between volume of resistance exercise and gains in muscle size and strength recommended by the ACSM for optimal benefits is two to three times per week. However, the largest gains are seen between undertaking zero and one session per week, with decreasing gains beyond this (13). Substantial increases in strength (~20%) have been observed with a single session of exercise per week if it is performed to momentary failure; in this context, the specific load does not appear to influence the magnitude of the adaptations (14). Furthermore, it has been found that the frequency of resistance exercise does not influence the magnitude of change in strength or hypertrophy if the volume of exercise (sets per week) is equated (15,16).
Thus, a single set of exercise per muscle group per week appears to be an effective dose for adaptation, and programmes using this approach could potentially address the barrier of a lack of time. However this in itself, does not necessarily help overcome the need for access to a gym facility with strength training equipment. Developing protocols that can be performed at home may help with this. Most of the evidence in the literature for home-based resistance exercise comes from studies in older (>65 years) adults (17) but there is limited evidence in younger (18-64 years) volunteers.

One approach to overcome barriers of daily time commitment and access to specialised facilities/equipment is to carry out a resistance exercise programme with low time commitment and performed at home with minimal equipment. This may be a more convenient way to undertake resistance exercise and improve long term adherence. We first attempted to study in this in our ongoing ONE study (MVLS ethics approval number 200180137). Preliminary quantitative data of the ONE Study (with n =17 completed out target n of 54) shows that one minute of resistance exercise per day produces a trend increase in muscle endurance after 12 weeks. Preliminary qualitative data shows that participants enjoyed the programme, but would prefer to have more flexibility in how the exercises were distributed throughout the week, a greater choice of exercises, and the potential to undertake more than this minimum prescription. The current study aims to extend the ONE study in light of these qualitative insights, and to deliver the intervention completely online (via an app), given current social distancing restrictions. This will also help trial the online delivery platform for future widescale implementation. We plan to deliver this as a randomised control trial (RCT) with a comparison group undertaking a flexibility exercise programme (which would be expected to improve flexibility but not muscular endurance).

The main aim of this study is to compare the effects of an app-based home-based resistance exercise programme vs a home-based flexibility programme on muscular endurance (number of press-ups, bodyweight squats and crunches achieved, assessed online during a zoom call) and flexibility (sit and reach, assessed online during a zoom call) in healthy adults. Secondary aims are a) to determine participants' adherence to both exercise programmes, b) to determine participants' choice of weekly exercise volume (compared to minimum prescription) in both exercise programmes c) to determine participants' distribution of exercise throughout the week in both exercise programmes d) to determine the effects of a exercise programmes on well-being, and finally e) to determine participants' perceptions, feelings, thoughts, enjoyment, tolerance and acceptability of both exercise programmes.

This study is being undertaken in collaboration with BBC Scotland for a programme called "The Truth About Getting Fit at Home" and a subset of participants will feature on the programme.

1. Saric J, Lisica D, Orlic I, Grgic J, Krieger JW, Vuk S, et al. Resistance Training Frequencies of 3 and 6 Times Per Week Produce Similar Muscular Adaptations in Resistance-Trained Men. J Strength Cond Res [Internet]. 2018 Oct;1. Available from: https://journals.lww.com/nsca-jscr/Fulltext/publishahead/Resistance_Training_Frequencies_of_3_and_6_Times.95086.aspx
2. Kraemer WJ, Ratamess NA, French DN. Resistance training for health and performance. Curr Sports Med Rep [Internet]. 2002;1(3):165–71. Available from: https://doi.org/10.1007/s11932-002-0017-7
3. Ashton RE, Tew GA, Aning JJ, Gilbert SE, Lewis L, Saxton JM. Effects of short-term, medium-term and long-term resistance exercise training on cardiometabolic health outcomes in adults: Systematic review with meta-analysis. Br J Sports Med. 2020;54(6):341–8.
4. World Health Organization. Global Recommendations on Physical Activity for Health [Internet]. 2011 [cited 2019 Mar 28]. p. 1. Available from: https://www.who.int/dietphysicalactivity/physical-activity-recommendations-18-

64years.pdf?ua=1
5. PCSFN. Physical Activity Guidelines for Americans [Internet]. 2019 [cited 2020 Jul 3]. Available from: https://www.hhs.gov/fitness/be-active/physical-activity-guidelines-for-americans/index.html#:~:text=For substantial health benefits%2C adults,or an equivalent combination of
6. Scholes S. Health Survey for England 2016 Physical activity in adults [Internet]. 2017. 20 p. Available from: https://files.digital.nhs.uk/publication/m/3/hse16-adult-phy-act.pdf
7. Bromley C, Dowling S, Gray L, Hinchliffe S, Hughes T, Leyland A, et al. The Scottish Health Survey [Internet]. Vol. 1, The Scottish Health Survey. 2012. Available from: www.scotland.gov.uk
8. Hurley KS, Flippin KJ, Blom LC, Bolin JE, Hoover DL, Judge LW. Practices, Perceived Benefits, and Barriers to Resistance Training Among Women Enrolled in College. Int J Exerc Sci [Internet]. 2018;11(5):226–38. Available from: http://www.ncbi.nlm.nih.gov/pubmed/29795737%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC5955292
9. Trost SG, Owen N, Bauman AE, Sallis JF, Brown W. Correlates of adults' participation in physical activity: review and update. Med Sci Sport Exerc. 2002;34(12):1996–2001.
10. Hancox JE, Van Der Wardt V, Pollock K, Booth V, Vedhara K, Harwood RH. Factors influencing adherence to home-based strength and balance exercises among older adults with mild cognitive impairment and early dementia: Promoting activity, independence and stability in early dementia (praised). PLoS One. 2019;14(5):1–19.
11. Tulloch H, Sweet SN, Fortier M, Capstick G, Kenny GP, Sigal RJ. Exercise facilitators and barriers from adoption to maintenance in the diabetes aerobic and resistance exercise trial. Can J Diabetes [Internet]. 2013;37(6):367–74. Available from: http://dx.doi.org/10.1016/j.jcjd.2013.09.002
12. Dworkin SL. A woman's place is in the ... cardiovascular room?? Gender relations, the body, and the gym. In: Athletic intruders: ethnographic research on women, culture and exercise. Albany: State University of New York Press; 2003. p. 131–58.
13. Westcott W. ACSM STRENGTH TRAINING GUIDELINES. ACSMs Health Fit J [Internet]. 2009 Jul;13(4):14–22. Available from: http://insights.ovid.com/crossref?an=00135124-200907000-00007
14. Ismail AD, Aba Alkhayl FF, Wilson J, Johnston L, Gill JMR, Gray SR. The effect of short duration resistance training on insulin sensitivity and muscle adaptations in overweight men. Exp Physiol [Internet]. 2019;(October 2018):2–7. Available from: http://doi.wiley.com/10.1113/EP087435
15. Gentil P, Bottaro M, Giessing J, Steele J, Fisher J, Campos MH, et al. Effects of equal-volume resistance training with different training frequencies in muscle size and strength in trained men. PeerJ. 2018;6:e5020.
16. Grgic J, Schoenfeld BJ, Davies TB, Lazinica B, Krieger JW, Pedisic Z. Effect of Resistance Training Frequency on Gains in Muscular Strength: A Systematic Review and Meta-Analysis. Sport Med [Internet]. 2018;48(5):1207–20. Available from: https://doi.org/10.1007/s40279-018-0872-x
17. Kis O, Buch A, Stern N, Moran DS. Minimally supervised home-based resistance training and muscle function in older adults: A meta-analysis. Arch Gerontol Geriatr [Internet]. 2019;84(March):103909. Available from: https://doi.org/10.1016/j.archger.2019.103909
18. ACSM. ACSM's Guidelines for Exercise Testing and Prescrption. 10th Editi. Wolters Kluwer; 2016.

19. Radaelli R, Fleck SJ, Leite T, Leite RD, Pinto RS, Fernandes L, et al. Dose-Response of 1, 3, and 5 Sets of Resistance Exercise on Strength, Local Muscular Endurance, and Hypertrophy. J Strength Cond Res [Internet]. 2015;29(5). Available from: https://journals.lww.com/nsca-jscr/Fulltext/2015/05000/Dose_Response_of_1,_3,_and_5_Sets_of_Resistance.25.aspx
20. Ritchie J, Lewis J, McNaughton Nicolls C, Ormston R, editors. Qualitative Research Practice: A Guide for Social Science Students and Researchers. 2014th ed. Sage; 2003.

2. Describe the design of the study and methods to be used. If multiple methods are to be used, please describe them each in turn. Include details of the study sample size and how you decided this. Statistical advice should be obtained if in doubt.

The study design is an RCT with two groups, a flexibility exercise group (which will be the comparison group), and a resistance exercise group. Mixed methods will be used.
Participants will be male and female, aged between 18-64 years old, who perform ≤ 30 min a week of aerobic vigorous physical activity (compendium of physical activities) and do not to perform any kind of resistance exercise. Exclusion criteria will include failure of the Physical Activity Readiness Questionnaire Plus (PAR-Q+), performing 30 minutes or more of vigorous intensity exercise from the IPAQ, having a job that compromises manual labour, a history of cardiovascular disease, diabetes and any other illness that would prevent the participation in a resistance exercise or flexibility exercise programme.
After screening, participants will undergo baseline measurements (online), and after that they will be randomised into two conditions: a flexibility exercise group (comparison group) and a resistance exercise group. Participants will then undertake a 12-week flexibility or resistance exercise intervention. Baseline measurements will be repeated after 6 and 12 weeks. Assessments will include muscle endurance, adherence, quality of life and participants perceptions, feelings and thoughts of the intervention.

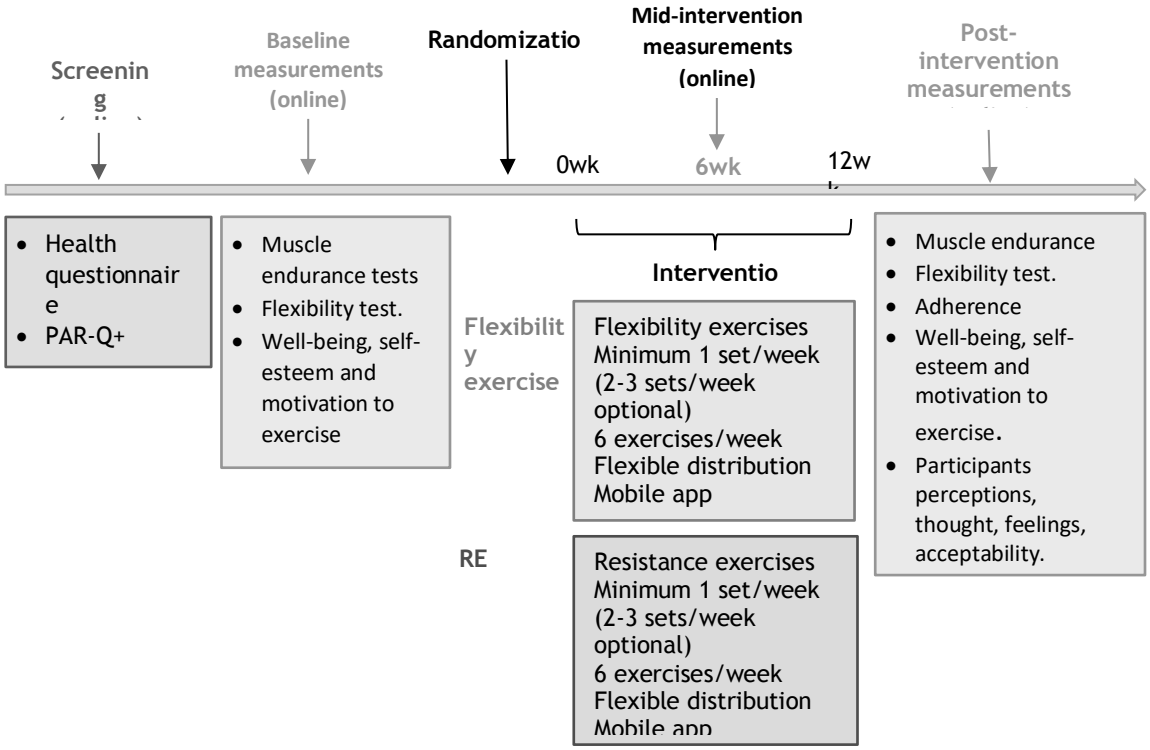


Figure 1. Overview of study protocol.

Assessments

IX. Screening measurements (appendix 1):

13) Health questionnaire:

(undertaken at 1 time-point; screening)

Participants will be asked to fill a health questionnaire to determine if they are suitable to participate in the study.

14) PAR-Q+:

(undertaken at 1 time-point; screening)

Participants will be asked to fill the Physical Activity Readiness Questionnaire Plus to determine their safety to undertake physical activity.

15) IPAQ-SF:

Participants will be asked to fill the International Physical Activity Questionnaire (short form) to determine their level of physical activity. We will ask an additional question to determine if participants are participating in any resistance exercise.

X. Baseline, 6 weeks and post-intervention measurements:

1) Muscle endurance:

(undertaken at 0, 6-weeks and 12 weeks)

Muscular endurance will be measured at baseline, 6 weeks and 12 weeks. Three tests will be used: i) Push up test: maximum number of press-ups (undertaken on feet, on knees, against a worktop or against a wall, depending on individual capacity); ii) Half-squat test: maximum time achieved in a half-squat against a wall (participant will have to maintain a squat position with 90 degree knee flexion and with their back against a wall as long as possible depending on their individual capacity); iii) Plank test: maximum time achieved on a plank (participant will have to maintain the plank position with forearms and feet as long as possible depending on their individual capacity). Number of press-ups will be the primary outcome, the other measures will be secondary outcomes. The measurement will be via zoom, with the participant and research team member blinded to the intervention group on each end of the videocall. See SOP attached.

2) Flexibility

(undertaken at 0, 6-weeks and 12 weeks)

Flexibility will be assessed via a sit-and-reach test, via zoom at baseline, 6 and 12 weeks. This will be a secondary outcome.

3) Adherence:

Participants will record all of their exercise sessions as they complete them using an online app. Adherence will be assessed at 12 weeks from the in-app data using the following outcomes:

- Percentage of the minimum number of exercise sets prescribed undertaken.
- Percentage of participants that drop-out from the study. Drop out considered as: a) participants who no longer record their exercises on the app, but complete the outcome measurements; and b) participants who neither record their exercises nor complete the outcome measurements.

4) Choice of exercise volume and progression (as assessed at 12 weeks from the in-app data)**:**

- Number of sets of exercise undertaken relative to minimum prescribed dose during each week of the intervention.

5) Choice of distribution of exercise throughout the week (as assessed at 12 weeks from the in-app data)**:**

- Distribution of participants undertaking their exercise different numbers of days of week throughout the intervention period.

6) Well-being, self-esteem and motivation to exercise questionnaires
(undertaken at 0, 6 weeks and 12 weeks)

Well-being will be assessed using the Cantril Ladder, WEMWBS questionnaire and subjective vitality scale. Self-esteem will be assessed using Rosenberg's self-esteem questionnaire, and motivation to exercise will be assessed using the adapted Behavioural Regulations in Exercise Questionnaire (BREQ-2) questionnaire. The questionnaires will be delivered through the app.

7) Participants' perceptions, feelings, thoughts, enjoyment, tolerance and acceptability of a home-based resistance exercise programme
(after the intervention period)

Semi-structured online interviews (each lasting 30-60 minutes) will be conducted with a subset of participants in both exercise groups (n = 18-24 participants overall). The interviews will be conducted via Zoom or WhatsApp, both recently approved by the University for online data collection during the COVID 19 pandemic, and depending on people preferences. A topic guide will be used to guide discussions – indicative questions are provided in appendix 3.

Intervention

All participants will be asked to follow a 12-week home-based exercise programme. Participants will be asked to perform a minimum amount of resistance or flexibility exercise of 1 set/week for each of six exercises and will have the opportunity to increase their volume of exercise to 2 sets or 3 sets/week per exercise if it is their choice. In addition, participants will be able to distribute the exercises during the week according to their preference (all in one day or spread over several days of the week, etc.). Participants will be encouraged to have a minimum of one day of rest per week. If participants choose to increase to 2 or 3 sets/week some examples will be given to distribute the exercises throughout the week including:

a) Two or three sets of the same exercise per day with a minimum of one minute of rest between sets.

b) One set of two or three different exercises per day.

c) Four or six sets per day of 4 different or 3 different exercises (3 sessions a week) with 4 days of rest.

5) Flexibility exercise group (FE [comparison] group).

The flexibility exercise group will be asked to perform 6 flexibility exercises per week (2 different for legs, 1 shoulder and arms, 1 chest, 1 back and 1 core). Participants will be able to choose from a bank of flexibility of exercises to perform. Participants will perform passive static stretching exercises (appendix 4). They will be asked to stretch to the point of feeling tightness or slight discomfort, to hold the stretch for 30 seconds (each side), and repeat that twice (in total 60 seconds of stretching per side) according to the ACSM's guidelines for flexibility exercises (18).

6) Resistance exercise intervention (RE group)

Participants in the resistance exercise group will be asked to perform a total of 6 exercises per week (2 different leg exercises, 1 shoulder exercise, 1 chest exercise, 1 back exercise and 1 core exercise, Appendix 4). Participants will have the opportunity to choose the exercise they want to perform from a bank of exercises that will be provided. Each exercise will have several levels. At the beginning of the exercise programme, participants will be asked to choose a level in which they are able to perform between 6-20 repetitions. During each exercise session in the programme, they will be asked to complete as many repetitions as possible. If the participant is able to perform >20 repetitions, they will be able to progress to the next exercise level. For the plank, participants will progress to the next level of difficulty once they can maintain the posture for 60 seconds. Participants will receive a complete set of resistance bands (4 bands of different tensions) to perform the band exercises.

Video and written instructions for all exercises (flexibility and resistance) will be delivered via an app which will be free and only available for study participants. Participants will have access only to the bank of exercise for their intervention arm (i.e. flexibility or resistance). Participants will be asked to record each exercise session they perform during the 12-week exercise programme, recording type of exercise, level, number of repetitions or time (for plank exercises) achieved and Rating of Perceived Exertion on a scale of 1-10 (RPE). The app will send participants reminders about the exercise schedule and targets. Participants will also be able to access their own records in the app, and the investigators will be able to access all data inputted into the app via the 'back end'. For all data in the app, participants will be only identified by a study number and no identifiable personal information will be recorded.

Once the study period is over, all participants will have access to all exercises through the app (flexibility and resistance exercises) and the exercise diary. The data after the study period will not be collected and will not be used by the research team.

Sample size and power calculation

There are limited published data available evaluating the effects of resistance exercise on muscular endurance. A previous investigation has reported an 8.7 kg increase for muscle strength for bench press after a resistance exercise training, with a 9.9 kg SD for change in muscle strength (19); thus with power of 90% and an alpha of 0.05, groups of 29 participants will be needed. Considering 20% of drop out during the study, we propose to recruit 36 participants per group with a total of 72 participants. Preliminary data from 7 participants

from the ONE Study showed a difference of 8.5 repetitions for press-up endurance (over primary outcome) pre to post-intervention with a SD of 7.06 in baseline press-up endurance. While this low n means that we are not confident to use these data in our power calculation, these data suggest that we would require 16 participants per group to detect this difference with 90% power and alpha 0.05. Our power calculation using muscular strength as the outcome is likely therefore to be conservative.

Data analysis

The primary outcome for the study will be change in number of press-ups from baseline to 12-weeks. Secondary outcomes will be change in number of press-ups from 0-6 weeks and 6-12 weeks; and changes in time achieved on the half-squat test and plank test, distance achieved in the sit-and-reach test and change in well-being between all timepoints. Differences between groups in these measures will be assessed by 2-way ANOVA (group x time) with repeated measures on the time factor. We will report descriptive data for adherence, volume and progression of exercise, and distribution of exercise throughout the week. A subset (likely n = ~10) of participants will feature on the BBC programme. We will perform sensitivity analyses to determine whether changes observed in these participants differed from the wider group.

Qualitative interviews data will be transcribed by an external company approved by the University of Glasgow (e.g. 1st Class Transcription Services). Anonymised transcripts will be analysed thematically using an adapted Framework approach (20) using NVivo 12 software to determine participants' perceptions, feelings, thoughts, enjoyment, tolerance and acceptability regarding both exercise programmes.

3. How will potential participants in the study be (i) identified, (ii) approached and (iii) recruited? Give details for cases and controls separately, if appropriate

You should explain how a person becomes identified as a potential participant and then an enrolled participant. If the initial approach uses a poster, social media or email then the materials should be submitted for review.

xiii. **Identification:** Volunteers will be recruited via our study partners, the BBC, who will advertise the study online and via social media, and via the research team's personal contacts and snowballing. Interested parties will be directed to a weblink where they will input their level of physical activity and age. If participants do not meet initial inclusion criteria (i.e. age 18-64, <30 min/week vigorous physical activity, no resistance exercise), they will receive an automated message thanking them for their interest but saying they are not eligible. If they do meet these inclusion criteria, they will be asked to input their contact details.

xiv. **Approach:** After an initial expression of interest and eligibility check, study volunteers will be approached by email or telephone, and they will be sent the PIS and consent form via email. Following this, an appointment will be made for a video call (Zoom or WhatsApp) for detailed screening (health history questionnaire, PAR-Q+ and IPAQ) and an opportunity to ask questions.

xv. **Recruitment:** Participants will initially be contacted by phone, email or a video call and will be screened on an online visit 1 (via Zoom or WhatsApp) according to inclusion and exclusion criteria. During the first visit participants will be given a detailed explanation of the study, including risks and benefits. They will be given a study information sheet and a consent form, which they can read in detail at their convenience and ask questions about the study. Verbal consent will be requested during the Zoom/WhatsApp call and will be recorded and stored at the university servers. After giving verbal consent, the researcher will share the screen on the Zoom video call to show the participant the screening questionnaires. The researcher and the participant will then complete a "Health Questionnaire", PAR-Q+ and IPAQ-SF assess the participant's eligibility for the study (See "Health questionnaire", "PAR-Q+" and "IPAQ-SF" documents attached). If the participant is suitable for the study, address details will be requested, to enable postage of the study materials (resistance bands for the resistance exercise group).

4. Describe the research procedures as they affect the research participants and any other parties involved. It should be clear exactly (i) what will happen to the research participant, (ii) how many times and (iii) in what order. If your research involves administration of a substance, for example saline, topical anaesthetic etc. then please give full details on the substance and manufacturer. Reference to an existing standardised operating procedure is acceptable.

Volunteers will be asked to attend online visits on four/five occasions.

Screening, online visit 1 – Participants will be asked to attend an online visit via Zoom for a brief screening procedure, to determine if they are suitable for the study. An explanation of study including screening with inclusion/exclusion criteria. The volunteer information sheet and written informed consent will be given. Verbal consent will be obtained. After consent is given screening procedure will proceed as described above (Section 3). This part of session 1 will take 30 min.

Baseline measurements, online visit 2 – On another online visit, if the participant is suitable for the study the researcher will send a web link, the "study link" and a unique code to log in to take the following measurements. A well-being questionnaire (WEMWBS) will be accessed and completed via the link. After that muscle endurance tests will be assessed. These measurements will be made by a researcher blinded to the group allocation of the participant. Participants will be asked to perform four tests (push-ups test, half-squat test, plank test and sit-and-reach) with two minutes of rest between them. The tests will be performed in that order for all participants. Participants will have access to videos and sound signals (with the specific cadence for each test) with instructions for the tests via the link. The participants will be asked to put their camera in a specific position for each test. The session will take 30 min and it will be recorded for verification purposes.

Exercise intervention (week 1 to week 12) – The exercise intervention will follow as the description above (Section 2).

Intervention Exercise diary record (week 1 to week 12) – All participants in the study will be asked to fill an exercise diary for the duration of the intervention (12 weeks) using the study app provided by the research team.

Mid-intervention measurements (6-week), online visit 3 – A well-being questionnaire (WEMWBS) will be accessed via the link. After that muscle endurance tests will be assessed by a researcher blinded to the group allocation. Participants will be asked to perform four tests (push-ups test, sit ups test, squat test and sit-and-reach) with two minutes of rest between them. The tests will be performed in that order for all participants. Participants will have access to videos and sound signals (with the specific cadence for each test) with instructions for the tests via the link. The participants will be asked to put their camera in a specific position for each test. The session will take 30 min and it will be recorded for verification purposes.

Post-intervention measurements (12-week), online visit 4 - A well-being questionnaire (WEMWBS) will be accessed via the link. After that muscle endurance tests will be assessed by a researcher blinded to the group allocation. Participants will be asked to perform four tests (push-ups test, sit ups test, squat test and sit-and-reach) with two minutes of rest between them. The tests will be performed in that order for all

participants. Participants will have access to videos and sound signals (with the specific cadence for each test) with instructions for the tests via the link. The participants will be asked to put their camera in a specific position for each test. The session will take 30 min and it will be recorded for verification purposes.

Qualitative Interviews (12-week), online visit 5 – A subgroup of participants will be asked to be interviewed online by a member of the research team. Each interview will take between 30 and 60 minutes and participants will be asked to demonstrate and talk the interviewer through their exercise programme (if possible), describe how they fit the exercise programme into their normal routine, and what has helped/prevented them from doing so (see attached interview guide).

5. What are the ethical considerations involved in this proposal? You may wish, for example, to comment on issues to do with consent, confidentiality, risk to participants, etc.

Consent and participation
Participants will voluntarily consent to the study and will be told that they can withdraw from the study anytime they want without consequence or need to provide a reason. Verbal consent will be taken, which will be recorded and stored in the University of Glasgow's servers.

Exercise testing and intervention
Preliminary screening will exclude any subjects that fail the PAR-Q+, do > 30 min of vigorous physical activity, do any resistance exercise, any participant with a history of cardiovascular problems and those known to exhibit major risk factors for CHD. Exercise will be at maximal level at some points during the study and there is a possibility that the subject could suffer from acute muscle soreness. Participants in the flexibility exercise group will have access to the resistance exercise intervention (videos and instructions) after completion of the study period. Participants in the resistance exercise group will have access to the flexibility exercises after the study period.

Anonymity and confidentiality
The information obtained will be anonymised and individual information will not be passed on to anyone outside the research members. Each participant will be given a number to ensure anonymity for the results analysis. Participants will be asked to log on to the app with their ID number and unique code. All data stored from the app will therefore contain no personal identifiable information with participants only identified by a study ID. Personal identifiable data will be obtained by a member of the research team and will be stored in a different document protected by a password. This document will be stored in the University of Glasgow's servers. Only members of the research team (MFGT, JG, CG, SG) will have access to personal identifiable data.

Data retention
In case of withdrawal at any state of the study, data obtained from participants will be kept by the researchers. Data from volunteers that have been excluded from the study during the screening procedure will not be stored by the researches and will be destroyed.

6. Outline the reasons why the possible benefits to be gained from the project justify

any risks or discomforts involved.

The risks and discomfort associated with participating in this study are minor and the beneficial effect outweighs the small existing risk of participating. Subjects will receive feedback on muscle endurance gained throughout the experimental period, so will benefit from the study personally. The results of the proposed research will provide data on changes in muscle endurance modulated by the resistance training, information about the programme adherence, participants' feelings, thoughts and perceptions of a home-based resistance exercise delivered via the study app. This information may be important in the design of future studies and ultimately developing resistance exercise guidelines. The risks associated with participating in this study are very small.

7. Who are the investigators (including assistants) who will conduct the research? What are their qualifications and experience?

Professor Jason Gill has ~25 years of experience in conducting human metabolic and exercise studies.

Dr Stuart Gray (PhD) is a lecturer in exercise and metabolic health with over 15 years of experience in conducting human metabolic and exercise studies.

Professor Cindy Gray has over 12 years of experience in using qualitative methods, including conducting telephone/online interviews, to inform the development and optimisation of health behaviour change interventions (including physical activity/exercise programmes).

María Fernanda Gabler is a PhD student under the supervision of Professor Gill, Professor Gray and Dr Gray. She has been trained in exercise procedures under the MSc Sport and Exercise Science and Medicine 2017/2018 programme by the University of Glasgow and this work as an extension of her first PhD study (ONE Study, MVLS ethics approval number 200180137).

Ayan Merchant, Hesham Alfeheid, Philip McBride are PhD students who will be responsible for the blinded measurements of muscular endurance and flexibility over Zoom. They will be trained in these procedures by Maria Fernanda Gabler. Hesham and Philip both have an MSc Sport and Exercise Science and Medicine.

8. Are arrangements for the provision of clinical facilities to handle emergencies necessary? If so, briefly describe the arrangements made.

Not applicable for this study. Participants will be performing all activities at their home or at a place of their choice.

9. In cases where participants will be identified from information held by another party (e.g., a doctor or hospital), describe how you intend to obtain this information. Include, where appropriate, whether additional Research Ethics Committee approvals will be sought and gained (including overseas committees).

Not applicable for this study

10. Specify whether participants will include students or others in a dependent relationship and, where possible, avoid recruiting students who might feel to be, or be construed to be, under obligation to volunteer for a project. This is most likely to be when a student is enrolled on a course where the investigator is a teacher. In these circumstances, the recruitment could be carried out by one of the other investigators or a suitably qualified third party.

If students are enrolled on a course or supervised by Professor Gill, Professor Gray and Dr Gray, recruitment will be carried out by another member of the study team who is not directly involved with their studies. Participants will be under no obligation or incentive to volunteer for the study.

11. Specify whether the research will include children or participants with mental illness, physical disability or intellectual disability. If so, please explain the necessity of involving these individuals as research participants and include documentation of the suitability of those researchers who will be in contact with children or vulnerable adults (e.g., Disclosure Scotland or membership of the Protection of Vulnerable Groups Scheme).

The research/study will not include children. Participants will need to be able to access the intervention materials and upload data online and to participant in assessments via videocall. They will also need to be physically able to perform the prescribed exercises. If they are able to achieve this, then participants with mental illness, physical disability or intellectual disability may be included.

12. Will payment or other incentive, such as a gift or free services, be made to any research participant? If so, please specify, and state the level of payment to be made and/or the source of the funds/gift/free service to be used. Please explain the justification for offering an incentive.

No cash or exchange of funds will be offered.

13. Please give details of how consent is to be obtained and recorded. A copy of the proposed consent form, along with a separate information sheet, written in simple, non-technical language MUST ACCOMPANY THIS PROPOSAL FORM.

Participants will be sent the “Participant information sheet” and “Consent form” with at least 24hrs prior to the first online session. One of the study investigators listed on the study will seek verbal consent after an introductory session, which will involve a review of the PIS and a verbal explanation of the study in regard to the benefits, burdens and risks of the study with the opportunity to ask questions before providing verbal consent to participate which will be recorded and stored on the university servers.

14. Comment on any cultural, social or gender-based characteristics of the participants that have affected the design of the project or may affect its conduct.
In this study, the design has not been affected by any cultural, social or gender-based characteristics.

15. Please state (i) who will have access to the data, (ii) how the data will be stored, how will access be restricted, and (iii) what measures will be adopted to maintain the confidentiality of the research participants and to comply with data protection requirements.

For studies where participant responses are recorded and transcribed at a later date, give details of storage and transcription. Please give some detail on how long data will be stored for and where. You should clarify how identifiable, anonymised research data and consent forms will be stored.

xv) Only the named investigators will have full access to the data obtained. The information obtained will be anonymised and identifiable data will not be stored through the study link and will not be passed on to anyone outside the study group. Anonymised data, only coded with a participant information number, with all identifying information removed, will be shared with collaborators to maximise the life-time value of the data generated for human health, in line with best practice for data sharing

xvi) Anonymised data from the app will be stored on a secure external server. All files containing identifiable data will only be stored on University servers in password protected files separate from the study data. Access will be restricted by password-protection and data stored for 10 years.

xvii) Data will be anonymised with subjects being identified by a number rather than a name. Personal data including linkage of subject name and number will be held in a locked filing cabinet in the BHF Glasgow clinical research centre or as password−protected files saved on the University server, known only to the named investigators.

xviii) Recorded measurement sessions will be stored in password protected files saved on the University server, only know to named investigators.

Please tick to confirm that all relevant research data generated during and after the study will be collected and held in compliance with the General Data Protection Regulation (May 2018). [X]

Please tick to confirm that you have completed a data protection impact assessment form if required. [X]

If this is not required, please specify why not;

For guidance in this matter, please refer to the University Data Protection Office webpages:
https://www.gla.ac.uk/myglasgow/dpfoioffice/gdpr/

In regard to (ii) above, please clarify (tick one) how the data will be stored:

☐ **(a) in a fully anonymised form (link to participants broken),**

☐ **(b) in a linked anonymised form (data +/- samples linked to participant identification number but participant not identifiable to researchers), or**

X (c) in a form in which the participant could be identifiable to researcher.

If data are stored in linked anonymised form, please state who will have access to the code and personal information about the participant.

The data will be held securely for a period of ten years after the completion of the research project, or for longer if specified by the research funder or sponsor, in accordance with the University's Code of Good Practice in Research. (https://www.gla.ac.uk/research/strategy/ourpolicies/) Please tick and give further details below

Data will be stored for 10 years on University servers

16. To your knowledge, will the intended group of research participants be involved in other research? If so, please justify.
The study participants will not be involved in other research while they are undertaking this study.

17. Proposed starting date: 10-08-2020

Expected completion date: 31-12-2021

18. Please state location(s) where the project will be carried out, including all overseas laboratories, hospitals and other relevant locations.
The intervention will be conducted remotely with participants in their homes or another location at their convenience.

19. Please state briefly any precautions being taken to protect the health and safety of researchers and others associated with the project (as distinct from the research participants), e.g., where blood samples are being taken, home visits.
Not applicable for this study

20. Please state all relevant sources of funding or support for this study.
The work is funded by a PhD Scholarship to Ms Gabler from Beca Chile CONICYT and the BBC.

21a). Are there any conflicts of interest related to this project for any member of the research team? This includes, but is not restricted to, financial or commercial interests in the findings. If so, please explain these in detail and justify the role of the research team. For each member of the research team please complete a declaration of conflicts of interest below.

Researcher Name: __ Jason Gill _____ conflict of interest
No

Researcher Name: ___ Stuart Gray _____ conflict of interest
No

Researcher Name: ___Cindy Gray _____ conflict of interest
No

Researcher Name: ___ María Fernanda Gabler _____ conflict of interest
No

Researcher Name: ___ Ayan Merchant _____ conflict of interest
No

Researcher Name: ___ Hesham Alfeheid _____ conflict of interest
No

Researcher Name: ___ Phillip McBride _____ conflict of interest
No

21b). If there are any conflicts of interest, please describe these in detail and justify conducting the proposed study.

Not applicable

22. How do you intend to disseminate the findings of this research?
Please include details of how the study participants will be notified of the study finding. If they are not to be informed, please justify.

The results will form part of María Fernanda Gabler's PhD thesis. An associated paper, presentation and a poster will be made. In addition, we plan to present the findings in a peer-reviewed scientific journal. Results of the subgroup of participants recorded for the BBC will be disseminated on a BBC TV programme.

I confirm that have read the University of Glasgow's Data Protection Policy.
https://www.gla.ac.uk/myglasgow/dpfoioffice/

Please initial box	X

Name _ Maria Fernanda Gabler Trisotti _____ Date _20-07-2020_
(Proposer of research)
Please type your name on the line above.

For student projects:

I confirm that I have read and contributed to this submission and believe that the methods proposed and ethical issues discussed are appropriate.

I confirm that the student will have the time and resources to complete this project.

Name __Jason Gill _____ Date __20-07-2020_
(Supervisor of student)
Please type your name on the line above.

Please upload the completed and signed form, along with other required documents by logging in to the Research Ethics System at - https://frontdoor.spa.gla.ac.uk/login/

Appendix P: Consent form REFLEX Study

University of Glasgow | College of Medical, Veterinary & Life Sciences

Project Number:

Participant Identification Number for this trial:

Title of Project: **Effect of a home-based REsistance exercise vs a home-based FLEXbility exercise programme on muscular endurance and flexibility in healthy adults (REFLEX).**

For the consent process, this form will be shared on screen during a Zoom call between an investigator and participant. The questions read out loud to the participant, who will provide verbal responses. This verbal consent will be recorded and stored on a secure server. The researcher will tick the boxes below during the call an additional record.

Name of Researcher(s): Maria Fernanda Gabler Trisotti, Ayan Merchant, Hesham Alfeheid, Phillip McBride, Stuart Gray, Cindy Gray and Jason Gill.

CONSENT FORM

Version 2, 04/08/2020

Do you confirm that you have read and understood the Participant Information Sheet version 2 dated 04/08/2020?	☐
Do you confirm that you have read and understood the Privacy Notice version 1 dated 23/07/2020.	☐
Have you had the opportunity to think about the information and ask questions and do you understand the answers you have been given?	☐
Do you understand that your participation is voluntary and that you are free to withdraw at any time, without giving any reason, without your legal rights being affected?	☐
Do you confirm that you agree to the way your data will be collected and processed and that data will be stored for up to 10 years in University archiving facilities in accordance with relevant Data Protection policies and regulations?	☐

Do you understand that all data and information you provide will be kept confidential and will be seen only by study researchers and regulators whose job it is to check the work of researchers?	☐
Do you agree that your name, contact details and data described in the information sheet will be kept for the purposes of this research project?	☐
Do you understand that if you withdraw from the study, my data collected up to that point will be retained and used for the remainder of the study?	☐
Do you agree to your Zoom online assessment sessions to be recorded for verification purposes?	☐
Do you agree for an interview about your perceptions and experience of the study to be audio-recorded?	☐
Do you understand that the recorded interview will be transcribed word by word and the transcription stored for up to 10 years in University archiving facilities in accordance with Data Protection policies and regulations?	☐
Do agree to be contacted by the research team in around 6 months' time about taking part in another interview?	☐
Do you agree for the data you provide to be anonymously archived in the UK data archive or other approved archiving facilities, and that other researchers can have access to this data only if they have scientific and ethical approval, and agree to preserve the confidentiality of this information as set out in this form?	☐
Do you agree to take part in the study?	☐

_____ _____

Name of participant Date

_____ _____

Researcher Date

(1 copy for participant; 1 copy for researcher)

Appendix Q: Participant Information REFLEX Study

University of Glasgow | College of Medical, Veterinary & Life Sciences

Effect of a home-based REsistance exercise vs a home-based FLEXbility exercise programme on muscular endurance and flexibility in healthy adults (REFLEX).

PARTICIPANT INFORMATION SHEET
Version 4 (25/01/2021)

You are being invited to take part in a research study but before you decide whether to take part, it is important that you fully understand why the research is being carried out and what it will involve. This document is designed to help you decide whether you would like to participate. Please take time to read the following information carefully and discuss it with your friends and family. If anything is not clear or if you would like more information, please contact a member of the research team whose details are included at the bottom of the information sheet. If you decide to take part in this study, you will be given a copy of this Participant Information Sheet and the consent form to keep.

What is the purpose of the study?

Resistance exercise (e.g. lifting weights or using resistance bands) produces several health benefits and increases muscle mass, muscular strength and muscular endurance. Flexibility exercise improves joint flexibility (range of motion), postural stability and balance. Current physical activity guidelines recommend that adults do at least 150 minutes of moderate intensity aerobic physical activity (or 75 minutes of vigorous intensity) and weight-lifting activities on two or more days per week. Only a third of the population meet the physical activity guidelines. Therefore, finding a way of doing resistance exercise that is time efficient may increase the number of people that achieve the guidelines. The purpose of this study is to compare the effects of an app-based home-based resistance exercise programme vs a home-based flexibility programme on muscular endurance and flexibility in healthy adults.

Why have I been invited to participate?

You have been invited to take part in this study because you are a healthy adult aged between 18 and 64 years who does less than 30 min of vigorous physical activity per week, does not perform strength exercise and may benefit from a programme of resistance exercise. A total of 72 participants will be included in our study.

Do I have to take part?

No, it is up to you to decide whether or not to take part. Participation in this study is completely voluntarily. If you do decide to take part, you will be given this information sheet to keep and be asked to give verbal consent. If you decide to take part, you are still free to

withdraw at any time and without giving a reason. If you are a student and decide not to participate will not affect your grades in any way.

What will happen to me if I take part?

You will be involved in a research study in which you will be randomly assigned (by a computer) to one of two groups. The resistance exercise group will undergo a 12-week home-based resistance exercise programme. The flexibility exercise group will be asked to follow a home-based flexibility exercise programme for 12-weeks. If you are assigned to the flexibility exercise group, you will be given the opportunity to undertake the home-based resistance exercise programme after you have completed the study. If you are randomly assigned to the resistance exercise group, you will have access to the flexibility exercise programme at the end of the study. A small group of participants will be asked to take part in an interview about their perception and experience about the exercise programme. A qualitative researcher will arrange an online interview (via Zoom or WhatsApp) and talk to you about your experiences of doing the study resistance exercise programme. You may be asked to demonstrate some of the exercises and talk about how you managed or did not manage to do them. The interview will last between 30 to 60 minutes. It will be audio recorded.

All participants will be asked to attend four or five online visits during the research period.

All participants will undertake the following measures:

f) Screening procedures:

Before enrolling in the study, you will be sent the Participant Information Sheet and the Consent form to read prior to the first online visit. During the first online visit we will:

- Explain what participation in the study involves and give you another opportunity to read the Participant Information Sheet.
- Provide an opportunity for you to ask questions about the study.
- As you to give verbal consent (which we will record) for your to participation in the study.
- Ask to complete the following questionnaires to determine if you fall into the group of people we wish to study and will also ensure that it is safe for you to participate:
    i. A health questionnaire regarding your personal details, family and personal medical history.
    ii. A “Physical Activity Readiness Questionnaire Plus (PARQ+)” to determine if it is safe for you to perform physical activity.
    iii. The “International Physical Activity Questionnaire (IPAQ)” to assess your current level of physical activity.

This visit will take around 30 minutes.

g) Experimental measurements:

Following the screening procedures and if you are eligible for the study, we will arrange a second online visit via Zoom with another member of the research team to perform an assessment of your muscular endurance and flexibility. You will also be sent a link to a study web app, in which you will be asked to log in with your ID number and password to complete questionnaires about your well-being, self-esteem and motivation to exercise.

During this Zoom session we will assess your muscle endurance with three tests: push-ups, plank and a half-squat; and your flexibility with a sit-and-reach test. You will be able to perform them at home and the researcher on the videocall will ask you to place your camera in a specific position for each test. You will be asked to perform the tests with a rest between them in that specific order. You will be asked to until you cannot do them anymore (exhaustion or fatigue).

For the push-up test you will be asked to do as many push-ups you are able to do without pausing until you cannot do them anymore. You will perform a specific type push-up depending on your capacity, either: on your feet, on your knees, against a worktop and against a wall. If you are not able to perform two push-ups in a row with the correct technique, the test will end by the researcher and you will be told to stop. We will use the same type of push-up test for your measurements at each of the three times we perform this test in the study (e.g. if you do your first test with push-up against a worktop, all of your later push-up tests will be against a worktop, even if you are able to do push-ups on your knees by the end of the study). This is so we can make a direct comparison of any changes over the course of the study.

For the plank test you will be asked to lie on your stomach on the floor with your forearms and feet on the floor. You will be asked to lift your body on the air, keep it straight and hold the position as long as possible. If you are not able to keep the position the test will end by the researcher and you will be told to stop. The researcher will record the time you are able to hold the position.

For the half-squat test you will be asked to do a squat by resting your back on a wall. Your knees and legs need to be in 90 degrees and you will have your arms crossed on your chest. You will be askes to maintain the position as long as possible. If you are not able to hold the position, the test will end by the researcher and you will be told to stop. The researcher will record the time you are able to hold the position.

Your flexibility will be measured with the “sit-and-reach test”. You will be asked to sit down on the floor with your legs together and extended, and to reach to try to touch (or reach past) your toes. You will be asked to measure the distance of the tip of your fingers to the tip of your toes.

You will be able to access the tests videos with instructions on an email that will be sent to you. The researcher watching you will be counting the number of repetitions and the time achieved.

These tests will take around 30 minutes in total. These measurements will be repeated after 6 weeks and 12 weeks of the exercise programme. For the 6-week and 12-week measurements, it is very important that you do not tell the researcher taking your measurements which of the two exercise groups you were in, since this could influence the study results. All Zoom measurement sessions will be recorded for verification purposes. Only the research team will have access to them.

All participants will undertake the following:

You will be asked to follow an exercise programme for 12-weeks at your home or any other place of your choice. You will be asked to perform a minimum of 1 set/week for each of six exercises and will have the option to increase to 2 sets or 3 sets/week per exercise if you wish to do so. You will be able to distribute the exercise throughout the week as you please. For example, you can do all the exercises on a single day, or spread them over 3 days a week, 6 days a week, or any other choice as long as you do at least 1 set of each exercise per week. We encourage that you have at least one day of rest every week. The exercises that you do will depend on whether you have been randomly allocated to the flexibility exercise group or the resistance exercise group.

<u>For participants in the home-based flexibility exercise training programme:</u>
You will be asked to perform six stretching exercises per week (2 different leg exercises, 1 shoulders and arms, 1 chest, 1 back and 1 core). For each exercise you will be asked to stretch to the point of feeling tightness or slight discomfort, to hold the stretch for 30 seconds (each side) and repeat that twice (in total 60 seconds of stretching per side). You will have the opportunity to choose from a bank of flexibility exercises and will be able to access the exercise instruction videos via the web app. You will be asked to record on the web app each time you complete an exercise.

<u>For participants in the home-based resistance exercise training programme:</u>
You will be asked to perform 6 exercises per week (2 different leg exercises, 1 shoulder exercise, 1 chest exercise, 1 back exercise and 1 core exercise). You will be able to choose the exercise you want to do from a bank of resistance exercises that will be provided in the web app. Each exercise will have several levels. At the beginning of the programme you need to choose the level in which you are able to perform between 6-20 repetitions. During each exercise session during the programme you will be asked to complete as many repetitions of the exercise as possible. If you are able to perform more than 20 repetitions, you will be able to move to the next exercise level. For the plank exercise, you will be able to progress to the next exercise level once you are able to maintain the posture for 60 seconds. You will be able to access the instruction videos via the web app. You will be asked to record your exercise sessions on the web app, including the type of exercise, the level and number of repetitions (or duration) achieved. You will be able to see in the web app which exercises you still need to do for the week, the sets you have completed and the bonus sets (2-3 sets) you have completed for each exercise. You will also be able to see your progress throughout the study period.

For some exercises, you will require a resistance band. You will be sent, to an address of your choice, a set of 4 resistance bands with different levels of tension to enable you to do this.

Finally, a subgroup of participants will be asked to complete an online interview at the end of the exercise programme to help us understand more about your experiences of participation. For these participants, a qualitative researcher will contact you to arrange a time that is convenient for you for the online interview.

The following table explains which measurements will be taken in on which time point and number of visit and how long each visit is going take.

What will happen at this visit	Week 0 (visit 1) 30 min	Week 0 (visit 2) 30 min	Week 6 (visit 2) 30 min	Week 12 (visit 3) 30 min	Post Week 12 (visit 4) 45 min

Consent process	X				
PAR-Q	X				
IPAQ	X				
Health questionnaire	X				
Muscle endurance measurements		X	X	X	
Well-being, self-esteem and motivation questionnaires		X	X	X	
Qualitative Interview					X

What do I have to do?
If you are assigned to flexibility exercise group will ask that you follow the flexibility exercise programme and not to increase your levels of physical activity during the period of the study apart from this. If you are assigned to the resistance exercise programme we will ask that, other than undertaking the home-based resistance exercise programme, you continue with your usual lifestyle and do not to increase your levels of other aspects physical activity during the period of the study. After the study period, all participants will have access to all exercises (flexibility and resistance) via the web app. If you get selected, you could be asked to undertake an interview regarding perception and experience during the study period.

What are the possible disadvantages and risks of taking part?
Exercise has a very small risk in healthy adults, although exercise at maximal capacity could carry a very small risk of inducing myocardial ischaemia ("heart attack"). The screening procedure helps to minimise that risk. The primary symptom of myocardial ischaemia is chest pain on exertion. If you experience any unusual sensations in your chest, feel unwell or do not want to continue for any other reason during exercise you should cease exercising immediately. You may also feel some muscle soreness after the muscle endurance measurements and after the first few sessions of resistance exercise training programme.

What are the possible benefits of taking part?
This study will help increase understanding about the effect of the minimum amount of resistance and flexibility exercise needed to increase muscle endurance and flexibility, and to understand better peoples' behaviour and experiences about home-based exercise resistance and flexibility exercise programmes. The information gained during the study will allow us to give you feedback about your own muscle endurance and flexibility, and your well-being, as well as how these change in response to an exercise programme.

Will my taking part in this study be kept confidential?
All information which is collected about you, or responses that you provide, during the course of the research, will be kept strictly confidential. You will be identified by an ID number, and any information about you will have your name and address removed so that you cannot be recognised from it. Any data in paper form will be stored in locked cabinets in rooms with

restricted access at the University of Glasgow. All data in electronic format will be encrypted and stored on secure password–protected computers. The zoom sessions recordings will be stored on the University of Glasgow servers and will be password protected. Only the research team will have access to them if needed. No one outside of the research team or appropriate governance staff will be able to find out your name, or any other information which could identify you. Data will be anonymised and no personal data will be presented.

What will happen to my data?
Researchers from the University of Glasgow collect, store and process all personal information in accordance with the General Data Protection Regulation (2018). If you withdraw from the study, your data that has been collected at to that point will be retained and used by the researchers. The data will be stored in archiving facilities in line with the University of Glasgow retention policy of up to 10 years. After this period, further retention may be agreed or your data will be securely destroyed in accordance with the relevant standard procedures.

What will happen to the results of the research study?
The results will be coded (for anonymity) and analysed by the research team before being reported in research reports. The results will form part of María Fernanda Gabler's PhD thesis. Associated papers, presentations, and posters will be made of the findings. In addition, the results may be published in a peer-reviewed scientific journal, however, you will not be identified by name in any publications. You will be informed about the results of the study and a copy of the published results will be sent to you upon request by the research team.

Who is organising and funding the research?
The work is organised by the Prof Jason Gill, Dr Stuart Gray, Ms María Fernanda Gabler in the Institute of Cardiovascular and Medical Sciences and by Prof Cindy Gray in the Institute of Health and Wellbeing in the University of Glasgow. The work is funded by a PhD Scholarship to Ms Gabler from Beca Chile CONICYT.

Who has reviewed the study?
To protect your safety, rights, wellbeing and dignity, all research by the University of Glasgow is looked at by an independent group of people. This study has been reviewed and approved by the College of Medical Veterinary and Life Sciences Ethics Committee at the University of Glasgow.

Contact for Further Information
Any questions about the procedures used in this study are encouraged. If you have any doubts or questions, please ask for further explanations by contacting one of the investigators below:

Maria Fernanda Gabler Trisotti
Email: m.gabler-trisotti.1@research.gla.ac.uk
Tel: TBC

Professor Jason Gill
Email: jason.gill@glasgow.ac.uk

Independent Contact information:

Carlos Celis-Morales
Email: carlos.celis@glasgow.ac.uk
Tel: 0141 330 4201

Thank you for reading the Participant Information Sheet.

Appendix R: Health Questionnaire REFLEX Study

University of Glasgow

The REFLEX Study Health Questionnaire

Participant Name:

Date of birth:

Date:

It is important that volunteers participating in research studies are currently in good health and have had no significant medical problems in the past. This is to ensure (i) their own continuing well-being and (ii) to avoid the possibility of individual health issues confounding study outcomes.

Please complete this brief questionnaire to confirm fitness to participate:

2. At present, do you have any health problem for which you are:

(a) on medication, prescribed or otherwise	yes [ ]	no [ ]
(b) attending your general practitioner	yes [ ]	no [ ]
(c) on a hospital waiting list	yes [ ]	no [ ]

3. **Have** you ever had any of the following symptoms to a significant degree ***at rest or during exercise***? That is, have you had to consult a physician relating to any of the following?

	Rest	*Exercise*
Breathlessness	NO / YES	NO / YES
Chest Pain	NO / YES	NO / YES
Dizzy Fits/Fainting	NO / YES	NO / YES
Heart Murmurs	NO / YES	NO / YES
Palpitations	NO / YES	NO / YES
Tightness in chest, jaw or arm	NO / YES	NO / YES
Other*	NO / YES	

*(*Please specify*) ……

Muscle or joint injury:

Do you have/or have had any muscle or joint injury which could affect your safety in performing exercise ***(e.g. cycling or running),*** strength testing or strength training?
NO/YES

4**. Have you ever** had any of the following:

(a) Convulsions/epilepsy	yes [ ]	no [ ]
(b) Asthma	yes [ ]	no [ ]
(c) Eczema	yes [ ]	no [ ]
(d) Diabetes	yes [ ]	no [ ]
(e) A blood disorder	yes [ ]	no [ ]
(g) Digestive problems	yes [ ]	no [ ]
(h) Hearing problems	yes [ ]	no [ ]
(i) Disturbance of balance/co-ordination	yes [ ]	no [ ]
(j) Numbness in hands or feet	yes [ ]	no [ ]
(k) Disturbance of vision	yes [ ]	no [ ]
(l) Thyroid problems	yes [ ]	no [ ]
(m) Kidney or liver problems	yes [ ]	no [ ]
(n) Heart problems	yes [ ]	no [ ]
(o) Any other health problems	yes [ ]	no [ ]

5. **Have any of your family (parents, grandparents, brothers, sisters, children, aunts, uncles, cousins)** ever had any of the following: (if yes please give details including age of first diagnosis)

(a) Any heart problems	yes [ ]	no [ ]
(b) Diabetes	yes [ ]	no [ ]
(c) Stroke	yes [ ]	no [ ]
(d) Any other family illnesses	yes [ ]	no [ ]

If YES to any question, please describe briefly, including listing of current medication (e.g. to confirm whether problem was short-lived, insignificant or well controlled.) (Use a separate sheet if necessary)

……

……

……

……

Signature: _____ Date: _____

Appendix S: Physical Activity Readiness Questionnaire Plus (PARQ-Plus)

2020 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1) Has your doctor ever said that you have a heart condition ☐ **OR** high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** _____	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** _____	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it **does not limit your current ability** to be physically active. **PLEASE LIST CONDITION(S) HERE:** _____	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

☑ **If you answered NO to all of the questions above, you are cleared for physical activity.**
Please sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow Global Physical Activity Guidelines for your age (https://apps.who.int/iris/handle/10665/44399).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

PARTICIPANT DECLARATION

If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for its records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME _____ DATE _____

SIGNATURE _____ WITNESS _____

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER _____

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at www.eparmedx.com before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

Copyright © 2020 PAR-Q+ Collaboration

01-11-2019

2020 PAR-Q+

FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1. Do you have Arthritis, Osteoporosis, or Back Problems?

If the above condition(s) is/are present, answer questions 1a-1c If **NO** ☐ go to question 2

1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	YES ☐ NO ☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	YES ☐ NO ☐

2. Do you currently have Cancer of any kind?

If the above condition(s) is/are present, answer questions 2a-2b If **NO** ☐ go to question 3

2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck?	YES ☐ NO ☐
2b.	Are you currently receiving cancer therapy (such as chemotheraphy or radiotherapy)?	YES ☐ NO ☐

3. Do you have a Heart or Cardiovascular Condition? This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm

If the above condition(s) is/are present, answer questions 3a-3d If **NO** ☐ go to question 4

3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)	YES ☐ NO ☐
3c.	Do you have chronic heart failure?	YES ☐ NO ☐
3d.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	YES ☐ NO ☐

4. Do you currently have High Blood Pressure?

If the above condition(s) is/are present, answer questions 4a-4b If **NO** ☐ go to question 5

4a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
4b.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)	YES ☐ NO ☐

5. Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes

If the above condition(s) is/are present, answer questions 5a-5e If **NO** ☐ go to question 6

5a.	Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies?	YES ☐ NO ☐
5b.	Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.	YES ☐ NO ☐
5c.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet?	YES ☐ NO ☐
5d.	Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?	YES ☐ NO ☐
5e.	Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?	YES ☐ NO ☐

Copyright © 2020 PAR-Q+ Collaboration

2020 PAR-Q+

6. **Do you have any Mental Health Problems or Learning Difficulties?** This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome

If the above condition(s) is/are present, answer questions 6a-6b If **NO** ☐ go to question 7

6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
6b.	Do you have Down Syndrome **AND** back problems affecting nerves or muscles?	YES ☐ NO ☐

7. **Do you have a Respiratory Disease?** This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure

If the above condition(s) is/are present, answer questions 7a-7d If **NO** ☐ go to question 8

7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
7b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	YES ☐ NO ☐
7c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	YES ☐ NO ☐
7d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	YES ☐ NO ☐

8. **Do you have a Spinal Cord Injury?** This includes Tetraplegia and Paraplegia

If the above condition(s) is/are present, answer questions 8a-8c If **NO** ☐ go to question 9

8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
8b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	YES ☐ NO ☐
8c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	YES ☐ NO ☐

9. **Have you had a Stroke?** This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event

If the above condition(s) is/are present, answer questions 9a-9c If **NO** ☐ go to question 10

9a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
9b.	Do you have any impairment in walking or mobility?	YES ☐ NO ☐
9c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	YES ☐ NO ☐

10. **Do you have any other medical condition not listed above or do you have two or more medical conditions?**

If you have other medical conditions, answer questions 10a-10c If **NO** ☐ read the Page 4 recommendations

10a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	YES ☐ NO ☐
10b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	YES ☐ NO ☐
10c.	Do you currently live with two or more medical conditions?	YES ☐ NO ☐

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE: _____

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

Copyright © 2020 PAR-Q+ Collaboration

11-01-2019

2020 PAR-Q+

If you answered NO to all of the FOLLOW-UP questions (pgs. 2-3) about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME _____ DATE _____

SIGNATURE _____ WITNESS _____

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER _____

For more information, please contact
www.eparmedx.com
Email: eparmedx@gmail.com

Citation for PAR-Q+
Warburton DER, Jamnik VK, Bredin SSD, and Gledhill N on behalf of the PAR-Q+ Collaboration.
The Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) and Electronic Physical Activity Readiness Medical Examination (ePARmed-X+). Health & Fitness Journal of Canada 4(2):3-23, 2011.

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or the BC Ministry of Health Services.

Key References

1. Jamnik VK, Warburton DER, Makarski J, McKenzie DC, Shephard RJ, Stone J, and Gledhill N. Enhancing the effectiveness of clearance for physical activity participation: background and overall process. APNM 36(S1):S3-S13, 2011.
2. Warburton DER, Gledhill N, Jamnik VK, Bredin SSD, McKenzie DC, Stone J, Charlesworth S, and Shephard RJ. Evidence-based risk assessment and recommendations for physical activity clearance: Consensus Document. APNM 36(S1):S266-s298, 2011.
3. Chisholm DM, Collis ML, Kulak LL, Davenport W, and Gruber N. Physical activity readiness. British Columbia Medical Journal. 1975;17:375-378.
4. Thomas S, Reading J, and Shephard RJ. Revision of the Physical Activity Readiness Questionnaire (PAR-Q). Canadian Journal of Sport Science 1992;17:4 338-345.

Copyright © 2020 PAR-Q+ Collaboration

11-01-2019

Appendix T: International Physical Activity Questionnaire Short From (IPAQ-SF)

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

   _____ **days per week**

   ☐ No vigorous physical activities → ***Skip to question 3***

2. How much time did you usually spend doing **vigorous** physical activities on one of those days?

   _____ **hours per day**

   _____ **minutes per day**

   ☐ Don't know/Not sure

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

   _____ **days per week**

   ☐ No moderate physical activities → ***Skip to question 5***

SHORT LAST 7 DAYS SELF-ADMINISTERED version of the IPAQ. Revised August 2002.

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you have done solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

_____ **days per week**

☐ No walking → ***Skip to question 7***

6. How much time did you usually spend **walking** on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

This is the end of the questionnaire, thank you for participating.

SHORT LAST 7 DAYS SELF-ADMINISTERED version of the IPAQ. Revised August 2002.

Appendix U: Exercise Tests Links

First exercise tests:

Exercise test	Link
Push up test (men)	https://youtu.be/Iy8EHW29FZM
Push up test (women)	https://youtu.be/jxcSQfAT3AM
Crunch test	https://youtu.be/82Z9PLcVRy0
Squat test	https://youtu.be/f2BkhB1TjpM
Sit and reach test	https://youtu.be/9RxSN8qDlAc

Final exercise tests:

Exercise test	Link
Push up test	https://youtu.be/nZNMViahyFg
Plank test	https://youtu.be/bqdvLWpN2Ds
Half Squat test	https://youtu.be/W7Qq_2LhrYM
Sit and reach test	https://youtu.be/9RxSN8qDlAc

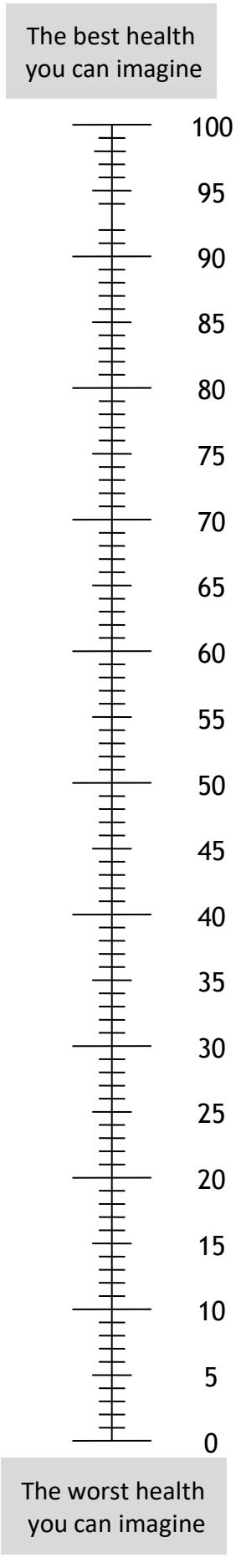
Appendix V: EQ Visual Analogue Scale

EQ Visual analogue scale (EQ VAS)

We would like to know how good or bad your health is today.

- This scale on the right is numbered from 0 to 100.
- 100 means the best health you can imagine.
  0 means the worst health you can imagine.
- Mark an X on the scale to indicate how your health is today.
- Now, please write the number you marked on the scale in the box below.

Your Health Today =



Appendix W: Warwick-Edinburgh Mental Wellbeing Questionnaire (WEMWBS)

The Warwick-Edinburgh Mental Well-being Scale (WEMWBS)

Below are some statements about feelings and thoughts.

Please tick the box that best describes your experience of each over the last 2 weeks

STATEMENTS	None of the time	Rarely	Some of the time	Often	All of the time
I've been feeling optimistic about the future	1	2	3	4	5
I've been feeling useful	1	2	3	4	5
I've been feeling relaxed	1	2	3	4	5
I've been feeling interested in other people	1	2	3	4	5
I've had energy to spare	1	2	3	4	5
I've been dealing with problems well	1	2	3	4	5
I've been thinking clearly	1	2	3	4	5
I've been feeling good about myself	1	2	3	4	5
I've been feeling close to other people	1	2	3	4	5
I've been feeling confident	1	2	3	4	5
I've been able to make up my own mind about things	1	2	3	4	5
I've been feeling loved	1	2	3	4	5
I've been interested in new things	1	2	3	4	5
I've been feeling cheerful	1	2	3	4	5

"Warwick Edinburgh Mental Well-Being Scale (WEMWBS)
© NHS Health Scotland, University of Warwick and University of Edinburgh, 2006, all rights reserved."

Appendix X: Subjective Vitality Scales

Individual Difference Level Version

Vitality Scale

Please respond to each of the following statements by indicating the degree to which the statement is true for you in general in your life. Use the following scale:

1	2	3	4	5	6	7
not at all true			somewhat true			very true

1. I feel alive and vital.
2. I don't feel very energetic.
3. Sometimes I feel so alive I just want to burst.
4. I have energy and spirit.
5. I look forward to each new day.
6. I nearly always feel alert and awake.
7. I feel energized.

State Level Version

Vitality Scale

Please respond to each of the following statements in terms of how you are feeling **right now**. Indicate how true each statement is for you at this time, using the following scale:

1	2	3	4	5	6	7
not at all true			somewhat true			very true

1. At this moment, I feel alive and vital.
2. I don't feel very energetic right now.
3. Currently I feel so alive I just want to burst.
4. At this time, I have energy and spirit.
5. I am looking forward to each new day.
6. At this moment, I feel alert and awake.
7. I feel energized right now.

Appendix Y: Rosenberg's Self-esteem questionnaire

Scale:

Instructions

Below is a list of statements dealing with your general feelings about yourself. Please indicate how strongly you agree or disagree with each statement.

1. On the whole, I am satisfied with myself.

Strongly Agree Agree Disagree Strongly Disagree

2. At times I think I am no good at all.

Strongly Agree Agree Disagree Strongly Disagree

3. I feel that I have a number of good qualities.

Strongly Agree Agree Disagree Strongly Disagree

4. I am able to do things as well as most other people.

Strongly Agree Agree Disagree Strongly Disagree

5. I feel I do not have much to be proud of.

Strongly Agree Agree Disagree Strongly Disagree

6. I certainly feel useless at times.

Self Report Measures for Love and Compassion Research: *Self-Esteem*

Fetzer Institute

Strongly Agree Agree Disagree Strongly Disagree

7. I feel that I'm a person of worth, at least on an equal plane with others.

Strongly Agree Agree Disagree Strongly Disagree

8. I wish I could have more respect for myself.

Strongly Agree Agree Disagree Strongly Disagree

9. All in all, I am inclined to feel that I am a failure.

Strongly Agree Agree Disagree Strongly Disagree

10. I take a positive attitude toward myself.

Strongly Agree Agree Disagree Strongly Disagree

Scoring:

Items 2, 5, 6, 8, 9 are reverse scored. Give "Strongly Disagree" 1 point, "Disagree" 2 points, "Agree" 3 points, and "Strongly Agree" 4 points. Sum scores for all ten items. Keep scores on a continuous scale. Higher scores indicate higher self-esteem.

Appendix Z: Adapted Behavioural Regulations in Exercise Questionnaire 2 (BREQ-2)

Please rate the extent to which each statement below is true for you.
*(Please tick **ONE** box on **EACH** line)*

ADAPTED BREQ-2

People have different reasons why they exercise. If you were to exercise, please rate the extent to which each statement below is true for you.

	Not true for me		Sometimes true for me		Very true for me
1. I exercise because other people say I should	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
2. I feel guilty when I don't exercise	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
3. I value the benefits of exercise	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

	Not true for me		Sometimes true for me		Very true for me
4. I exercise because it's fun	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
5. I feel ashamed when I miss an exercise session	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
6. It's important to me to exercise regularly	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

	Not true for me		Sometimes true for me		Very true for me
7. I can't see why I should bother exercising	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
8. I enjoy my exercise sessions	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
9. I exercise because others will not be pleased with me if I don't	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

	Not true for me		Sometimes true for me		Very true for me
10. I don't see the point in exercising	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
11. I feel like a failure when I haven't exercised in a while	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
12. I feel under pressure from my friends/family to exercise	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

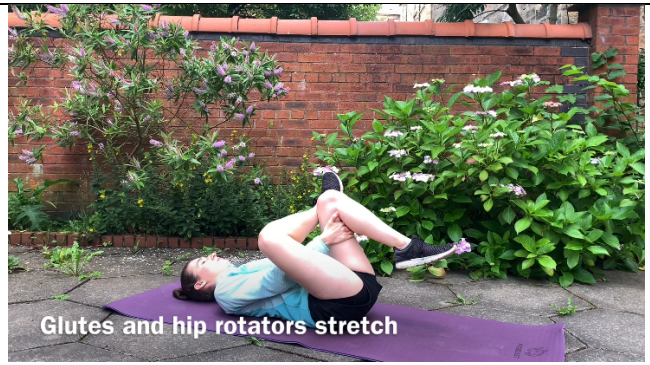
	Not true for me		Sometimes true for me		Very true for me
13. I get pleasure and satisfaction from exercise	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
14. I think exercising is a waste of time	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
15. I consider exercise a fundamental part of who I am	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Appendix AA: Webapp and exercise programme video instructions links

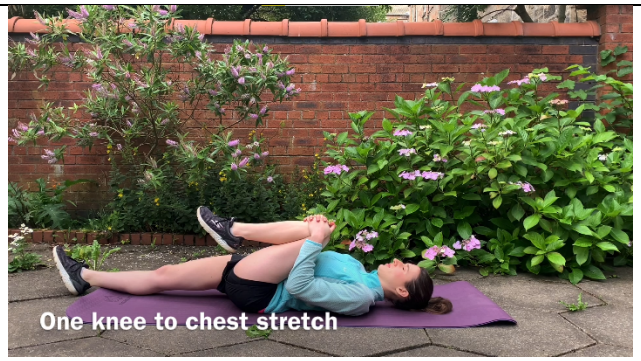
Video Instructions	Exercise Group	Link
Webapp instructions	Flexibility group	https://youtu.be/-KOZoHh9kzk
	Resistance group	https://youtu.be/jWXWHtd7o7Q
Programme instructions	Flexibility group	https://youtu.be/t99OYaMzXz8
	Resistance group	https://youtu.be/oWeiErJ2wbM

Appendix AB: Flexibility exercise programme video links

Muscle group	Exercise	Link	Exercise video image
Legs	Quadriceps stretch	https://youtu.be/iW4oFCAG6Lc	
	Hamstring stretch	https://youtu.be/Xl1ycIFOlD8	

	Piriformis stretch	https://youtu.be/UVm56Eqiuv8	
	Glutes and hip rotators stretch	https://youtu.be/i52n5ktQClU	

	Adductors stretch	https://youtu.be/kbXJB9aBrmo	
	Hip-flexor stretch	https://youtu.be/p5uKUoEGj_o	

	One knee to chest stretch	https://youtu.be/ntkoc6xOq-w	
	Calf stretch	https://youtu.be/KTnlZOLl-bE	

Shoulder and arms	Shoulder (cross arm) stretch	https://youtu.be/08UUvDHT0Mg	
	Biceps stretch	https://youtu.be/jqc9qEVmkiQ	

	Triceps	https://youtu.be/i23vVLirJoI	
Chest	Chest (pectoralis) stretch	https://youtu.be/jY8tpd9Gbdg	

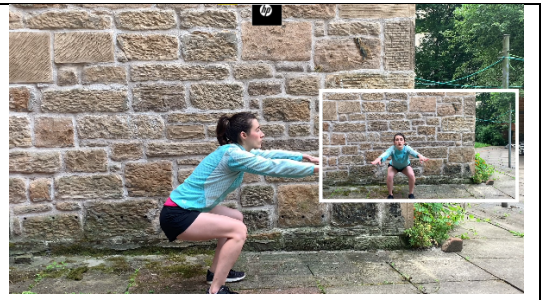
Back	Low back stretch	https://youtu.be/kybt1CRhTxA	
	Knees to chest stretch	https://youtu.be/HFCphLNuMo0	

Core	Abdominals (core) stretch	https://youtu.be/WrT-jokVFpU	
	Cat-dog stretch	https://youtu.be/tQfx-dFo1c0	

			 Cat-Dog stretch

Appendix AC: Resistance exercise programme video links

Muscle group	Exercise type	Level	Exercise	Link	Exercise video image
Legs	Squat	1	Squat on chair	https://youtu.be/LK6-T_0JTMY	
		2	Squat	https://youtu.be/0VY15svm5bA	
		3	Slow squat	https://youtu.be/yX9Z4-lHodA	

					
		4	Squat jump	https://youtu.be/kAwBcTdjG9k	 

		5	Squat on one leg	https://youtu.be/yE8pC8EJyfo	

	Deadlift	1-4	Deadlift with band 1-4	https://youtu.be/_ygP65gSLvs	
	Front lunges	1	Front lunges with a wall	https://youtu.be/KjiignRGQWU	
		2	Front lunges short step	https://youtu.be/kytHejbL2io	

		3	Front lunges long step	https://youtu.be/jhSuHUKyo0E	
		4	Front lunges and jump	https://youtu.be/dSxOcwAa8RY	 

Shoulders and arms	Upright row	1-4	Upright row with band 1-4	https://youtu.be/CNNv7fi4pQM	
	Lateral raise	1-4	Lateral raise with band 1-4	https://youtu.be/6M8nw9_bR64	
	Shoulder press	1-4	Shoulder press with band 1-4	https://youtu.be/humH5PpeCrA	

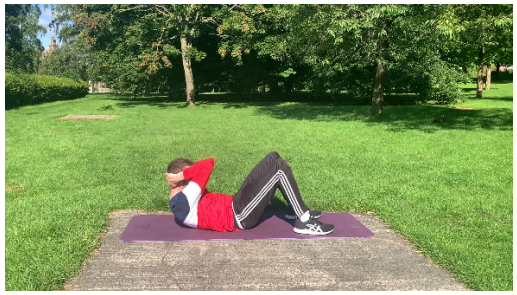
Chest	Push ups	1	Push ups on a wall	https://youtu.be/0K39tcjbnwQ	
		2	Push ups with knees	https://youtu.be/xmUL6Ycf2Mg	
		3	Push ups with feet	https://youtu.be/RBIgAdONF2Y	

		4	Push ups with feet on a chair	https://youtu.be/y2w_N2CAmWE	
		5	Push ups with a clap	https://youtu.be/9Ofl1NbhlvI	 

Back	Seated row	1-4	Seated row with band 1-4	https://youtu.be/eRoMeLmDN8U	
	Seated wide row	1-4	Seated wide row with band 1-4	https://youtu.be/bqulqO23POE	
Core	Plank	1	Plank with hands and knees	https://youtu.be/sX_bZsaun9M	

		2	Plank with hands and feet	https://youtu.be/A8MZGovMCGE	
		3	Plank with forearms and wide feet	https://youtu.be/4I1EPVvbFO4	
		4	Plank with forearms and closed feet	https://youtu.be/Q2y3mbn1ubI	

		5	Dynamic plank	https://youtu.be/t4FEtFAO5ho	
		6	Superman plank	https://youtu.be/k7e7RFrr0Zk	
	Crunches	1	Crunches with hands on legs	https://youtu.be/I1p10oS0vao	

		2	Crunches with hands on legs with a pause	https://youtu.be/a1G1M_zncYM	
		3	Crunches with arms crossed on chest	https://youtu.be/LbGy6SdoS7k	
		4	Crunches with hands behind the head	https://youtu.be/Gc0hqnK3ugI	

		5	Crunches with hands behind the head and raised legs	https://youtu.be/-8GS86o6SlI	
		6	Crunches with hands behind the head, raised legs and a twist	https://youtu.be/w4rDqkJEWCc	

Appendix AD: Topic guide Interviews REFLEX Study

ID PARTICIPANT	
GROUP	
NAME RESEARCHER	
DATE	

Introduction

1. Welcome participants.
2. Remind participants that they have previously given consent for the interview.
3. Explain why they were chosen for the interview.
4. Explain the study aims.
5. Tell that it will last between 30 – 60 min.
6. Tell participant that I might be writing things down during the interview.
7. Tell the participant there are no right or wrong answers.
8. Get their verbal consent again.

Interview

*Start recording.

Participation in the study

1. When did you participate in the Reflex Study?

2. Where did you find out about the study?

3. What were your reasons for wanting to take part?

   Prompts:
   a. Be more active.
   b. It is a reason to start doing exercise.
   c. It is interesting.

4. Can you tell me about the online exercise programme you did?

   Prompts:

   a. What did you think of the web app?
   b. What did you think of the video instructions? (did they tell you everything you needed/ what else would have helped?)
   c. Can you describe the exercises you did?
   d. What did you think of the exercises? (prompt: were some better that others, which did you enjoy, not enjoy)
   e. What do you think about the exercise diary?

5. How did you do the exercises?

   -Prompts-

   a. Where did you do the exercises?
   b. What time of the day did you do the exercises? Did this change during the programme? How?
   c. How many times a week did you do the exercises? Did this change during the programme? How?
   d. Did you use any other materials? What did you use?

      -Prompts-
      a. Shoes
      b. Clothes
      c. Exercise mat

   *<u>Only Resistance exercise group:</u>
   e. What do you think about the different exercise levels?
   f. Did you change to thicker bands during the programme? When? How did you find that?

6. How did you feel while doing the exercises?

   Prompts:
   a. Was this the same each time?
   b. Why do you say this?
   c. Also probe for their confidence/skill in doing the exercises – did this change over time?

7. How did you feel after doing the exercises? (Was this the same each time? Why do you say this?)

8. What motivated you to do the exercises each day? (did this change as the programme went on?)

9. What got in the way of you doing exercises?

10. Is there anything else you can think of that might have helped you do the exercises? (encourage them to expand on anything they say)

Impact of the programme

1. Did you notice any changes as a result of doing the programme?
   If yes, what were they? When?

   Prompts-
   a. What kind of physical and mental changes?
   b. Any negative changes?
   c. Any positive changes?

2. Did you tell other people about you doing the exercises? Who did you tell? What was their reaction?

3. Did you continue doing the exercises after the programme ended?

   *If no, Why did you stop?

Improving the programme

1. If you could change something from the programme, what would it be?

2. Do you have any other suggestions for the programme?

3. Finally, if you were trying to encourage a friend to take part in the programme, how would you describe it to them?

Notes

Appendix AE: Codebooks Thematic Analysis REFLEX Study

General:

Code	Description
1. Pre Study lifestyle	Anything participants say about their lifestyle before the start of the study. Include physical activity, diet, sleep and any reference to COVID.
2. Reasons for joining the study	Anything that motivated the participants to participate in the study, including expectations of what it would involve, what they would achieve from it.
3. Health	Anything related to participants health, like weight, previous or current injuries, diseases, stress/anxiety, depression, pain, etc.
4. Choice of exercise	Which exercises the participant chose to do, why they chose them and how much exercise they did during the programme.
5. Progression	Which exercises the participant was able to progress/advance in levels, how much they progressed, levels in band exercises and body weight exercises, lack of progression, desire for progression, etc.
6. Experience of doing the exercises	Participants' opinions, feelings, ideas and experience while they were performing the exercise and after it (including exercise bands and soreness) during the programme.
7. Experience of the webapp	Participants' opinions, feelings, ideas and experience while they were using the webapp. Include selection of exercises, interface of the webapp, exercise diary change of weeks.
8. Information	Participants' perceptions of the instructions received from the research team regarding the programme, the video instructions for the programme, the video instructions for the exercises, the resistance bands, and the webapp. Including how they learned how to do the exercises (video, mirror, experiential learning, previous experience).
9. Programme during daily life	Participants' descriptions of how they fitted the exercises into their daily life (including time and place they did them, and clothes, shoes, exercise mat, bands used, etc) and any planning they did (morning, afternoon, evening, reminders, routine, place in which do the exercise etc).
10. Barriers and facilitators	Anything that: a) stopped or was an impediment to, or b) eased, helped,

	simplified, or supported the participants to do resistance and flexibility exercises.
11. Motivation to do resistance or flexibility exercises	Anything that motivates the participants to do resistance or flexibility exercises. Reasons for lacking motivation.
12. Other people	Anything participants experience, feelings, behaviours, perceptions, opinions regarding other people.
13. Impact/changes of the programme	Participants' references to the results they have experienced from taking part in the exercise programmes, including physical, mental and behavioural changes. Include satisfaction, achievement, changes in physical activity habits, etc.
14. Suggestions for the programme	Participants suggestions to improve/change the programme or adapt it for other populations.
15. Selling the programme	Participants' description of the programme for other potential participants.
16. Other	Anything that seems relevant but does not seem to belong to 1-16.

Choice of exercise:

Which exercises the participant chose to do, why they chose them and how much exercise they did during the programme.

Subcodes	Description
1. Convenience	Everything that the participants mention about the convenience of the exercises or the lack of it.
2. Hard/Easy to do	Participants' thoughts and opinions regarding if the exercises where hard or easy to perform, and which exercises they are referring to.
3. Improvement or progression	Participants' perception of their improvement, achievement, physical benefit, progression and feeling of moving on during the programme.
4. Competence	Everything the participants mention regarding their competence, skills and body shape.
5. Volume of exercise	Everything participants mention regarding the amount of exercise that they performed during the programme, reasons they did it or did not, increase or decrease.
6. Pain or discomfort	Everything the participants mention about them feeling discomfort or pain during the exercise programme and the reasons why they experienced it.
7. Variety or not variety	Participants' thoughts and opinions regarding the exercise programmes exercise variety or the lack of it.
8. Bands	Everything the participants mention regarding the resistance band exercises. Only for resistance group participants.

Experience of doing the exercises:

Participants' opinions, feelings, ideas and experiences while they were performing the exercise and after it (including exercise bands and soreness) during the programme.

Subcodes	Description
1. Perception of ability	Everything the participants say about their fitness, preparedness, health condition and preconceptions of what they can or cannot do).
2. Immediate responses to exercise	Participants' immediate physical, mental or other responses to exercise on a week-by-week basis.
3. Doing the exercise right and concerns.	Participants' thoughts, feelings and perceptions of doing the exercises correctly and their concerns about this.

Programme of Daily life:

Participants' descriptions of how they fitted the exercises into their daily life (including the time and place they did them, and clothes, shoes, exercise mat, bands used, etc) and any planning they did (morning, afternoon, evening, reminders, routine, place in which do the exercise etc).

Subcodes	Description
1. Time of the day and reasons	When the participant did the exercises and the reasons why.
2. Place of exercise and reasons	The regular place chosen by the participant to perform the exercises (e.g. in their home).
3. Disruptions	Participants experienced disruptions during the programme (e.g. holidays, going away, places other than home).
4. Clothing and equipment and reasons.	Participants' chosen clothing and equipment used, and any reasons related to them.
5. Pattern of their exercise during the week.	What happened during the week.
6. Routine	Anything the participants mention about establishing or not a routine, it's importance, their planning, reminders and changes to it.
7. Priorities.	Participant's priorities, including competing priorities.
8. Weekdays vs weekends	Anything the participants mention related to their programme experience comparing weekdays and weekends.
9. COVID	Anything the participants mention about COVID in relation to planning, routine and priorities.

Barriers and facilitators:

Anything that: a) stopped or was an impediment to, or b) eased, helped, simplified, or supported the participants to do resistance and flexibility exercises.

1. Convenience	Participants' experiences of the timing of the exercise, space used and time spent doing the exercise.
2. Routine and scheduling	Participants' experiences of routines, schedules, how they help them or how they got in the way of doing the exercise.
3. Work	Participants' experiences of their work getting in the way of doing the exercise or enabling them do to it.
4. Life events	Everything the participants mention about different life events, like holidays, illness or unexpected disruptions of their normal routine.
5. Competing priorities	Participants' thoughts and experiences about their priorities and how that affected or enabled them to do the exercise.
6. Online exercise programme	Any mention of technical problems during the programme that might have affected them while doing their exercise.
7. Exercise intensity and volume	Everything the participants mentioned about the exercise intensity and volume that might have helped them or got in the way of doing the exercise.
8. Other people	Any mention of other people and family that helped them or got in the way of them doing the exercise.
9. Accountability	Participants' thoughts of how being accountable might have helped them or got in their way during the exercise programme.
10. Identity	Anything the participants mention about them not liking exercise, having a lack of fitness, their perception of themselves, thoughts and opinions about how the benefit of the exercise they did and any mention about forgetting to do the exercise and how these helped or got in the way of doing exercise.
11. Laziness and tiredness	Anything the participants mention about laziness and tiredness and how that affected doing the exercise.
12. Weather	Anything the participants mention about the weather and how that helped or got in the way of doing the exercise.

Impact and changes of the programme:

Participants' references to the results they have experienced from taking part in the exercise programmes, including physical, mental and behavioural changes. Include satisfaction, achievement, changes in physical activity habits, etc.

Code	Description
10. Physical changes or lack of them	Everything the participants mentioned regarding the physical effect of the whole programme on their body, strength, flexibility, endurance, pain, and others.
11. Mental and emotional changes and the lack of them	Everything the participants mentioned regarding the mental or emotional effect of the whole programme on themselves.
12. Ripple effect	Everything the participants mention about how they have started to change different things (diet, physical activity, confidence, willingness, etc) due to doing the exercise programme.

Appendix AF: Framework Matrix Choice of exercise

ID number	Characteristics	Bands	Competence	Convenience	Hard or Easy to do	Improvement or progression	Pain or discomfort	Variety or not variety	Volume of exercise
Reflex028	Flexibility / <35 y / Female / Completer	NA	NA	NA	Really easy to do and it felt like meditation. "I think they were easy to do so I did them but also they were less demanding on my body and they were verging on doing meditation in a way for me. It wasn't necessarily pushing my body but more my mind and getting in a space of doing an exercise."	NA	Had knees pains because of sitting in front of the computer and the exercise helped her body. "I feel like in a way it actually helped my body itself in terms of I had less knee pains because that is where I started because I spend so much time in front of the computer so it was good thing."	Would have liked more variety and more levels. "Yes, I would have liked to have more diversity or a level up at one point but probably this wasn't the aim of the programme itself but for the future probably it would be interesting to have different levels of improving or more...we function this way that we like rewards and achievement and I think it would have been nice to have the goal itself moving forward and did this, good, let's move on."	Three sets for each of the six muscle groups, did the maximum amount. "I: How many times every day, do you remember? Reflex028: Just once going through all of them. I: You were doing it once a day all of them? Reflex028: Yes, so it was a combination of three I think, three types of exercise once a day. I know that I did the maximum possible. I: You did three sets? Reflex028: Yes, three sets."

Reflex024	Resistance / <35 y / Female / Completer	NA	Shoulder press was complicated to perform and did struggle to fin the correct tension for the band.	NA	Wanted to do the exercises that found particularly difficult. "I generally chose them when I was doing them based on, kind of, just trying to have some variety in what I was doing, and they're all ones that I really referred or ones that I found particularly difficult, so I wanted to do them. So, there was the one where you kind of are lifting your arm like this and actually I just got my COVID vaccine, the second one, so my arm is quite sore, but I found that one really difficult. So, I ended up doing that one a lot because I found it hard and I thought,	Lateral raise exercise thought is was a good exercise to improve.	NA	she chose them trying to have some variety. "I generally chose them when I was doing them based on, kind of, just trying to have some variety in what I was doing, and they're all ones that I really referred or ones that I found particularly difficult, so I wanted to do them. "	One set per muscle group per week.

ID number	Characteristics	Bands	Competence	Convenience	Hard or Easy to do	Improvement or progression	Pain or discomfort	Variety or not variety	Volume of exercise
					like that's a good one to improve on. But, yeah, I choose them at the time I was doing them, and I didn't really plan it in advance." Found push up against the wall, lunges difficult. Plank was surprised that small changes in position made it harder. Squats found them difficult because she couldn't be sure if she was doing them correctly.				

Reflex023	Flexibility / 35-50 y / Female / Completer	NA	NA	Standing exercises convenient because she can do them quickly next to her desk during working hours. "Reflex023 : I think I preferred the standing exercises, because if you're at your desk all day, you can just jump up and quickly do a quick exercise. Whereas, if you need to do any kind of floor-based exercises, you need to go and find somewhere to do it. I: Right. Okay.	Seemed too easy. some of them were a bit too strenuous. "Yes. It almost seemed too easy. Because you were holding the poses for 30 seconds. But there was a good mix of poses. And some of them were a bit too strenuous for me, but there were alternatives there. So, I could go for an easier option."	NA	NA	There were alternatives of exercises, so she could choose an easier option. "Yes. It almost seemed too easy. Because you were holding the poses for 30 seconds. But there was a good mix of poses. And some of them were a bit too strenuous for me, but there were alternatives there. So, I could go for an easier option."	at least one set a week for each muscle group. Maybe added a couple of upper body exercises.

ID number	Characteristics	Bands	Competence	Convenience	Hard or Easy to do	Improvement or progression	Pain or discomfort	Variety or not variety	Volume of exercise
				Reflex023: But that's only because I was fitting things in with working from home while I'm at my desk."					

Reflex032	Flexibility / 35-50 y / Female / Non-completer	NA	NA	NA	Hard to follow the chest stretch instructions, was able to figure it out with time. "Reflex032: You know the chest when you put your arm and turn? I: Uh-huh. Reflex032: [Voices overlap 04:06] good with that to start with, I thought, I can't, I don't understand how that works that exercise. But after a while I got to understand how that one..."	NA	NA	NA	Two sets for each muscle group. Didn't feel the need to do it a third time. "I: Perfect, and then do you remember how many times you did the exercises on a weekly basis and, kind of, how many…? Reflex032: I try to do them twice a week. I: Right, so you chose…so twice a week, would that be…? Let me be a bit more specific. Did you separate the six exercises in two or did you do all of them twice a week, you know what I mean, kind of, one or…? Reflex032: Yeah, maybe two more, yeah, [more in two 08:24] or so, like, on a Monday and then more like a Wednesday sort

									of time as well. I: Nice. And then do you remember how many sets did you do? Reflex032: Two. I: For each one of them? Reflex032: Yeah. I: Right. Did that suit you? Reflex032: Yes, it did. I: And why two and not three or just one if…? Reflex032: I think because if I've done it twice, I seem to feel a bit more…you know, I felt a bit more… Especially like, when you're lying in bed and doing them, the back ones and the stretchy ones and holding that for a minute, I think if you've done it twice you didn't…well, I didn't feel the need to do it again."

ID number	Characteristics	Bands	Competence	Convenience	Hard or Easy to do	Improvement or progression	Pain or discomfort	Variety or not variety	Volume of exercise
Reflex038	Flexibility / 35-50 y / Male / Non-completer	NA	His legs are tighter than other parts of his body. "I don't know. I just find them all similar sort of level but the legs ones were the harder ones for me but just because I'm tighter there anyway."	NA	Found them hard to do, but good to them and that should be doing it more. Leg stretches were harder.	NA	NA	NA	One or two sets a week for all muscles groups.

ID number	Characteristics	Bands	Competence	Convenience	Hard or Easy to do	Improvement or progression	Pain or discomfort	Variety or not variety	Volume of exercise
Reflex030	Flexibility / >50 y / Female / Completer	NA	NA	NA	NA	Her shoulder improved with the chest stretch. "There was the…funnily enough, there was a chest exercise where you had to put your hand against the wall and I'm still doing that one but that's probably the only one that I'm still doing because I've had a bit of a dicky shoulder and I didn't know what was wrong with it and that exercise seemed to actually help it and improve it so I'm still using that one."	Felt pain with the abdominal stretch. "I didn't particularly like the abdominal one where you had to lie on the floor and then lift yourself up off the floor, I didn't like that one. That one was quite sore"	She did try to different exercises every week. "Yes, I did try to check that just to make sure I wasn't doing the same ones all the time so I did try and use that to make sure that the next week I would do something different from what I'd done the previous week."	One set a week usually. Sometimes would do two sets of some muscle groups. She was not sure of how much she could do. "So six exercises, a minimum six exercises and I can't remember now, is it two legs, one chest, one arm, one whatever…back and abdominals. Yes, so I did all then and then I sort of threw in an extra couple here and there along the way. I was a bit wary. I wasn't sure if I should be doing more or stick exactly and I did try and [voices overlapping]."

Reflex044	Flexibility / >50 y / Female / Completer	NA	Poor flexibility in her arms. "My flexibility with my arms, it was just very, very poor but I mean, that's something I can try and work on." Her stomach got in the way on one exercise. "Well, the one with one knee to the chest was fine, that was one of my favourites but it was the one with both knees to the chest, I found that quite difficult to get in the position you did and I think my stomach got in the way. I can remember thinking to myself,	NA	Biceps stretch very difficult for her. Found arms exercises more difficult. Knees to chest was difficult as well, more than what she was expecting it to be.	In general she felt the exercises were getting easier to do with the programme. She felt some improvement with the back exercises and the abdominal stretch. " I did the knee to chest stretch and the one knee to chest stretch and also the back exercises, the cat and dog and the back…I think it's a back stretch where you spread out because I found that very beneficial as well, actually. Yes, I felt a bit of an improvement in myself with some of the back exercises. Oh, and the other one, the abdominal stretch I think it is where you lie on the floor, you lever yourself up and you pull yourself up, yes."	Was uncomfortable with one of the exercise due to her stomach getting in the way. "Well, the one with one knee to the chest was fine, that was one of my favourites but it was the one with both knees to the chest, I found that quite difficult to get in the position you did and I think my stomach got in the way. I can remember thinking to myself, goodness me, you're going to have to do something about the stomach, because…and I do remember thinking that if anybody had, you know, was perhaps severely overweight, they might find	NA	One set for all muscle groups minimum. Sometimes 2 sets for some muscles groups, maybe doing 12 sets in total.

ID number	Characteristics	Bands	Competence	Convenience	Hard or Easy to do	Improvement or progression	Pain or discomfort	Variety or not variety	Volume of exercise
			goodness me, you're going to have to do something about the stomach, because…and I do remember thinking that if anybody had, you know, was perhaps severely overweight, they might find that one quite uncomfortable."				that one quite uncomfortable."		

Reflex060	Flexibility / >50 y / Female / Completer	NA	Scoliosis in her torso. "Then there was the sitting down stretches and leg stretches, again all of those I think were fine for me apart from one, which was lying on my front and extending my back, pushing up with my arms and stretching up with my torso. I have very slight scoliosis at the base of my spine and that causes me a little bit of difficulty."	NA	Chest stretch was difficult to so because it was not clear to her if she was doing the exercise correctly or not. Difficult to do abdominal stretch. "And actually out of all the exercises that was the one that I found most difficult for the simple reason that, although it was explained very well, when you watch the video it's not really quite clear how…whether you're doing it correctly or not. So I was never really quite sure whether I was doing that one correctly or not. It does say in the video you should feel this bit of your body stretching, whatever, but	NA	NA	NA	One set for each muscle group. Six sets in total per week. "I did one each day, yeah. That worked best for me. And then I had a rest day as well. So there are six exercises, I think, in a week, so had one day when we didn't do any. Sometimes I'd do a little bit more of one exercise than the set time, but, yeah, I stuck to one exercise per day."

ID number	Characteristics	Bands	Competence	Convenience	Hard or Easy to do	Improvement or progression	Pain or discomfort	Variety or not variety	Volume of exercise
					to be honest, with me, because I have quite tight muscles and I'm not young and fit as she is, it's not always the obvious place that you feel the stretch, so that doesn't really help you to know that you're stretching in the right way…Well, the chest stretch wasn't the one I enjoyed the least, it was just that was the one I found the most difficult to know whether I was doing it correctly."				

ID number	Characteristics	Bands	Competence	Convenience	Hard or Easy to do	Improvement or progression	Pain or discomfort	Variety or not variety	Volume of exercise
Reflex035	Flexibility / >50 y / Female / Non-completer	Na	NA	NA	Found all exercises fairly easy since has done Pilates and Pure Stretch.	NA	NA	NA	One set for each muscle group. Six sets in total per week.

Reflex052	Flexibility / >50 y / Male / Non-completer	NA	NA	NA	NA	NA	NA	Tried to rotate exercises to keep a variety. "Yeah. So basically I did the, it was split up into something like five different exercises. Obviously I didn't have a list of the exercises, if you had I could have told you, but basically I did chest exercise where you, sort of, put your arm up and you push back, and the leg exercises where you, sort of, grab your leg and pull it up into your buttocks, stretch along there. The core exercises, on the floor stretching the back. So they were the basic ones. I tried to, sort of, rotate it with some of the other ones, just keep a bit of a variety. "	One set for the six muscle groups per week.

ID number	Characteristics	Bands	Competence	Convenience	Hard or Easy to do	Improvement or progression	Pain or discomfort	Variety or not variety	Volume of exercise
Reflex055	Flexibility />50 y / Male / Completer	NA	NA	NA	NA	There was no levels for the exercises.	NA	There were was not variety for the exercises, no levels.	At the beggining two sets a week for each muscle group, at the end just one set per week. "So I used the app on my phone to set up the programme, doing two leg-based stretches each session and then other parts of the body, just one exercise each session. I think there were sort of six to eight exercises in each session and I did it. Initially, I was able to do two sessions a week but in the end I ended up just doing one session a week towards the end of the study."

ID number	Characteristics	Bands	Competence	Convenience	Hard or Easy to do	Improvement or progression	Pain or discomfort	Variety or not variety	Volume of exercise
Reflex053	Resistance / <35 y / Female / Completer	NA	NA	Squats were convenient because you just do them once, you get used to them.	NA	NA	Doing crunches hurts her neck.	NA	One set for each muscle group per week.

Reflex080	Resistance / <35 y / Male / Completer	It was terrifying to use the bands because they don't instantly stretch. he has never used the bands before. He liked the ones with the bands, because changing levels meant changing the band. P: Using the bands were terrifying, because, especially when you use it for the first couple of times, you think they don't work. I don't know if you've ever used the bands? I: No. Reflex080: You don't kind of instantly, they don't stretch. Then you realise you just have to put in a lot of work, and then finally you're	If we was tired because of his aby crying all night and lost sleep, that had a major impact in his performance. Also, the order he did the exercises varied his performance. "I think what surprised me was one week, I did maybe 19, I then went to aim for the full 20, and I only got 14 on the same band. So, again, it just showed that you weren't just keeping on building and building, but if I was tired, like if the wee one had been crying all night, and I hadn't slept much, that had a major impact on	NA	Seated row was hard to do.	Improved push ups. The better he got the better he felt about doing the exercise. Improved some band exercises, changing to the next band. "So I did a lot of the press ups ones, and I went from, I can't remember my initial, maybe ten or 11, I think it was, and I felt myself really building up. So, I got right to the very end of the press ups ones, oh no, the one before where I had to have my feet up on a chair. And if I'd been doing one more week, I would have been onto the final one where I would have been clapping. So that's now one that I'm doing myself, now that the programme's finished. That was good, because it gives a true estimation of me progressing. I could see myself getting better. The better I got, the better I felt, and so the more confident I felt about going for it. So yeah, that one was good. "	NA	He like the variation. "But I liked the variation, so if didn't want to do press ups, I could do a plank. If I didn't want to do the rowing one, I could do…so there was enough there to make each week a bit more interesting."	One set for each muscle group each week.

ID number	Characteristics	Bands	Competence	Convenience	Hard or Easy to do	Improvement or progression	Pain or discomfort	Variety or not variety	Volume of exercise
		really beginning to feel them. So, I think that was a real positive for me, having never done the bands. If I'd have bought them myself, and watched maybe videos, I don't think I'd have stuck at it, because I think I'd have chickened out to think, I just can't manage with these. I liked the ones with the bands. Again, same reason, because I felt, when you changed to a new colour, it was almost like, hey, look at this, I'm going up a band. "	me. I also varied the order I did things, which probably had an impact on it. " His height made doing lunges not pleasurable. "There was none that I thought I didn't like. Some of the big lunges, the single lunges, I'm not a big fan of those. When you're tall to begin with, jumping up even higher doesn't make it more pleasurable."						

Reflex016	Resistance / 35-50 y / Female / Completer	Upright row was convenient.	Doesn't have much strength in her arms.	Upright row was convenient to do while the kids watched television. Easy to do. they were easy to fit in.	Lateral raise hard to do, because she doesn't have much strength in her arms. "There was an exercise, I think, because I do…I don't have much strength in my arm, so I recognise that, there was…I don't know what it's called but your band and you're standing there and you're kind of going out to the side. Is it called lateral raise? I can't remember, but I know I didn't do that as often, plus avoided because it's harder." Crunches was really hard from the start,, while planks not. Planks are easier to improve. "So, the one that was, I think, focusing	Planks were easier to see improvement, because you increase seconds.	NA	NA	One set for each muscle group per week.

ID number	Characteristics	Bands	Competence	Convenience	Hard or Easy to do	Improvement or progression	Pain or discomfort	Variety or not variety	Volume of exercise
					on the core where you could do plank or crunch, and I definitely opted to do more planks. Probably because it…initially you can do it, it's the sort of thing you can increase seconds by. So, you'll do it and you'll see the improvement from how long you can do it. Whereas a crunch I suppose is really hard from the off. That's being honest, that's probably what…why I opted for that."				

Reflex037	Resistance / 35-50 y / Female / Non-completer	NA	NA	The exercises were really quick to do, which was really handy. "I actually quite enjoyed the exercises and they're really quick to do, which was really, really handy. So, even if it got to Tuesday night and I was thinking, right, easy to get them done. It was easy enough to do them. "	NA	Improved in squats and went up several levels. Improved push ups repetitions, but didn't go up levels. Improved in planks. "So, there was squats, I moved through a few levels of that one. So, that went from the…a sitting one, or one where there was a chair that you could sit down on, or sit on that level, and that got up to the dynamic one, where there was a jump involved in it. The other leg one I did was the deadlift one with the resistance bands, and then for…I can't remember if it was arms or back, it was rowing, there was a wide row and then a narrow row. Chest was always push ups. I didn't get past doing push ups on my knees. But I did get them better, but I didn't get past doing push ups on my knees. Plank, I did progress in plank for core. So, I tended to do plank more than…the other option for that was the crunches, but I did more of the plank. So, I went up the levels with that	NA	NA	At the beggining more than one set, but decreased to one set per muscle group due to time. ": Right. How many sets were you doing every week, do you know, you remember? Reflex037: Mainly just one set. At the beginning, I did do more sets, but towards the end, I was…it was the evening, so I had to get…I just took…I'll just do one set before I can go to my bed. I: No worries. Why did you decrease to the minimum? Reflex037: I think it was just time, just trying to fit in. "

ID number	Characteristics	Bands	Competence	Convenience	Hard or Easy to do	Improvement or progression	Pain or discomfort	Variety or not variety	Volume of exercise
						and had just about got to the dynamic plank when the twelve weeks was up. And there was lateral press, the folder ones, so they were quite good with that. I actually quite enjoyed the exercises and they're really quick to do, which was really, really handy. So, even if it got to Tuesday night and I was thinking, right, easy to get them done. It was easy enough to do them. Occasionally, if I was doing them, my children wanted to join in."			

ID number	Characteristics	Bands	Competence	Convenience	Hard or Easy to do	Improvement or progression	Pain or discomfort	Variety or not variety	Volume of exercise
Reflex047	Resistance / 35-50 y / Female / Non-completer	NA	Patient referred to have "so much wobble in her". Was worried if she was going low enough in the squats. She has poor knees, so she wasn't comfortable doing squats.	NA	Found the plank hard to do.	She felt that the squats helped her more that the front lunge and deadlift.	Felt pain in her arms during the planks, because of a fall that hurt her arms (outside programme).	NA	Wasn't sure how much volume of exercise she could do, so ended up only doing one set of exercise per muscle group per week. Though refers to be doing three sets for legs by the end of the programme. Note: Not clear how much the participant did.

Reflex057	Resistance / 35-50 y / Female / Non-completer	NA	NA	Exercises convenient, because she can do then next to her desk in front of computer or anywhere while travelling. "So I feel like most of the time I would do them in my office, because that's where my computer is, so I can watch the videos and just do them in the space I've got at my desk. But if I was travelling, not home, I'd just have some time to do them at [inaudible 10:53], I wouldn't necessarily	Found planks very hard to do and uncomfortable.	NA	Found planks very uncomfortable to do.	NA	One set of exercise per muscle group per week.

ID number	Characteristics	Bands	Competence	Convenience	Hard or Easy to do	Improvement or progression	Pain or discomfort	Variety or not variety	Volume of exercise
				do all six at the same time. I'd do some on some days then I would just do them wherever. You can do lunges and press anywhere."					

ID number	Characteristics	Bands	Competence	Convenience	Hard or Easy to do	Improvement or progression	Pain or discomfort	Variety or not variety	Volume of exercise
Reflex050	Resistance / 35-50 y / Male / Completer	NA	Gets physically tired very quickly if he does too much exercise, so tried to do the minimum. "I decided that I wanted to keep it as simple as possible. As I mentioned before, one thing I noticed in my previous life is I get tired very quickly if I do too much exercise. So, I wanted to keep it as minimal as possible to avoid that."	NA	NA	Improved in push ups, squats, deadlift. It was difficult to pull the harder bands, it was uncomfortable. "Reflex050: The ones I liked least were the dead lifts I think, because I was using the strongest band and my legs were stronger than my hands; it hurt my hands to pull the band up. I: Okay. Was it too thick, like a very thick band to kind of just pull yourself up? Reflex050: Yeah, I think it's because it doesn't have a handle, the band kind of pulls unevenly on the hand and it's a bit uncomfortable. I think you can get handles for exercise bands but I never got round. I thought it was becoming a step too far to get a handle, but I might do that now."	It was uncomfortable to pull the thicker bands because the band didn't pull evenly in his hand. "I: Okay. Was it too thick, like a very thick band to kind of just pull yourself up? Reflex050: Yeah, I think it's because it doesn't have a handle, the band kind of pulls unevenly on the hand and it's a bit uncomfortable. I think you can get handles for exercise bands but I never got round. I thought it was becoming a step too far to get a handle, but I might do that now."	There was a really good selection of exercises. "I liked them all. I thought it was a really good selection of exercises. I found some more tiring than others."	One set per muscle groups per week.

Reflex031	Resistance / >50 y / Female / Completer	Enjoyed the resistance band exercises and thought they were good. "I generally quite enjoyed the ones with the resistance bands, they were good. Personally, I didn't enjoy doing things like lunges and that, but that's just me, I've never liked them much. The resistance bands were good. " Deadlift exercise was alright. "I: Which ones didn't you like? Reflex031: I didn't like lunges, I've never liked lunges. I don't particularly like squats either. What else was there for legs? Hmm. I: Why? Reflex031: I suppose the	Always found squats and lunges tricky to do, "her knee doesn't like them". She doesn't she does them very well (lean too forward). Has long legs, very long arms and a short body which affects the way she does those exercises. "Reflex031: I didn't like lunges, I've never liked lunges. I don't particularly like squats either. What else was there for legs? Hmm. I: Why? Reflex031: I suppose the one with the bands that was alright. I: Why don't you like them?	NA	NA	NA	Her knee doesn't like squats or luges, feel uncomfortable.	There wasn't a good variety of leg exercises. Wanted more variety of that.	One set per muscle group per week. "I:...do you remember how many sets you did every week of the exercises, did you keep just one per exercise a week or did you increase up to two or three? Reflex031: I just did one. I: Do you remember that you could do more if you wanted to? Reflex031: I remember that now, yes. I: No, but generally, like, doing the study did you have that in mind, oh actually I can do more but I just want to do one, or…? Reflex031: No, I think it was a case of, right, I'll do them all and then get them done and then if I feel like doing any more

		one with the bands that was alright."	Reflex031: I don't know, I just…well, probably partly because my knee doesn't like them. And I just find squats…I don't like lunges because of my knee. Squats? I don't know, I just always have found them a bit tricky. I: In what sense, can you explain it to me? Reflex031: I don't know, just that I feel like I lean forward too much when I'm doing them and I don't feel I do them very well. So I suppose because I don't think I do them very well I don't						later in the week, I can do it. But I just didn't get around to doing any more than the one."

			like them whereas there's some exercises I really enjoy doing. It is partly because of the shape of people as well. I've got long legs and a short body and very long arms and some exercises other people find very easy, I just think, this is really weird and I can't do it – whereas other exercises that they can't do so well, I can do alright. So I suppose it's just your body likes some exercises, doesn't it, and doesn't like others, and my body doesn't seem						

ID number	Characteristics	Bands	Competence	Convenience	Hard or Easy to do	Improvement or progression	Pain or discomfort	Variety or not variety	Volume of exercise
			to like squats and definitely not lunges."						

Reflex061	Resistance / >50 y / Female / Completer	NA	Couldn't do lateral raise properly with bands above level one. "Yes, there were some that I enjoyed less than others maybe, if I go negatively. I suppose the seated ones you enjoy more than others. I found the lateral raise one a challenge and I couldn't…I really couldn't do that effectively above a band one, which I found interesting. So I just kept to the band one and just kept going. I did try with the band two, but I really	Some exercises were convenient while she was on holiday in a motorhome. The lunges and the band exercises were not as handy while there.	Found lateral raise hard to do. Sometimes the plank felt like she wasn't doing anything (too easy).	Was not able to progress in lateral raise. Started on level one and progressed levels, band four for most band exercises. Progressed quickly on leg exercises. Shoulder exercises took longer because she wanted to be careful due to an old injury. "I think it varied as to which exercise I was doing. I think the leg ones went up quite quickly. My legs are definitely my stronger part of me rather than my shoulders. I was very wary. I didn't want…with my shoulders I have had a shoulder injury a long time ago and I was very wary, I didn't want to aggravate anything, so I took maybe a bit longer with the other ones, so I went up a bit slower."	NA	NA	NA

ID number	Characteristics	Bands	Competence	Convenience	Hard or Easy to do	Improvement or progression	Pain or discomfort	Variety or not variety	Volume of exercise
			couldn’t do it properly."						

Reflex021	Resistance / >50 y / Male / Non-completer	Seated row fairly simple. Preferred band exercises, it was more fun and engaging. Transitioned in one band to the next and that gave him a few knee pains. "But I preferred doing them with the tension bands, 'cause there were some exercises where you'd do like push-ups, but I kind of enjoyed…between the two, if I had to choose, I would much rather use the bands than just simply do press-ups. It seemed more fun, more engaging."	NA	Rowing exercises convenient because you just needed a band.	Preferred exercises that were easier to do so he would choose those. "There was a set of exercises for different body parts. So when I went onto the website, I selected one for your arms, one for your back, one for your legs – and there were other categories, I can't quite remember – and as long as they had like four or five different exercises that was the quota for the week. And I basically discovered there were ones I preferred or that I found it easier to do. So the following week I would kind of opt for those just because, as I say, they were easier to do."	Some band exercises went to next level and plateaued in the number of repetitions.	Had some pain in his knees after progressing to next level with the other band.	NA	One set for each muscle group per week.

Appendix AG: Framework Matrix Experience of doing the exercises

ID number	Characteristics	Immediate responses to exercise	Doing the exercise right and concerns.	Perception of ability
Reflex028	Flexibility / <35 y / Female / Completer	Bored of the exercises, since wanted more intensity. Exercises felt like almost meditation. She felt that it was not pushing her body but her mind. "I think they were easy to do so I did them but also they were less demanding on my body and they were verging on doing meditation in a way for me. It wasn't necessarily pushing my body but more my mind and getting in a space of doing an exercise." Struggled to keep up with the volume of exercise that she had set up to do (max). " also got probably bored at one point. I was hoping that maybe midway requirements would change and things would get a bit more intense. I felt like it was a bit less demanding on my body."	NA	Exercises were not very demanding for her body.
Reflex023	Flexibility / 35-50 y / Female / Completer	Enjoyed doing the exercises.	NA	NA

Reflex032	Flexibility / 35-50 y / Female / Non-completer	Enjoyed the exercises lying in stomach and back. Could feel the stretch while doing the exercise. Felt more calm, invigorated, better after doing the exercises. "I think sometimes I felt a bit more calm, because I think sometimes the reason you want to get up and go is because you're feeling stressed or you're doing a task that's quite complicated or you think a lot and you're like, oh I just need a bit of a break. And then you do that and come back and feel a bit invigorated, ready to do it, ready to carry on more .. No, I think you just felt better for, like, moving, like you said."	NA	NA
Reflex038	Flexibility / 35-50 y / Male / Non-completer	Felt proactive after the exercises because she hadn't been doing anything before the programme started.	NA	Felt her legs quite tight before the study. "I: Did you have some that you enjoyed more and others that you least enjoyed? Reflex038: Well, to be fair, because it was stretching, I'm quite tight in my legs so it was quite good to do them although they're hard but I find them probably something I should be doing more of but, yes."

Reflex030	Flexibility / >50 y / Female / Completer	She felt her shoulder quite sore after the abdominal stretch, didn't feel comfortable.Felt quite happy and enjoyed doing them. doing the chest exercise hurt on one side for the first couple of times. Felt achievement once she finished doing them.	NA	Has been to the gym previously and knew how to do several of the exercises. Tried to see if she could go further than last session, and was not always convinced she could.

Reflex044	Flexibility / >50 y / Female / Completer	Didn't feel any discomfort. Felt very pleased with herself since she was doing something to improve her health. Enjoyed to do the exercises.	If she didn't feel the stretching in the areas described in the video, she would watched it again and adjust the way she was doing the exercise. "I felt the stretching, all the pulling in the areas that you described and if I didn't, as I said, I stopped and watched the video again."	Felt her flexibility improved. At the beginning she felt quite ashamed of herself because her first attempt was embarrassing. Realised that she couldn't do the exercise, but after a few weeks she was able to. "I think is it the quad stretch where you stand on one leg and you get the other leg by the ankle, the first time I attempted that it was embarrassing and I was actually…I actually felt quite ashamed of myself. I thought, how could you get in such a state that you can't stand on one leg and comfortably pull the other leg and get in that position, but after about three or four weeks there was a…just doing that exercise with the required repetitions I found there was an improvement in me being able to do that exercise." Reported to have very poor flexibility in her arms. Found that her stomach would get in the way of one particular exercise (knees to chest).
Reflex055	Flexibility / >50 y / Male / Completer	Comfortable and good to do the exercises. Most of the time quite enjoyable to do them with exception of the chest. Felt nothing else (physical or mental).	Found the chest stretch quite difficult and didn't know if he was doing it right.	Has done yoga for the last 30 years so a lot of the exercises were quite familiar.

Reflex060	Flexibility / >50 y / Female / Completer	Felt sore after doing the abdominal stretch. Felt pain in her back due to having scoliosis in her back. Enjoyed the exercises. Didn't feel exhausted, tiredness or pain. Felt hugely relaxed after the exercises and an endorphin buzz.	She couldn't really see herself if she was doing the exercises correctly. One particular exercise was not very clear for the participant to know if she was performing the exercise correctly or not (chest stretch).	Reported having quite tight muscles and not being young and fit. Has slight scoliosis at the base of her spine so that put a bit of difficulty in one exercise.
Reflex035	Flexibility / >50 y / Female / Non-completer	Satisfied when she completed her exercise session. "I do like stretching out. I think it's good to stretch your muscles and whatnot so it is…yes, I guess it's quite satisfying when you've completed the set of stretches."	Na	Felt exercises were within her capabilities.

Reflex052	Flexibility / >50 y / Male / Non-completer	Felt some pain when had to sit down over her legs and ankles. Felt uncomfortable in her right knee, a bit of a pain. Felt some pain after the chest exercise. Didn't feel anything in the other exercises, maybe a bit loser.	NA	Her ankles didn't have the flexibility to be able to sat on them. some issues with her right knee, painful unless sitting with some padding under.
Reflex024	Resistance / <35 y / Female / Completer	She would get distracted while doing them because they were a bit of a "faff" and not straightforward. Enjoyed doing the exercises, particularly the floor based ones. Felt a bit sore sometimes, arms after push ups and legs. Felt satisfied and achievement. Also, she felt a boost in her mood, it was helpful. " think that I noticed, you know, whenever I was doing them there would be a boost in my mood which was helpful, which I was kind of aware of anyway. That doing physical activities especially something that kind of was making me sweat would be helpful for my mood. So, yeah, that was helpful."	Found some exercises a bit difficult to follow and perform. Worried a lot about the form on standing exercises, lunges, squats, etc. she was worried that she would injure herself. "I found that a lot of the ones where I was standing I worried a lot about form. So, I worried a lot about form and lunges thinking about whether my knee was going passed my toes and squats and, kind of, thinking about that. So, I enjoyed the floor based ones more, and I think that just reflects like my general sense of these types of strength exercises is that I worry a lot that I'm going to injure myself or something."	Surprised of how difficult the push ups were. Found lunges, shoulder press and shoulder raise ones quite difficult. Finds squats really difficult to do, kept asking for help in regards of form.

Reflex053	Resistance / <35 y / Female / Completer	Felt most of the time bored and in a lot of pain. Doing the exercises doing her free time (not a lot) and preferred doing something else. Also, the pain because the exercise was really hard. Felt awful, really hot (heatwave during the study), flushed and nauseous. Doesn't get endorphins from exercises (ever). "Most of the time I would kind of feel like [interruption from child] feel kind of bored mostly and then also, then like in a lot of pain. Because primarily I'm doing it during my free time and I don't really get that much free time, and so I'm always like, oh my God, I'd rather not be doing this, kind of thing. And then, it's also, you know, kind of painful [interruption from child]. Kind of, you know, it's also like painful I'm going to say. Like, oh my God, oh, my leg hurts. Like, this is really hard."	NA	She was able to recognise the exercises most of the time. As time went on, she felt more confident in doing the exercise. she has learnt the exercise. "I felt like, yeah, I felt more confident in like, oh yeah, I know what this is and I can, I know how to do it and I got stuff. Yeah, as time went on, I felt like I kind of learned the exercise. But never enough that I could totally remember which one was which from just the name. Because a lot of them were kind of similar. But then, if I could, if I look at the video and I saw what she was going, or he was doing, I could…I was like, oh yeah, I remember how to do that, or whatever."
Reflex080	Resistance / <35 y / Male / Completer	Enjoyed doing all the exercises. No exercise he didn't like. Found that it was fun to do the exercises. Felt exhausted to do the exercises, after the plank (mainly)-press ups felt sore and a bit hot after the others. the pain went away if he walked around after it, if he stayed still the pain would last for longer. He felt happy.	NA	He is a quite confident person anyway. Felt more confident in using the bands as the programme progressed.

Reflex016	Resistance / 35-50 y / Female / Completer	Good, sense of achievement, because she was doing something for herself (after having a baby, 16 months post), increase in repetitions made her feel encouraged.	NA	Realised that she wasn't used to do exercises and notices less aches as the study progressed. Reports not having much strength in her arms. Found the crunches really hard from the beginning. Her body has changed from having a baby 16 months ago.
Reflex050	Resistance / 35-50 y / Male / Completer	Enjoyed the exercises and liked all the exercises. The one-leg squat found it specially tiring. Used the hardest band for deadlift and pulling it hurt his hands. Felt fine while doing the exercises, but as they got harder enjoyed them a bit less. Felt quite neutral (apart from enjoying them). Lunges were the only ones that make him bit sore a couple of days after, specially the jumping lunges.	NA	NA

Reflex037	Resistance / 35-50 y / Female / Non-completer	Enjoyed doing the exercises and enjoyed using the bands as well. Put a lot of concentration while doing the exercises. Felt sense of achievement after doing the exercises, specially after seeing her personal best. Felt a bit disappointed when she wasn't as good as the previous session. "I always felt a bit of a sense of achievement actually, especially when you could see your personal best and you were able to see what you'd done the last time. There were times when I wasn't as good as I had been before, and that always felt a little bit disappointing. But otherwise, there's definitely a sense of achievement afterwards." First couple of week felt achy the next day and didn't last too long (one day). Felt more achy on the weeks that did more sets and tried the next level. "To begin with, the first couple of weeks, not right afterwards, but the next day, I was a bit achy, but then that went away and it didn't seem too long. But I was definitely a bit achy, especially with the first couple of weeks, because I'd done a couple more sets where I'd tried maybe the easy level, but then also done the next level. So, I was more achy those weeks, but not laterally."	Used a mirror to check if she was doing the exercises correctly, specially for squats and lunges. After a while stopped using it for plank and push ups. With the programme progressing she realised that her body knew what shapes she needed to do and how they should feel. "I still used the mirror, just because it happened to be in one of the rooms that I was doing them in. So, I did use it, just to check, especially for squats, that my knees weren't going too far forward, and for the lunges, again, that my knees weren't going too far forward. But I didn't…after a while, I didn't use it for the planks and I didn't use it for the push ups. ...I think that my body knew what shapes it should be making and how it should feel. So, I think once I was more comfortable in knowing, for example, in a plank, where my hips were, and making sure I wasn't sticking my bottom up in the air, what have you. Once I knew what that felt like, then I didn't need it."	She is not very good a push ups what makes not like them. At the beginning did not know how to use the bands. Enjoyed using the bands.

Reflex047	Resistance / 35-50 y / Female / Non-completer	Found the exercises in general very enjoyable. Was confused with the instructions, though. Doing the plank hurt her arms and knees, that was due to a previous fall.	Felt apprehensive of doing the exercises right. Worried about picking up the right level, picked the correct band, doing the exercise correctly, stretching herself enough and following the instructions. Did know that she wouldn't do lunges to the correct ("control") standard. Did not know if she was doing the squat properly, going low enough.	Thought that the bands were not easy. Was horrified to realise the deterioration of her fitness in the last couple of months. She was really trying (pushing) to get 2 reps on the exercises. "At the start of the study it was just that horrification of how your body can just go to being ineffective in such a few number of months, and literally I last went running the end of September, very early October through to…no, that's not true, I went out just before October half term, so mid October, so mid October to June, how you could have just lost everything but without noticing that you've lost it." Participant reported having a poor core since having children. She knew she wouldn't be able to do lunges properly. Participant reports having "poor knees" and age affecting her ability to perform squats.

Reflex057	Resistance / 35-50 y / Female / Non-completer	Felt please with herself because she was exercising. Felt sense of achievement that she has checked out the list for the week. Felt a bit sore after the session. Felt a little sense of satisfaction of having done her exercises consistently.	NA	Participant felt that it was easy and an achievable amount. Found push up challenging and hard to improve. Was disappointed that could not improve. Also, felt afraid and not confident enough to do jump lunges (break ankle). Her balance is not the best. "Some of them felt like…I don't know, like the lunges and the squats, I was never really willing to work at jumping, so I was not willing to go to the next level, because I just, I don't know, I was afraid I was going to break my ankle or… I just don't feel like confident enough, so I was fine just doing 20 of the level I was because, yeah, I didn't feel comfortable [inaudible 07:47] jump, they were hard."
Reflex031	Resistance / >50 y / Female / Completer	generally quite enjoyed doing the band exercises. Didn't like lunges and push ups. After the exercises felt good, invigorated and that they were done and move on (sometimes). It would depend on her mood, never felt bad after them. "I: And how did you feel after doing the exercises, so once you'd finished them kind of? Not the programme itself, I mean, when you were doing some, for example, push-ups and then you finished, how did it make you feel afterwards? Reflex031: I suppose that really sometimes you just felt, that was good, I feel, you know, invigorated. Other times I just thought, oh good, that's that done, right, I'll go and do something else now. So it is really, you know, depending on my mood. I never felt bad after them."	NA	Doing the exercises showed her how weak her arms were. Knee doesn't "like" squats and lunges, found them tricky. She feels she doesn't do them very well. Her body doesn't like to do those kind of exercises (body shape, short body, long legs and arms).

Reflex061	Resistance / >50 y / Female / Completer	Some exercises (lunges, push ups, plank)she felt her heart rate increase considerably. She felt good while doing the exercises, making an improvement. "Some of the ones it did raise my heart rate considerably, which was interesting because you don't think you're doing a huge amount. It's not as if you're running. Which I suppose is good, I think. I suppose generally I felt quite good doing them. I felt it was making an improvement, so I suppose I felt quite good doing them." A day later after doing some of the leg exercises felt that her muscles had been used (not strained). The feeling went away after a while and it was okay. Felt good about herself about doing the exercises, pleased that she had done them. "No, no it was just if…yeah, I think it changed when I changed the lunge from a short one to a long one, that helped. I got more…I wouldn't say stiffness, more a, you think you've used that muscle. I mean I didn't take any painkillers or any anti-inflammatories, nothing like that. It was just you think, oh…as if you'd been on a long walk and you thought, oh gosh, I've definitely exercised my muscles today, yeah."	As the programme progressed felt that she was learning how to do the exercises properly, specially the band ones. "I got to know the exercises more, so you felt as though you were doing them properly. Definitely a skill with some of the bands, how to hold it and how to get it round your feet et cetera."	NA

Reflex021	Resistance / >50 y / Male / Non-completer	Band exercises were more fun and engaging. Felt a few pain in his knees after changing to the next band. Felt a few twinges/nigly pains during squats and lunges. they would stop after the exercise. Felt fine while doing the exercises, not overly stressed. Didn't get out of breath. while doing push ups felt uncomfortable and a slight pain. Stopped doing them when started to feel uncomfortable. After doing the exercises felt a sense of achievement, tick off a list, felt positive that he had he had acieved that.	NA	Put on weight over lockdown and is carrying too much weight, giving him more twinges during squats and lunges. Was cautious and careful with the exercises because of lack of exercise over time, age, family history and a friends experience. Also, that it is difficult to see doctors during lockdown. " I: Why were you cautious? Reflex021: A combination of a lack of exercise over time, so erring on the side of caution. My age - I'm 51 and one of my good friends two weeks ago was out running, he's training for the London Half Marathon, he felt unwell and he went to see his doctor and last week he was fitted with three stents. And he is healthy, he eats well, he's not overweight and he runs. He's running at a level for 13 miles, sort of thing. And it turns out he has three blockages in the arteries leading to his heart and he had to have three stents fitted. So I'm aware of my age and the kind of…again, family history. My father has had a triple bypass, there's been angina in the family. And during lockdown you can't really get to see doctors. That kind of caution was over, I'm doing a bit of exercise for the first time in a long time, so I'm erring on the side of caution in terms of not pushing myself, not making myself overly uncomfortable. So that

				was part of the reasoning was just being careful."

Appendix AH: Framework Matrix Programme of daily life

ID number	Characteristics	Time of day and reasons	Place of exercise and reasons	Pattern of their exercise during the week	Routine	Clothing and equipment and reasons	Priorities	Disruptions	Weekdays vs Weekends
Reflex 028	Flexibility / <35 y / Female / Completer	Started during the day, but after a week ended doing the exercises at night before bedtime.	Bedroom	Monday to Friday (5 times a week). 18 sets per week. Struggled to keep up as the programme progressed. Got bored.	NA	Trainers and comfortable clothing.	NA	NA	NA

ID number	Characteristics	Time of day and reasons	Place of exercise and reasons	Pattern of their exercise during the week	Routine	Clothing and equipment and reasons	Priorities	Disruptions	Weekdays vs Weekends
Reflex 023	Flexibility / 35-50 y / Female / Completer	The majority during working hours 9:00-17:00. Some quad stretches at night before bed.	Next to desk. Not much space needed and could fit them during working hours to break sitting time. Living room. There is more space for the exercises.	Fitted the exercises while working on her desk at home. Do some standing exercises in between working hours. Ended up doing more standing than floor based exercises. Changed during the programme, flexible, depending on how she felt she wanted to achieve. At the beginning of the week usually, at least once a week, but no more than 3 times. Conscious of her inactivity/tightness and wanted to break it with some exercises. Did some leg exercises at night (stretches) because of tightness feeling due to work.	NA	Trainers most of the time. Started with changing to comfortable clothes and then just whatever she was wearing at the time, because it was a faff. Used yoga matt at the begging and then rug, realised she did not need it. In general realised that did not need anything extra to do the exercises. Timer on phone to count the 30 seconds. "Initially, it was like, yes, I need this, this and this, and then I thought, hold on a minute, no, I don't, I can just do it as is."	NA	NA	NA

ID number	Characteristics	Time of day and reasons	Place of exercise and reasons	Pattern of their exercise during the week	Routine	Clothing and equipment and reasons	Priorities	Disruptions	Weekdays vs Weekends
Reflex 032	Flexibility / 35-50 y / Female / Non-completer	Usually during the evening, but also sometimes during working hours.	Dinning room and living room.	Monday and Wednesday, two sets for each exercise.	NA	Usual clothes (leggings and t-shirt), whatever she was wearing that day. Did not use anything else.	NA	NA	NA

ID number	Characteristics	Time of day and reasons	Place of exercise and reasons	Pattern of their exercise during the week	Routine	Clothing and equipment and reasons	Priorities	Disruptions	Weekdays vs Weekends
Reflex 038	Flexibility / 35-50 y / Male / Non-completer	Normally in the morning, after getting up. Sometimes at night if she forgot to do them.	At home bedroom and living room. She felt she could do them anywhere.	Generally once a week, sometimes twice a week. Always did them all in one block due to motivation to do the exercises (felt like keep going)	NA	No trainers (bare feet) and no extra materials.	Children. Get them ready for school. Work until 17:30, but could do some exercises during working hours.	Holidays, did not interrupt the programme since the exercises did not need a lot of space.	NA

ID number	Characteristics	Time of day and reasons	Place of exercise and reasons	Pattern of their exercise during the week	Routine	Clothing and equipment and reasons	Priorities	Disruptions	Weekdays vs Weekends
Reflex 030	Flexibility / >50 y / Female / Completer	Changed. Depended on work. sometimes in the morning, other times at lunchtimes or at night, or between working hours. Really random.	Living room on the carpet. It would make her get up and get away from the computer. Working from home	Fitted the exercises during breaks "Slot things in". Helped to break working times. First week did the exercises on one day. After that it varied, really random, no structure. Whenever she got time for them between busy work periods. Distribution of the exercises was more based around work (not how she was feeling that particular day), because she was doing them in the house.	NA	Used a towel for holding hands during one of the exercises. Did not change clothes because was wearing comfortable clothes due to be working at home. Did exercises in bare feet or just socks. That was comfortable.	Work. Turn computer on first thing in the morning. Walk during lunchtime. House chores. No desire to do exercise after dinner.	One week (not sure when) work was very intense which pushed the exercise sessions to the last day.	NA

ID number	Characteristics	Time of day and reasons	Place of exercise and reasons	Pattern of their exercise during the week	Routine	Clothing and equipment and reasons	Priorities	Disruptions	Weekdays vs Weekends
Reflex 044	Flexibility / >50 y / Female / Completer	Started very variable. Then decided to do it early evening. Because it was the most suitable time for her to do them and to relax. This lasted until the end of the programme. "It varied. Initially I did them on various days at various times and then latterly I decided because you could do them, because of various things I had on I found that the best time for me to do it and be able to relax and do them was probably early evening."	Bedroom with the door closed. To not be disturbed.	Started doing 6 exercises a week and then increase to 11-12 per week (different exercises). Started doing them one or two everyday, after 4 weeks decided to spread them into 2-3 days (Wednesday/Friday/Sunday or Wednesday/Saturday/Sunday) until the end of the programme (the last 8 weeks). This was because of they were so quick to do that she felt that she was in danger to forget to do them.	NA	Wall, because an exercise required it. Exercise mat. Changed every time for exercise. Running shoes and tracksuit bottoms. They were far more comfortable and more practical for one of the exercises.	NA	Holiday. Had to condense the exercises on two days.	NA

Reflex 060	Flexibility / >50 y / Female / Completer	NA	NA	Generally did one exercise per day with a day of rest. Sometimes would do a little bit more.	Set a reminder in her phone in order to remember to do her exercise every day at the same time. Did one exercise every day (6 days a week) consistentl y. She knew that at that time of the day, she would have time to herself to be able to do the exercises. Reminder in calendar (phone) would pop up at certain time everyday. People got used to the fact that she was doing	Used timer on phone. Did not change clothes or shoes. Only made sure to do exercises on somewhere soft on the floor.	Her wellbei ng. Someti mes felt too tired (suffer s from fatigue)to be able to do them. Other people s needs	NA	NA

ID number	Characteristics	Time of day and reasons	Place of exercise and reasons	Pattern of their exercise during the week	Routine	Clothing and equipment and reasons	Priorities	Disruptions	Weekdays vs Weekends
					the exercises.				

ID number	Characteristics	Time of day and reasons	Place of exercise and reasons	Pattern of their exercise during the week	Routine	Clothing and equipment and reasons	Priorities	Disruptions	Weekdays vs Weekends
Reflex 035	Flexibility / >50 y / Female / Non-completer	Evenings. Maybe a couple of times during the day. Because works during the day and does things for the family. The evening is time for herself. "Because I've been working during the day, doing things for the family and it's a bit of my time in the evenings."	Living room.	One set a week, because she thought she was in the controlled group. Did all exercises during one session once a week (sometimes on a Tuesday), because she had to log in her results with her ipad and did not find them very difficult, and took between 15-20 min.	NA	Exercise mat. Used trainers and tracking bottoms, but she usually wears them at home. Therefore did not change clothes.	Work and family, exercise.	Holiday for a week that was extended up to two weeks, missed her exercises.	NA
Reflex 055	Flexibility / >50 y / Male / Completer	Normally mid-morning because it is easier to find time in her schedule. Sometimes during the afternoon depending when she had work meetings.	In the kitchen with hard tile floor.	Started with two sessions a week, but ended up with just one (six exercises) a week. Doing her sessions during the day and by the end of the programme it was rather busy.	NA	Yoga mat, tracksuit or lose clothes.	Decreased from 2 to 1 session a week because it got rather busy. Work meetings.	Holiday away for two weeks, poor phone reception and no internet. Could not use the app.	NA

ID number	Characteristics	Time of day and reasons	Place of exercise and reasons	Pattern of their exercise during the week	Routine	Clothing and equipment and reasons	Priorities	Disruptions	Weekdays vs Weekends
Reflex 052	Flexibility / >50 y / Male / Non-completer	Between 12 and 2 pm quite stable during the 12 weeks.	At first in the front room of the house, but after did the standing exercises out and about while waiting for his son to finish his music lesson in the courtyard or back garden of the studio. At home would do the kneeling exercises, because of convenience.	Six exercises a week (one set per exercise).	NA	Wall. No special clothes or shoes.	NA	NA	NA

Reflex 024	Resistance / <35 y / Female / Completer	Afternoon between 4 and 7 pm. during the whole programme.	Living room. Because she has a very small home (one living space), and felt that she was taking over the space a little bit.	Started with two sessions (six exercises in total) a week (Monday and Friday) but found herself squeezing them whenever she had time because the end of the week was coming up and she had not done the exercises. Does not have a strong life routine so she found difficult to do the exercises at that time.	Aimed to do them twice a week (two sets), but that did not always happened. Set up a reminder at 6 pm in her phone, but in reality it did not seem like a good time for certain reasons (dinner, out of the house or really hungry). Found doing them a bit of a faff, not straightforward, while navigating in and out the app got distracted.	Things suggested in the videos like a chair, a yoga mat, yoga leggings and a t-shirt (used to wear that for most of the last year) and trainers for indoor exercise, because it was more comfortable to put the bands under the feet with shoes on.	NA	NA	NA

ID number	Characteristics	Time of day and reasons	Place of exercise and reasons	Pattern of their exercise during the week	Routine	Clothing and equipment and reasons	Priorities	Disruptions	Weekdays vs Weekends
Reflex 053	Resistance / <35 y / Female / Completer	Always did them in the evening, when the children were asleep.	Living room.	Most of the time one session in one day per week, sometimes two days. Most of the time she would forget to do them and remembered to do them just before the end of the week. Would have liked to spread it through the week and do more exercises, but takes care of the kids all day and in the evenings she is tired. Hard to find motivation to do them.	NA	Music. Tried to concentrate in the music to help her keep going and because it can be a bit boring. Energizing pop music. No shoes most of the time (does not wear shoes inside of the house) but for the band exercises used flipflops or slippers with a hard sole. Normally uses leisure clothing at home, but sometimes would wear shorts that day if she was planning to do the exercises that evening. Used a rug.	Children. She takes care of the children all day. Did exercise in the evening when the children were sleeping.	NA	NA

ID number	Characteristics	Time of day and reasons	Place of exercise and reasons	Pattern of their exercise during the week	Routine	Clothing and equipment and reasons	Priorities	Disruptions	Weekdays vs Weekends
Reflex 080	Resistance / <35 y / Male / Completer	Late at night.	Living room.	Usually the night (late at night) in a panic before the week ended. Because of having a baby recently, but time is not his own.	Tried to do it before dinner, but time is not his own due to having a newborn baby.	Things required for exercise like a chair. Exercise clothes (bare minimum). One day wearing usual clothes. Bare feet, no shoes.	Past couple of months having a newborn baby. Time is not his own. Dog, 8 week old baby, being exhausted, sleep deprived.	NA	NA

ID number	Characteristics	Time of day and reasons	Place of exercise and reasons	Pattern of their exercise during the week	Routine	Clothing and equipment and reasons	Priorities	Disruptions	Weekdays vs Weekends
Reflex 016	Resistance / 35-50 y / Female / Completer	Usually in the evening after the children went to bed. Sometimes during the day.	Usually in the lounge and sometimes in the kitchen. The lounge because is the biggest room in the house, she keeps the bands there and it has foam mats on the floor for the children.	Depended on the schedule for the week. Sometimes did 2/3 exercises to catch up and some other weeks she would do more than the six exercises. Six days a week. Did not want to do too much exercise because was not sure what was the limit and skew study results.	Usually six days a week, maybe some weeks three days. This depended on her week schedule.	Did not use special clothes. Did her exercises in whatever she was wearing, usually some sort of pyjamas. No shoes or trainers.	Could easily fit the exercises after the children went to bed.	some days husband is away at night and she has to take care of the children.	NA

ID number	Characteristics	Time of day and reasons	Place of exercise and reasons	Pattern of their exercise during the week	Routine	Clothing and equipment and reasons	Priorities	Disruptions	Weekdays vs Weekends
Reflex 037	Resistance / 35-50 y / Female / Non-completer	Mostly during the evening after the children went to bed. Because she works during the day and once she arrives at home it a very busy time. During the evening she has a bit of time for herself to get her head into doing it. A couple of times on a Saturday during the day.	In the house, mainly in the study or the spare bedroom downstairs with carpeted floor and an exercise mat.	Usually during the evening after the children went to bed. Sometimes on a Saturday during the day with the children around. Mostly did all her exercise during one evening, but sometimes did two days a week (a couple of exercises each night). At the beggining did more than one set, but towards the end did one set for each exercise before bed. Because of time and trying to fit in the exercise.	NA	Used comfortable clothes. Usually would be wearing leggings anyways, but used a t-shirt or would put a vest (wear to bed) if it was evening.	After the childre n went to bed. Works during the day and cannot fit it in during that time. Decrea sed to one set a week, due to time, trying to fit in the exercis e.	NA	NA

ID number	Characteristics	Time of day and reasons	Place of exercise and reasons	Pattern of their exercise during the week	Routine	Clothing and equipment and reasons	Priorities	Disruptions	Weekdays vs Weekends
Reflex 047	Resistance / 35-50 y / Female / Non-completer	Early morning between 6-8 am. She is a morning person.	Lounge.	At the beginning of the programme she did six times a week, but changed to three times a week because of the school holiday and major changes in the teaching programme. Did it always before work because it is her time and would not forget to do it. That how she found that habit.	Did it always before work because it is her time and would not forget to do it. That how she found that habit.	Exercise mat, a rug sometimes if she was not able to find her mat. Laptop to see the videos. started barefoot, but started to use trainers because the bands pulling under her feet would hurt. Mostly used her sports clothes, because it made her feel that she was doing exercise, after she would have a shower and then change for work.	NA	NA	NA

ID number	Characteristics	Time of day and reasons	Place of exercise and reasons	Pattern of their exercise during the week	Routine	Clothing and equipment and reasons	Priorities	Disruptions	Weekdays vs Weekends
Reflex 057	Resistance / 35-50 y / Female / Non-completer	Usually in the morning, but it varied. Depending of her work schedule and because the children are at day care, so that was the main time to do them.	In her office (space she has at her desk) where her computer is, so she can watch the videos. The band ones did them in front of her computer.	Three days a week (pretty consistently) doing two exercises each day. There were one/two days in which she forgot to do them and did them as soon as she remembered.	Three days a week.	Did not change into other clothes because she works from home and uses some level of athletic wear at all times. Yoga mat for exercises on the floor, but sometimes did them directly on the carpet (she is not super picky). Athletic sandals, felt they were sufficient, stable and have a good sole. Not always comfortable with those, specially jumping.	Work schedule and small children.	If she was travelling would do them wherever, could do lounges and press ups anywhere.	NA

ID number	Characteristics	Time of day and reasons	Place of exercise and reasons	Pattern of their exercise during the week	Routine	Clothing and equipment and reasons	Priorities	Disruptions	Weekdays vs Weekends
Reflex 050	Resistance / 35-50 y / Male / Completer	Morning, right after he woke up.	Front room on the floor.	Six days a week starting on a Friday. Thursday was a resting day.	NA	Exercise mat he already had. Trainers, because his feet would her with the bands under his feet. Will put shorts and t-shirt after waking up and change for work once finished.	NA	Went on holiday and took the bands with him.	NA
Reflex 031	Resistance / >50 y / Female / Completer	It changed a lot. Preferred during the morning, but not the first thing. Press ups and plank tried during the morning, because she felt she was better at them during that time. Sometimes it was in the evening.	Usually in her spare room, because there is plenty of space. Occasionally did it in other rooms, like the living room, or away on holiday.	Very varied, changed a lot. Does not have a routine and spends a lot of time looking after her dad. Depended on what she was doing and sometimes would do them in the evening. The press ups and plank always tried to do them in the morning, she felt she was better at them at that time. Tried to spread them out during the week, but sometimes might have done them in one day (last of the week), not all at the same time. It was perfect for her, suited her.	Did not form a routine and that suited her. Would have not been able to follow the programme if there was a routine.	Some days in pyjamas, some other days changed into leggings and things. It would depend on what she was doing beforehand. Did not particularly put gym clothes all the time. Sometimes she did, particularly for leg exercises. No trainers, just bare feet.	Other activities, what she has arranged for the week, looks after her father.	Holiday, did the non-band exercises away and the band ones before her holiday at home.	NA

ID number	Characteristics	Time of day and reasons	Place of exercise and reasons	Pattern of their exercise during the week	Routine	Clothing and equipment and reasons	Priorities	Disruptions	Weekdays vs Weekends
Reflex 061	Resistance / >50 y / Female / Completer	I was very varied. Spread it through out the day.	Kitchen while cooking dinner, in the bathroom while brushing her teeth, she could fit things during the day.	It varied, but not in the morning since she is not a morning person. Did them in between activities, like cooking dinner or brushing her teeth. She was doing them some every day, after that it was a bit random, but near the end she tried to do it over three days. I was really varied.	I was very varied. Spread it throughout the day and does different things every day. Did not have a set routine.	Usual clothing, did not use special clothing. does not wear tight clothes usually. Some days used shoes, but some other no shoes. Rug in her bedroom.	NA	NA	NA

ID number	Characteristics	Time of day and reasons	Place of exercise and reasons	Pattern of their exercise during the week	Routine	Clothing and equipment and reasons	Priorities	Disruptions	Weekdays vs Weekends
Reflex 021	Resistance / >50 y / Male / Non-completer	It varied. sometimes when he remembered to do them, like before showering in the morning. some other times in the afternoon. It tended to be later by the end of the programme in the evening.	Primarily either in the bedroom or the living room.	For the first couple of weeks found time during the day (morning/afternoon) from Monday to Friday. Sometimes did the 6 exercises or sometimes 2. From week 3 or 4 started to do all exercises on one day, to get them out of the way. They felt like they were an afterthought.	Struggled to find time during the week to set aside for the exercises. Because he is not travelling, teaching online the routines have gone out of the window. He needed a bit of a routine and that was his failing (his words).	Did not change into special clothes, just wearing trousers and a t-shirt. Because he was not getting out of breath or sweating, so did not feel the need to change clothes.	Work, kept pushing the exercise. Found it an issue to find time to set aside during the week.	Go away on the weekend. Kept doing exercises on a Saturday (last day of the week).	Went away to holiday flat every weekend and took the bands with him. Had to cram the exercises before midnight on Saturday.

Appendix AI: Framework Matrix Barriers and Facilitators

ID	Characteristics	Accountability	Competing priorities	Convenience	Exercise intensity and volume	Identity	Laziness and tiredness	Life events	Online exercise programme	Other people	Routine and scheduling	Weather	Work

Reflex028	Flexibility / < 35 y / Female / Completer	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Work and university work got more busy and she didn't know exactly how to navigate that. "I guess it was just university and work and then the regular things that come together when you have deadlines and you don’t know exactly how to navigate those.

ID	Characteristics	Accountability	Competing priorities	Convenience	Exercise intensity and volume	Identity	Laziness and tiredness	Life events	Online exercise programme	Other people	Routine and scheduling	Weather	Work
													Then you think about organising your life in such a way that it is good for your mind and for your body."
Reflex030	Flexibility / > 50 y / Female / Completer	NA	NA	Easy to do them.	NA	NA	NA	NA	NA	NA	NA	NA	NA

ID	Characteristics	Accountability	Competing priorities	Convenience	Exercise intensity and volume	Identity	Laziness and tiredness	Life events	Online exercise programme	Other people	Routine and scheduling	Weather	Work
Reflex032	Flexibility / 35-50 y / Female / Non-completer	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Reflex035	Flexibility / > 50 y / Female / Non-completer	NA	Something else came up that made her forget about the exercise.	Found them easy and quick to do. "Reflex035: Well you only have to do it once a week the minimum anyway, don't you, which is the set of six exercises. I: Yes. Reflex035: So I did find them quite minimal, as in easy and didn't take very long."	Found the exercises and thought she was in the control group, which got in the way of doing exercises and decided to only do one set. "Reflex035: I don't know, really. Maybe I didn't feel that it was…maybe I felt…I think probably I felt I was in the control, in the control arm and that wouldn't actually affect my outcomes that much. So, yes, that's probably why I didn't go full on that."	Forgot to do the exercises since something else came up.	NA	Went on a holiday and there was a fire, stayed there for two weeks to help and that also got in the way of the exercises. "So I did the stretching programme which was once a week although I think I probably missed a few sessions, two	NA	NA	NA	NA	The twos weeks on holiday was also working and that made her really busy, which got in the way of doing her exercise.

								or three in the 12-week programme. The first one, I must say, I was at…I went on a working holiday up to Cumbria because my parents are changing their house into a holiday cottage and it's kind of all hands-on deck. So on					

								that Tuesday when I…I think I was planning to do my exercises on the Tuesday but on the Tuesday morning my brother's farm caught on fire and it was right opposite my mum and dad's place so we just…we saw it. It was a big silage shed					

								went up and his buildin g next to it so it was just a…yes, everyt hing went out the windo w that day. Then I ended up staying up there for two weeks becaus e there was so much work to do so I wasn't great with it but I was still contin					

ID	Characteristics	Accountability	Competing priorities	Convenience	Exercise intensity and volume	Identity	Laziness and tiredness	Life events	Online exercise programme	Other people	Routine and scheduling	Weather	Work
								uing my walking and whatnot."					

Reflex038	Flexibility / 35-50 y / Male / Non-completer	NA	Other priorities like work, kids, lifestyle. "Well, my kids are up early so you're up early with the kids to get them ready for school, then I've normally got meetings on here and I don't move from here until 5:30, six o'clock and then halfway through you don't really think about, oh, I'll get up and do an exercise, because you're always constantly… it depends how busy you are but I'm pretty busy so, yes."	NA	NA	She forgot to do the exercises sometimes.	NA	NA	NA	Her children wake up early and needs to get them ready for school.	NA	NA	Busy with work, meetings. Sometimes was able to do an exercise in between work. "Well, my kids are up early so you're up early with the kids to get them ready for school, then I've normally got meetings on here and I don't move from here

ID	Characteristics	Accountability	Competing priorities	Convenience	Exercise intensity and volume	Identity	Laziness and tiredness	Life events	Online exercise programme	Other people	Routine and scheduling	Weather	Work
													until 5:30, six o'clock and then halfway through you don't really think about, oh, I'll get up and do an exercise, because you're always constantly…it depends how busy you are but I'm pretty busy so, yes."

Reflex044	Flexibility / > 50 y / Female / Completer	NA	NA	Doing the exercises took her 5-10 minutes. Convenient, could do them anywhere with enough floor space, a bit of privacy. they are very easy to do. "I: Is there anything that got in the way of doing the exercises? Reflex044: No, not for me becaus	NA	NA	NA	NA	NA	Husband disturbed her while doing the exercises. Let her stepdaughters and husband know when she wanted to be alone do to her exercises. "Reflex044: Yes, initially there were a couple of times when my husband disturbed me but I was in the	Got herself into a routine, chose a day and time to do the exercise and not forget. "I found that if I had some spare time, I would just do a few of the exercises and then I got myself into the routine in order to really programme me into thinking, right, it's this day, this sort of time, time for the ten minutes of exercises so there is no danger of forgetting."	NA	NA

				e I could do them anywhere, even when we went up, we've got a cottage in Cumbria we're renovating and it's in a pretty awful state but even there, I could go up to one room which was the only carpeted room left and we've got Wi-Fi so I could						middle of them and said…and he'd forgotten, he'd basically forgotten and after that, I let him or when my stepdaughters are here, I'd let them know, I'm going to do my exercises, I'll be ten minutes and I can't be disturbed, so that was it."			

				easily do the exercises there and some of the leg exercises I could do outside using the house wall as a support. So I mean, you could do them in a hotel room, anywhere really, as long as there is enough floor space then you're not particul									

ID	Characteristics	Accountability	Competing priorities	Convenience	Exercise intensity and volume	Identity	Laziness and tiredness	Life events	Online exercise programme	Other people	Routine and scheduling	Weather	Work
				arly tied to equipment or anything or any sort of huge space or whatever. As long as you've got a bit of privacy, a bit of floor space and you know what you're doing then they're pretty easy to do, pretty easy to fit in anywhere."									

ID	Characteristics	Accountability	Competing priorities	Convenience	Exercise intensity and volume	Identity	Laziness and tiredness	Life events	Online exercise programme	Other people	Routine and scheduling	Weather	Work
Reflex052	Flexibility / > 50 y / Male / Non-completer	NA	NA	NA	NA	NA	NA	NA	NA	NA	Had a routine, regular time that suited him and did his exercises there.	NA	NA

Reflex055	Flexibility / > 50 y / Male / Completer	NA	NA	NA	NA	NA	NA	Holiday for a couple of weeks with no phone reception. could not access web app.	Web app would not let him log in, which got in the way of doing the exercises "Is there anything else that got into the way of doing the exercises? Reflex055: Only the odd occasions where I couldn't get into the app to log. I: That is during the holiday? Reflex055: No, there were times when I couldn't log-in and I had to do a password reset, so that happened on three occasions on the 12 weeks. So M helped me the first time and suggested I do the web reset rather than the app, so I was able to do that myself when it happened again. But it did mean that if I went when I had 15	NA	NA	NA	NA

ID	Characteristics	Accountability	Competing priorities	Convenience	Exercise intensity and volume	Identity	Laziness and tiredness	Life events	Online exercise programme	Other people	Routine and scheduling	Weather	Work
									minutes available, if I went to try and do it and couldn't log-in, then I would have to miss that session."				

Reflex060	Flexibility / > 50 y / Female / Completer	NA	NA	NA	NA	NA	Tiredness got in the way of doing the exercises. Once or twice too tired to do them. "I: What got in the way of doing exercises, if anything got in your way of doing exercises? Reflex060: Tiredness, actually, because I do suffer from fatigue, so sometimes it would be time to do the exercise and I would just think, oh, you know. That didn't happen very often, but once or twice I would be too tired to do it or just would not want to do them but did it anyway.	NA	NA	NA	Scheduled a reminder in calendar for every day. that helped her do the exercise. "Yeah, it would just pop up on my phone as a reminder in the calendar. I set it up every day, just said stretch in the calendar and it would pop up at a certain time every day and that was my time to do it. And then people got used to the fact that that's what I was doing."	NA	NA

ID	Characteristics	Accountability	Competing priorities	Convenience	Exercise intensity and volume	Identity	Laziness and tiredness	Life events	Online exercise programme	Other people	Routine and scheduling	Weather	Work
							And then just needing to do things for other people if they needed things. It's hard to not put their needs aside and I'd have to do something for somebody else rather than have my exercise time. But generally, because I had it in my diary and I was doing it at a consistent time, that didn't happen very often."						

ID	Characteristics	Accountability	Competing priorities	Convenience	Exercise intensity and volume	Identity	Laziness and tiredness	Life events	Online exercise programme	Other people	Routine and scheduling	Weather	Work
Reflex023	Flexibility / 35-50 y / Female / Completer	Having someone checking up on her and having to do something helped to do the exercise.	Kept pushing the exercise. "Just me, just saying, right, okay, I'm going to do it today, but then today went by and it's like, oh, I've not done that yet, okay, right, I'll do it tomorrow. So, maybe time got in the way, or focus, the mental focus to do it."	NA	NA	Does not like exercise, feels the most inflexible in her life, feels like a mental block to do exercise, general exercise negativity. It was not difficult to remember, she knew she had to do them by Sunday, but kept pushing doing them.	NA	NA	NA	NA	NA	NA	NA

Reflex024	Resistance / < 35 y / Female / Completer	NA	NA	Exercises did not take long to do, it was not difficult to make them fit. Brilliant to have an app to look there, not very convenient because it has several stages. "I think, so I set up a reminder on my phone to say, like do the exercises now but what I	NA	History of chronic illness that has made it difficult to engage in PA. Feeling of being inadequate and not good, herself perception gets in the way of engaging with PA. This improved thanks after the programme. "I think just because in my own history with physical activity. So, like I have a history of chronic illness and I	NA	NA	NA	NA	Set up a reminder but it always seemed to be the wrong time to do the exercises (dinner, out of the house, hungry). After getting into a routine of doing the exercises, found it hard to record the exercises in the app.	NA	NA

				found is that I just…I don't know how to say it, because the thing is they don't take long. So, it's not as if it was difficult to fit them in" "I found that it was brillian t to have an app because it was a focused place to look, but I found that once I'd got into a		haven't really found it easy to engage in a lot of physical activity because I was always unwell. So, I have a lot of, kind of, feelings of being inadequa te and being not good at those kind of activities. " "I: Did that change after the program me or did it stay the same that perceptio n? Reflex024 : Yeah. I mean, I think somethin							

				routine of what I wanted to do I would have found it easier to do them if I had a way of accessing, like the exercises altogether, because when I was going into the app, like there were quite a lot of stages to go through before you could add your		g that is as strong my kind of self-perception is that it would take a lot to change, but I didn't.... So, yeah, but no I think it has improved after the programme, and when I look back at what I've actually done since then in terms of the activities that I've been doing I have been doing more resistance activities							

ID	Characteristics	Accountability	Competing priorities	Convenience	Exercise intensity and volume	Identity	Laziness and tiredness	Life events	Online exercise programme	Other people	Routine and scheduling	Weather	Work
				exercises. So, like sometimes I would kind of be trying to get through and be like, yeah, okay"		and I've been pushing myself to do activities that I would have felt very uncomfortable to do before. So, I think that has been a contributing factor to that as well. "							

Reflex031	Resistance / > 50 y / Female / Completer	She made sure to do them because she said she would. I: And do you think there might be anything that could have helped you to do the exercises, like, more than one…? Reflex031: No, I don't think so. I mean, I made sure I did them every week (a) because I thought it was	NA	NA	NA	She did the exercises because of their benefit., that helped her do the exercises.	NA	NA	NA	NA	She doesn't have a routine and was able to fit in the exercise in.	NA	NA

ID	Characteristics	Accountability	Competing priorities	Convenience	Exercise intensity and volume	Identity	Laziness and tiredness	Life events	Online exercise programme	Other people	Routine and scheduling	Weather	Work
		doing me good and (b) because I said I would do it. But no, I mean, I made sure I did fit it in while I was doing the programme.											

Reflex037	Resistance / 35-50 y / Female / Non-completer	NA	Something happened with her children or at home that got in the way of doing exercises and missed doing them.	NA	NA	NA	NA	Got a cold and she missed doing the exercises. unexpected things happened at home. "Reflex037: So, there were a couple of weeks where I wasn't feeling very well when I did do them, just because I wasn't feeling good, or the night that	NA	Children, something happened to them and that got in the way of doing the exercises.	NA	NA	NA

								I'd planned to do them, something else happened with the children, or something else happened at home, so those… there were a couple of weeks that I missed it, or missed doing it. Because I thought, I'll do it that night, and then				

								something happened, and I thought, it's okay, I'll do it on the next set, and then something else happens and then I was out of time for that week. I: Yes. What happened to you within those weeks that you weren't feeling well?						

ID	Characteristics	Accountability	Competing priorities	Convenience	Exercise intensity and volume	Identity	Laziness and tiredness	Life events	Online exercise programme	Other people	Routine and scheduling	Weather	Work
								Reflex 037: So, it was just more like a cold, or a bit rundown, it was nothing serious. But I didn't do those weeks. "					

Reflex047	Resistance / 35-50 y / Female / Non-completer	Being accountable gave her the push to do the exercises. "So for me it was perfect because it gave me that, got to do this, and that was my only apprehension of doing it. So, again, it was good because it made me time accountable so I had to do it. Part of the reason that I chose to do it	NA	NA	NA	NA	NA	NA	NA	Made sure to do the exercise before her children woke up.	Did the exercise in the morning before the kids woke up. "Part of the reason that I chose to do it before work is I fall into very bad habits but work doesn't stop because you're at your house, there is no packing it away. So I was just concerned that if it was left until the evening when the kids are in school you get pulled into, have you done this, have you got that, whereas in the morning neither of them wake up so it's my time. So that's why I found that habit so, again, it was	NA	NA

		before work is I fall into very bad habits but work doesn't stop because you're at your house, there is no packing it away. So I was just concern ed that if it was left until the evening when the kids are in school you get pulled into, have you done this, have you got that, whereas in the									good and, again, I'm going to keep with that as well."		

ID	Characteristics	Accountability	Competing priorities	Convenience	Exercise intensity and volume	Identity	Laziness and tiredness	Life events	Online exercise programme	Other people	Routine and scheduling	Weather	Work
		morning neither of them wake up so it's my time."											

Reflex050	Resistance / 35-50 y / Male / Completer	Found it helpful to be part of a structured study, that was going to be tested and see if he has done the exercise . "I think it was helpful that it was part of a structured study. If I'd just downloaded that app by myself I would have found it more difficult psychologically to make sure I did it	NA	NA	NA	NA	Experiences general laziness and that got in the way of doing the exercises.	Went on holiday , but took the bands with him. Was able to do the exercises. The holiday di not get in the way of doing the exercises. "I just did them anyway. As I said, I took my bands with me. I think I picked exercises such that I only	NA	NA	NA	NA	NA

ID	Characteristics	Accountability	Competing priorities	Convenience	Exercise intensity and volume	Identity	Laziness and tiredness	Life events	Online exercise programme	Other people	Routine and scheduling	Weather	Work
		every day I was supposed to do it. The fact that I was going to be tested on my results, and I guess you could see whether I'd done it properly or not, is a good motivator for doing it thoroughly."						needed to take a couple of bands, so it was a bit easier. And then I could do the ones that didn't need them at all, like press-ups. So, I just carried on while I was on holiday."					

Reflex053	Resistance / < 35 y / Female / Completer	NA	Her children and house chores are more relevant than the exercises. Did the exercises after the children went to sleep. Goes to her parents/sister house to visit for about 3 days and does not want to do the exercises there. "Reflex053: I would…normally, if I'm going to exercise, I exercise in the evening, so my kids are asleep Reflex053: I would, in theory, I would like to spread that out	NA	NA	Forgetting to do the exercises got in the way of doing them. "Well, most of the time I would forget. And so, then I would remember like, oh, like it runs over on Wednesday, so I'd better do it now. Sometimes I would even do it…so, five at my time is when it would turn over, and so sometimes I would…normally, if I'm	NA	NA	NA	She takes cares of her children all day and in the evening she is tired, which gets in the way of doing the exercise. "I would, in theory, I would like to spread that out more, or do more exercises. But I…like, all day I've got the kids and then in the evening I'm tired	NA	Very hot weather (32-43 degrees) made her not want to do anything, to not move around. "And then, also there were a couple of weeks where it was like 90 degrees and 110 degrees,	NA

			more, or do more exercises. But I…like, all day I've got the kids and then in the evening I'm tired and…so, it's hard for me to find the motivation to do it. Like, oh, I can just do it later kind of thing." "Reflex053: So, we go to visit my parents, my mum and my sister a lot and so, I don't, you know, if I don't bring the bands with me, I don't kind of remember, then that's like three days that I can't do it. And so that would get in the way. Reflex053:			going to exercise, I exercise in the evening, so my kids are asleep. But, sometimes I'd be like, oh my gosh, I forgot until like today and it's going to expire in five hours so I'd better do it right now kind of thing."				and…so, it's hard for me to find the motivation to do it. Like, oh, I can just do it later kind of thing." Goes to visit her family and did not want to do the exercise there. Husband normally comes in the evening and help her with the children, but sometimes he is late, and she		like, I didn't really want to do anything. Like, those days, I'm like no, I don't even want to move around kind of thing."	

			It’s more like there’s not a lot of space in their place… Reflex053: And, you know, it’s not really like working kind of thing. I mean, I didn’t remember to bring the bands but if I had brought the bands, I might have done it, but I didn’t really intend on bringing the bands in the first place."							is more tired and that gets in the way of doing exercis e.			

Reflex057	Resistance / 35-50 y / Female / Non-completer	NA	NA	NA	NA	Sometimes forgot to do the exercise because of work being really busy.	NA	NA	NA	NA	In the beginning thought of setting up a reminder on phone, but never did it. "Okay. Is there anything else that could have helped you to do the exercises that was not in the programme and maybe it would have contributed to you doing the exercises better or more? Reflex057: If I'd thought about it at the beginning I should have like set up a notification on my phone or something like that to remind me, I should have just done that, but I never bothered to. If there were	NA	Work was really busy and that got in the way of doing the exercises. "And then is there anything got into the way of you doing the exercises? Reflex057: Not really. No, not really. Sometimes I would just forget that [inaudible 20:09], work is

											an app it would be great to have the app, it would be like, hey, it's been eight days since you've done this one or something like that, that would be helpful. But again I could have just done it myself on my calendar, I just didn't for whatever reason."		super crazy right now, so just end of the week I'd realise that I had not done two a day so I had to do them all at once. So work pressures would be at times, because they were like easy to do and didn't require much set up it was pretty easy to work it in.

ID	Characteristics	Accountability	Competing priorities	Convenience	Exercise intensity and volume	Identity	Laziness and tiredness	Life events	Online exercise programme	Other people	Routine and scheduling	Weather	Work
													Much easier than going to the gym or something like that, so I reckon I could do it at home."

Reflex061	Resistance / > 50 y / Female / Completer	NA	NA	Difficult to do the exercises in the motorhome while away, because of not having any space. Was able to fit them around work and chores. "I'd say we were away a few times in our motorhome so that made it more difficult to do them. You can do	NA	NA	NA	NA	NA	NA	NA	NA	NA

				some of them. So I'd try and put some of them in. But not so easy other days to do that. So if I was away for weeks at a time I'd have to think about… it's not as if we've been away weeks at a time. I'd have to think of different ways of									

				doing that." "I suppose it fitted round the days. I mean occasionally I'd do sort of work, very odd days here and there and those days, there just probably wouldn't be very many…just the way it fitted in. But not necessarily because I'd									

				sometimes come home from work and do a couple then if I felt I hadn't done very many. I didn't feel bad thinking, I'll just do one exercise today and fit it in when I came home from work, while I'm cooking dinner or whatever."									

Reflex080	Resistance / < 35 y / Male / Completer	Being accountable for the exercise programme made him push himself to do it, despite being tired and sleep deprived. Once he does the exercise makes him realise that he can actually do it. Watch also makes him aware of his sleep and activity. "Yeah, so the advantage is,	NA	Only took 15 minutes to do it.	NA	Struggled to remember to do the exercise.	Very tired because recently had a newborn and was sleep deprived.	Had a newborn at the beginning of the exercise programme.	NA	Had a newborn at the beginning of the exercise programme. Was not able to sleep like usual because of the baby.	Had the intention to put a reminder in his calendar but did not. "Oh, do you know, I kept meaning to put in on my calendar on my phone, to remind me, but it didn't."	NA	NA

		my watch is then telling me what I'm doing. Psychologically I'm thinking, right, I've only had three and a half hours, but actually my watch tells me I've managed to get three and a half hours, whereas mentally I'm thinking, I've barely slept. So if I'm thinking, I've barely											

		slept, oh, I won't be able to do these exercises, it was a good push, because I had to get it done. So it showed that I could manage them, to stay fit, and I'm only getting… so anyone that says that they can't do it because they don't have time, or they're not sleeping very											

ID	Characteristics	Accountability	Competing priorities	Convenience	Exercise intensity and volume	Identity	Laziness and tiredness	Life events	Online exercise programme	Other people	Routine and scheduling	Weather	Work
		much, well they can get stuffed."											

Reflex016	Resistance / 35-50 y / Female / Completer	NA	NA	Found it easy to fit in, did not take very long to do them.	The volume and intensity was low which made it very short time commitment, and therefore that got in the way of doing the exercises. If it was more, would have done more. "And in a strange way I think if it had been a longer period of time I might have scheduled it differently into my…I think I'd imagined that I was going to do this programme and that I would maybe be doing it first thing in the morning, or I'd be setting [audio breaks up] in there, you know, where my husband would have the kids and…whereas actually it ended up being like something I just like slotted in very quickly and easily. So, [voices overlap] but your question about	NA	NA	NA	NA	Did the exercises after the kids went to bed.	NA	NA	NA

ID	Characteristics	Accountability	Competing priorities	Convenience	Exercise intensity and volume	Identity	Laziness and tiredness	Life events	Online exercise programme	Other people	Routine and scheduling	Weather	Work
					what would have made it easier that doesn't really answer the question, sorry…I guess…so I may have had a preference for it being more intensive because I knew that I was motivated to take part and so had it been more intensive I think I would have done it and it would have had an even bigger benefit, if that makes sense?"								

Reflex021	Resistance / > 50 y / Male / Non-completer	NA	NA	Thought they were convenient, could fit them in easily and did not need to change to sport clothes. "As I say, initially the curiosity motivated me and I did them when it was convenient and it was like, I could squeeze this in here. And my thinkin	NA	By the end of the study he would forget to do them and had to squeeze the exercises. "The latter stages of the time period when I was kind of squeezing it in because I'd forgotten about it, you know, it hadn't been at the front of my mind, kind of thing."	NA	NA	NA	Did the exercises without his wife around to not cause disturbance.	Not scheduling and dedicating a specific time got in the way of doing the exercises. "As I say, initially the curiosity motivated me and I did them when it was convenient and it was like, I could squeeze this in here. And my thinking was eventually, 'cause doing 15 arm raises or whatever doesn't take more than 30 seconds to do and I found I didn't have to transition into gym wear to do them. So initially it was convenient, I just did them as and where the notion	NA	NA

ID	Characteristics	Accountability	Competing priorities	Convenience	Exercise intensity and volume	Identity	Laziness and tiredness	Life events	Online exercise programme	Other people	Routine and scheduling	Weather	Work
				g was eventually, 'cause doing 15 arm raises or whatever doesn't take more than 30 seconds to do and I found I didn't have to transition into gym wear to do them. "							took me. But to maintain it I do realise I needed to sort of commit a particular timeslot or I needed to build it into my…I needed to set time aside for it."		

Appendix AJ: Framework Matrix Impact and changes of the programme

ID Number	Characteristics	Mental and emotional changes and the lack of them	Physical changes or lack of them	Ripple Effect
Reflex028	Flexibility / <35 y / Female / Completer	NA	Had fewer knee pains and they improved.	Started to do more exercise, with increasing levels. Will continue with another trainer from YouTube. started to go out for walks a bit more.
Reflex023	Flexibility / 35-50 y / Female / Completer	NA	Her flexibility improved with the programme. The exercises became easier.	Started to go for walks, and think about her diet, her water intake, and night sleep. "I: In general, any positive or negative changes throughout the study that you can remember? Reflex023: Yes. It was definitely…it enabled me to focus on me a lot more, because I was doing something for me, so…which then spilled over into, okay, right, I can go for a walk. So, there's more kind of add on stuff going on. I could exercise, go for a walk, or I could think about, do I really need to eat that, am I drinking enough water. So, there's all that kind of roll-on benefits."
Reflex032	Flexibility / 35-50 y / Female / Non-completer	No mental changes.	Felt slightly more flexible. She could push herself a bit more.	Was willing to continue the exercise.

ID Number	Characteristics	Mental and emotional changes and the lack of them	Physical changes or lack of them	Ripple Effect
Reflex038	Flexibility / 35-50 y / Male / Non-completer	NA	Better skills. Felt his shoulder improved due to the exercise, and does not feel as much pain as before. His flexibility did not improve.	NA
Reflex030	Flexibility / >50 y / Female / Completer	No mental changes.	Shoulder improved. Her flexibility improves as well.	NA
Reflex035	Flexibility / >50 y / Female / Non-completer	No mental changes.	Did not think her flexibility improved. She has lost 24lbs during the programme.	Continued to do stretching exercises around her daily activities. Started doing planks after the programme. Wants to do more exercise with bands.

ID Number	Characteristics	Mental and emotional changes and the lack of them	Physical changes or lack of them	Ripple Effect
Reflex044	Flexibility / >50 y / Female / Completer	She felt a lot better about herself. "A lot better, a lot better because I think when something is brought to your attention like that, obviously we're all getting older, I'm getting older but you're trying to keep as active as you can and as fit as you can and I think when you are unable to sort of do what would have been a straightforward manoeuvre for me ten years ago and you can't and then you see yourself being able to do it, I think it makes you feel a lot better. I felt a lot better about myself and it gives you a lot of incentive, as far as I'm concerned, I'm going to continue with this programme even beyond the obviously our three months because I could see the benefit to me."	She improved her flexibility. Saw the changes in several exercises. "I've seen the benefit to me. I guess it's my ignorance in a sense that if you see some improvement you want to do something even more and you've got to be careful not to do it too much but I think if you could do them say a couple of times a week, I might see even better improvements in my personal flexibility."	NA

ID Number	Characteristics	Mental and emotional changes and the lack of them	Physical changes or lack of them	Ripple Effect
Reflex052	Flexibility / >50 y / Male / Non-completer	No mental health changes. "Any mental health benefits you might have found? Reflex052: No. Mental health has stayed about the same."	Flexibility improved. Felt he wasn't as stiff as he used to be. The back felt stronger and no pain. His right knee has been painful because of kneeling on the floor, it could be a result of the programme. "I: Have you noticed or did you notice any changes as a result of doing the programme? Reflex052: Yes, I noticed that I wasn't as stiff as I used to be, in the sense sitting doing, getting up again, generally moving around. I felt more flexible in the sense of being able to climb up. And I've been lifting things, in the sense the back used to have a bit of a niggle because I'm tall, I use to always have things that I'd notice over the ten weeks, my back I felt has been a lot stronger. I haven't been, things I was doing which, sort of, beforehand caused my back to, sort of twinge, I haven't had that. So, yeah, I've been happy with that. " "I: Any negative changes that you may have had? Reflex052: No. Negative, only thing, as I said, is my right knee now being painful when I'm kneeling on it on a hard floor surface. I: Was that as a result of the programme or it was with you before? Reflex052: I think it could be a result of the programme. It wasn't there that I could recall before the programme."	He will continue because of the effect he felt on his back. "I: Did you continue doing the exercises, you just finished yesterday, so will you continue, do you think you will continue? Reflex052: Yes, I will. I: And why is that, why would you want to continue? Reflex052: Because, as I said, the flexibility, the strength I've felt, like I've got in my back. I'm very conscious of that because, as I said, I've hurt my back in the past. It's not pleasant, and so anything to, sort of, relieve that from happening again, and just ability to, sort of, to move around quite happily and climb into spaces where before I would get quite stiff trying to do that. I: Any other reason you would want to continue? Reflex052: No, that's primarily it."

ID Number	Characteristics	Mental and emotional changes and the lack of them	Physical changes or lack of them	Ripple Effect
Reflex055	Flexibility / >50 y / Male / Completer	No mental changes.	His flexibility in his upper body improved. One exercise have him pain in his back. " I've certainly…think I've noticed some improvement in my upper body flexibility." "One of the exercises did give me some soreness in the back. The exercise that I mentioned with lying on the front and lifting your shoulders up and your arms and trying to bend at the pelvis, that one did leave me with backpain. "	Started to go to yoga classes after the programme. "I: So did you continue? So you ended two weeks ago. Did you continue doing the exercises after that programme ended? Reflex055: No, I haven't but I have been able to do my yoga classes. I: And why did you stop? Reflex055: Because I was…one of the reasons I joined the programme, I suppose, was at the time I wasn't a member of a yoga class. I prefer to go to classes rather than exercise on my own, I just find it easier to hold that discipline if I'm committed to go to a class."
Reflex060	Flexibility / >50 y / Female / Completer	She experiences a big psychological shift, to think that she is able to change things and get fit. "I think it's quite a big one actually. Because I'm 56 now and I kind of got myself into the mindset that, oh, you're getting old, physically you're going to be getting worse now, things are not going to improve, they're just going to get worse. And I think doing this programme has been a big part of changing that for me, thinking, well, actually, no, I can get more physically fit. There are things I can do and I can change things. So that's helped a lot, that's quite a big psychological shift actually."	She thought her flexibility improved slightly, particularly in her legs and arms.	Wanted to find another exercise programme, like yoga or Pilates. "I guess it's just kind of a more positive attitude to exercise generally and stretching generally. I'm kind of thinking, well, I'd better start doing yoga or what about Pilates and that kind of thing. Previously I've thought, no, you're probably a bit too old for that now, you wouldn't be any good at that. But now, yeah, so more positive mental attitude towards all sorts of exercise, I guess."

ID Number	Characteristics	Mental and emotional changes and the lack of them	Physical changes or lack of them	Ripple Effect
Reflex024	Resistance / <35 y / Female / Completer	Felt more confident and changed her self perception in a good way. "Reflex024: Yeah. I mean, I think something that is as strong my kind of self-perception is that it would take a lot to change, but I didn't."	Core and leg strength improved. Performance in the exercises improved. "Reflex024: I mean, I think that realistically I wasn't doing the exercises frequently enough to notice big changes because, although it seemed like a dramatic thing for me to do the exercises once or twice a week for 12 weeks. I noticed, kind of, a little bit of difference in how I was feeling kind of core wise I felt stronger and my legs felt slightly stronger and I noticed that the main thing was the improvements in my performance on the exercises. "	Because of the programme she has been more interested in resistance trainig. She has suscribed to a training service, started rock climbing and other things. ": Great. Did you mean, like doing more things right after doing the exercises during your day or you mean after the programme itself? Reflex024: After the programme itself. So, it's made me more interested in doing other resistance based exercises. I: Great. So, you have done…so have you continued to do the exercises after? Reflex024: What I've done is I found like resistance training, like videos online that I've subscribed to the service where I can do these ten minute videos which have like very similar activities, but I like having somebody to kind of guide me through them. So, those are the ones that I've done since then. I've also, I've kind of started doing some different activities that use the same kind of skills. So, like started rock climbing and other things. So, kind of things that strengthen is more important."

ID Number	Characteristics	Mental and emotional changes and the lack of them	Physical changes or lack of them	Ripple Effect
Reflex053	Resistance / <35 y / Female / Completer	She feels a little bit better, less anxious, but is not sure it is a result of the programme and might be because of several factors.	Felt mor confident doing the exercise. Felt that she performed better during the testing sessions. Did not notice any changes to her flexibility or her weight. "Reflex053: So, I noticed, the only thing I really noticed is when they did the test thing, you know. Like, when they tested me that I did more. I felt like I had done more but if I just looked at like, my, you know, at what I was doing on the app, it all begun to look basically the same and I don't really feel any different. I did discover at some, well, like…my weight is about the same. I haven't lost any…I haven't noticed any flexibility or anything like that really. "	NA
Reflex080	Resistance / <35 y / Male / Completer	No mental changes. "Now I'm sure for a lot of people, yes, the exercises have changed them, maybe mentally, but it didn't do anything for me, 'cause I was so strong mentally anyway. I'm very positive, very happy, but physically more tired, because I'm not getting the same amount of sleep."	Flexibility and strength improved. Feels stronger and fitter. Also, felt like he has gained weight, he can visually see it. "I feel stronger, I feel like I've got fatter, but I think that's 'cause we're eating more, 'cause we're in the house more. That's nothing to do with the exercises, 'cause the exercises were making me physically stronger and fitter, but didn't necessarily work on the weight, does that make sense?"	He wants to do more exercise, planning to do the plan couch to 5k. Does not want to expend money, but do exercise independently. "I: So have you noticed any changes as a result of doing the programme? Reflex080: I've certainly became to think about trying to be more fit now. As I say, we went to the gym, and the whole point of me doing this programme, was to see if I could continue a level of fitness whilst not giving up 45 minuets to 50 minutes, you know, every day? I: Yes. Reflex080: Paying something stupid money, in order to belong to a gym. I think that was what pushed me to doing it. So now, I would, yeah, I want to keep going with it, to be fit myself, because before I thought I was fit. "

ID Number	Characteristics	Mental and emotional changes and the lack of them	Physical changes or lack of them	Ripple Effect
Reflex016	Resistance / 35-50 y / Female / Completer	NA	Her performance in the exercises improved (more repetitions). On the push-up was not able to progress levels but improved in repetitions. " don't know if you want me to talk about specifics but there were definitely…so, like I said, that I was surprised at how quickly I could do it per day, as in like five minutes a day, and I was wondering how much is that going to improve my strength, but I did notice that I was able to increase my repetitions. But then when it came to a press-up…push-up I'd done the maximum of one level but I just couldn't do the next one, like I couldn't even do one. So, I don't know that it necessarily followed. I know that push-ups are hard for women like with…and there's…and I haven't got much upper body strength, but apart from that the others I felt I could…I did see improvement in the number I could do from the beginning."	NA
Reflex037	Resistance / 35-50 y / Female / Non-completer	No mental changes.	Core strength improved and leg strength as well. "Reflex037: I am definitely…my core definitely is a bit stronger, so I definitely noticed that, and that's probably the biggest change I would notice. I suppose maybe noticed a wee bit more strength in my legs. But my core is probably what I've noticed more, has certainly improved. Obviously, my tummy is still a bit squishy, as my children like to tell me, but it's definitely more strength in my core than I had before. "	Is willing to continue the exercise.

ID Number	Characteristics	Mental and emotional changes and the lack of them	Physical changes or lack of them	Ripple Effect
Reflex047	Resistance / 35-50 y / Female / Non-completer	She started to feel more positive due to the circle of change.	Lost weight, about 1 stone, and her back has gone flatter. " I: Did you notice any changes as a result of the programme by the end of it? Reflex047: Loads, I had lost just over…I have plenty to lose but I've lost just over a stone in weight through doing them and my mother is convinced my bottom has gone square and flat although my stomach still looks like I'm ten months pregnant. But even my mum commented my back's gone flatter so, yeah, there is a difference."	NA
Reflex050	Resistance / 35-50 y / Male / Completer	No mental changes.	His performance is better, can do more repetitions and on heavier bands. But has not felt much change apart from that.	Wanted to continue doing the exercise programme and see how his fitness and performance progresses. "Reflex050: I think I'll continue with one set. I'll probably do one set for a few more months and see what happens. Because I noticed that the number of reps I could do with a specific band or exercise was levelling off quite a lot. Like with press-ups for example, I started off being able to do about ten I think, and now it's 16 or 17; but it's never any more than 17. So, I don't think I'm doing enough exercise to continue improving, but I think I've done enough to improve a bit. "

ID Number	Characteristics	Mental and emotional changes and the lack of them	Physical changes or lack of them	Ripple Effect
Reflex057	Resistance / 35-50 y / Female / Non-completer	Feels better about herself compared to the beginning. Exercising made her feel more like herself after having 2 babies. "Reflex057: Yeah, I feel a little better about myself. Yeah, I've had two babies in the last couple of years and so I've been feeling a little bit just like I…I don't know, exercising made me feel a little bit more like my old self, feel a little better about myself, so I do think that it's been helpful to my…I wasn't like depressed or anything before, but I do think I feel a little better about myself right now than I did at the beginning."	Her performance improved, not her balance. She feels slightly stronger/fitter. "In definitely strength I felt like I was able to do more, use the stronger bands. I think about balance not really. Not really, I didn't really notice any difference."	Started to have a healthy mindset, eating better, better eating schedule, decrease alcohol intake. Wants to keep logging her exercise because she thinks it is helpful. "I: So you feel there are some physical changes, so you feel a bit fitter? Reflex057: I do, I think so. I feel like I've been feeling a little better too, but I'm not sure if it's all the exercise. But when you get like the healthy mindset of exercising, but I feel like I'm usually eating better falls along with that really, as well as exercising I probably shouldn't eat like Cheetos right afterwards. So I guess I feel a little fitter, a little bit stronger maybe. I: You've mentioned something about diet, so that you felt that if you're exercising then you should also be eating better. Reflex057: Yeah, I do. I feel like the psychology works that way for me. If I'm just like in a gross place where I just want to eat and be lazy, then that's just how I am, whereas if I'm like actually putting energy into exercising then I'm usually a little bit more conscious of what I'm eating, put a little more effort into eating well. So they do go hand in hand for me, I feel. I: That's great. So has your diet changed in a way over the 12 weeks? Reflex057: Yeah, I think I've been making an effort to eat a little better, I think given this study opportunity is a chance to just overall improve my health. So since I'm exercising, certainly not perfect still, but I'm trying to eat more regular meals, I'm trying not to eat after seven o'clock, things like that. So trying to decrease my alcohol intake."

ID Number	Characteristics	Mental and emotional changes and the lack of them	Physical changes or lack of them	Ripple Effect
Reflex021	Resistance / >50 y / Male / Non-completer	NA	No changes in body or fitness. "I: It could be physical changes, like how did you feel physically after the programme? Mentally? Psychologically? Anything, any positive, negative? Reflex021: No, I didn't feel…I didn't lose weight, I didn't feel particularly fitter. So no, I did the 12 weeks and pretty much stopped and haven't continued. But not, it didn't have a positive and/or negative effect on me in a sense."	NA
Reflex031	Resistance / >50 y / Female / Completer	No mental changes.	Did not notice getting fitter in her day-to-day life, but she did progress in bands. "how you thought the programme was improving or was changing your fitness, did you notice any changes as a result of the programme? Reflex031: No, I don't think so. I mean, when I was good…I got up higher on the bands on some of them, but I didn't specifically notice anything in my general life, no."	Got an electric bike during the programme. She started to use it more after the programme. Goes now to aquafit. "Reflex031: I got it during but I didn't use it much. Even now, you know, I mean to use it a lot and half the time I just don't get round to it. But I am cycling a bit more now and I went to aquafit, so… But I do think I should still do the arm exercises in particular to try and build up my arms, I don't know."
Reflex061	Resistance / >50 y / Female / Completer	No mental changes.	Her legs and upper body got stronger, and noticed that during her day-to-day life (cycling, lifting things, performance). "Reflex061: I've noticed…I think my legs are stronger. I do cycle a little and I think I've noticed that going up some hills I'm not…it's easier. My legs have definitely improved. My upper body strength has definitely improved, because lifting things, I can that a lot easier. I even see from doing push-ups that I can do it longer, for more repetitions than before. So there's definitely a major difference."	She has continued to do the exercises and wants to keep doing them, with a mix of leg and upper body. "Reflex061: Yes, I have continued with them, and I hope to still do that, because I think I can still make some improvements or just maintain what I have. I find it difficult…I mean I do cycle; I find it difficult for upper body strength to do exercises that help. But now I've got the bands I think they do help that, without having to go to a gym and do weights and things like that."

Appendix AK: Descriptive Summary Pre-study life

1) Health

A couple of participants of the resistant exercise group reported having issues with their health that has affected them engaging in physical activity.

> "So, like I have a history of chronic illness and I haven't really found it easy to engage in a lot of physical activity because I was always unwell. So, I have a lot of, kind of, feelings of being inadequate and being not good at those kind of activities." (RE group, younger than 35 years old, female, completer)

> "I used to do quite a lot of exercises, but because of lockdown and health issues and things I found I'd been doing virtually none." (RE group, between 35-50 years old, male, completer)

2) Physical activity previous experience

A few participants reported having previous experience with physical activity. Participants reported going to the gym, doing yoga, Pilates, cycling and running. A couple of participants in this group have expressed that the exercises in the study programme were familiar to them because of their previous experience.

> "I think they were all fairly easy because I've done Pilates and like something called Pure Stretch before so they're all moves within that." (FLEX group, over 50 years old, female, non-completer)

> "I've been going to yoga classes on and off for the last 30 years, so a lot of the exercises were familiar or I've done similar exercises. I don't have any worries about engaging in exercise and I didn't have any before starting the programme." (FLEX group, over 50 years old, male, completer)

In addition, one participant reported stopping going to the gym previous to the study because of having a baby later on. Another participant said to have done exercises in a patchy way which lead her to not see any difference and was not convinced that she could see a difference. Finally, one participant reported having been trying to get in shape before the study.

3) Sedentary behaviour

A couple of participants reported to spend a lot of time sitting down. One of them reported that at this stage in her life she doesn't have to travel to work and that there is no reason to leave the flat so she was sitting down even more.

4) COVID

a. Weight

One participant reported to have gained weight during lockdown.

> "I have put on weight over lockdown and I'm now carrying too much weight so I kind of know that there were more twinges when I did things like the squats or the lunges." (RE group, over 50 years old, male, non-completer)

b. Working from home

A participant reported a big change in her lifestyle due to lockdown. She is now working from home, which changed her normal working hours starting work at 9am and finish at 5pm to turning her computer on first thing in the morning, having breakfast in front of her computer, and finishing at 7pm.

c. Gyms

A participant was going to the gym frequently (six years) and after COVID she stopped doing any exercise because all the gyms shut down.

Appendix AL: Descriptive Summary Reasons for joining the study

Almost all participants reported as their main reason to participate in the study to want to do more exercise. Some of the reasons reported for this were because of having a baby some months ago, the desire to move more, getting fitter, stronger, toned up, being more active and building more muscle mass.

> "I wanted to do some more sports because I don't usually move myself and I thought this would be a good impulse to do something." (FLEX group, younger than 35 years old, female, completer)

> "doing things with weights for your arms and stuff is meant to be good for you. And my arms are just rubbish, they've never been very strong but they're getting worse and worse. As you get older you kind of lose a bit of muscle don't you, I think, so I thought I should try to do something to just build up a wee bit of muscle." (RE group, over 50 years old, female, completer)

Half of the group reported as another reason to be interested in research and want to contribute to it. Some participants found the topic interesting and fun to be part of it. One participant reported as her main reason to join the study as wanting to contribute to the research and help future generations.

> "Partly because I'm involved in research myself, and I know that it can be quite tricky to get participants. So, I just wanted to give a bit of support to other colleagues working at the university who are trying to get participants for their research." (RE group, between 35-50 years old, female, non-completer).

> "I think it was, as I said, I saw the benefit to myself and I also saw the potential benefit depending on how the research…what the results yield of the result to others because we are getting an extremely unfit nation. I think anything that any of us can do to kind of help future generations who appear to be getting unfitter, you know, I feel quite strongly that we should all try and do what we can. So if we can, particularly people of my age who will not have a history of particularly good exercise habits for whatever reason and I think, as I said, if this research shows that these exercises are beneficial, I think it's nice to know if you've just played a little part in bringing that to people's attention." (FLEX group, over 50 years old, female, completer)

Some participants also mentioned that being part of a study would make them feel accountable, which would help them to do the exercise or to start doing exercise.

> "And also, genuinely, from a selfish point of view, having been poorly and so immobile I met the criteria, I needed the momentum to get on and do something so it seemed the ideal solution. This would make me be accountable because you wanted the results and whichever programme I ended up with, when you read the blurb, either one would have been more than suitable for me to start back onto something." (RE group, between 35-50 years old, female, non-completer)

> "Well I think the thing that appealed to me about it is that I'd been looking for a way to think more about strength based exercise, rather than kind of cardio or different kind of walking, running activities and I know that I find it quite difficult to stick to anything if I don't have a way to be accountable because I find it, kind of, a challenge to learn new things in terms of I don't know if I'm making the right kind of progress or whether I'm doing things the right way. So, I thought that a study where I had kind of responsibility to do the exercises for the research study would help me to be motivated." (RE group, younger than 35 years old, female, completer)

Finally, a couple of participants reported the home-based exercise programme to be suitable for them and being a reason for them to want to join the study.

> "Well, I like research anyway but when I read the description of the study, I just thought I kind of fitted the bill because I've not been doing any weights but I have been thinking about it, like, in due course because I've lost some weight, none during the study but prior to that so I'm at my weight now. I'm just wanting to get more toned up and I didn't see a problem which group I went in because it was only three months. So, I thought, yes, I'll do that, quite easy to do as well because I work at home now. So I can just slot it in my diary with it being videos, conferencing or whatever and it's worked out well." (FLEX group, over 50 years old, female, non-completer)

> "And especially since, you know, doing it all from home, again, everything was done from here, which was good." (RE group, younger than 35 years old, male, completer)

Appendix AM: Descriptive Summary Health

Some participants reported being cautious due to previous health issues, or not having been doing exercise in a long time, weight, family history and that during lockdown is not easy to see doctors.

> "So I'm aware of my age and the kind of…again, family history. My father has had a triple bypass, there's been angina in the family. And during lockdown you can't really get to see doctors. That kind of caution was over, I'm doing a bit of exercise for the first time in a long time, so I'm erring on the side of caution in terms of not pushing myself, not making myself overly uncomfortable. So that was part of the reasoning was just being careful." (RE group, over 50 years old, male, non-completer)

> "I think anything that I noticed was just more say, like pre-existing stuff. Like I sometimes get a bit of pain in my knees. So, if I was doing lunges I just had to be a bit careful about making sure my knees and hips were aligned and kind of things like that, but nothing that was like out of the ordinary." (RE group, younger than35 years old, female, completer)

In addition, a participant reported to have a history of chronic illness and hasn't found it easy to engage in a lot of physical activity. Another participant reported suffering from fatigue and that would sometimes get in the way of doing her exercises. Someone else, manifested to feel hot, nauseous and pain every time she exercised. In addition, her period would sometimes make her not want to exercise due to having a heavy flow and not wanting to make a mess. Other participant, also reported not having great knees and that refrained her from doing squats.

On the other hand, a participant was aware that with age people lose muscle mass and that she doesn't have much strength in her arms.

> "Well, I think weight-bearing and stuff is…well, doing things with weights for your arms and stuff is meant to be good for you. And my arms are just rubbish, they've never been very strong but they're getting worse and worse. As you get older you kind of lose a bit of muscle don't you, I think, so I thought I should try to do something to just build up a wee bit of muscle" (RE group, over 50 years old, female, completer*)*

In addition, a participant reported having lost 24lbs of weight before the study and wanted to build up and perform exercise.

One participant, reported to have had a bad shoulder before the study and the exercise programme seems to have helped to improve it. Participant reports that shoulder seemed more relaxed and programme helped to stretched it out and doesn't get shoulder pains as much as before.

> "Not really but when I did start them and I was saying to M before we started, I had a bad shoulder earlier in the year and when I started and we were doing the press-ups or whatever to show, and I had a bad shoulder and she said, are you sure you'll be able to go with the programme? I could feel it getting a wee bit better but it's actually I think the programme might have helped my shoulder so relax it off a bit and stretch it out." (FLEX group, between 35-50 years old, male, non-completer)

Someone else also reported to stopped having twinges in her back as a result of the programme.

Finally, a couple of participants from the flexibility programme reported that some exercises caused some pain. One of them said that kneeling caused pain in her ankles (sitting on her legs) because his ankles do not have that flexibility and pain in her right knee, needing something padded underneath it. The other one reported experiencing pain in his back which persisted by the end of the programme.

> "P: One of the exercises did give me some soreness in the back. The exercise that I mentioned with lying on the front and lifting your shoulders up and your arms and trying to bend at the pelvis, that one did leave me with backpain.
>
> I: And how long was the backpain before it ended?
>
> P: It's still with me." (FLEX group, over 50 years old, male, completer)

Appendix AN: Descriptive Summary Choice of exercise

1) **Bands (only Resistance group):**

A couple of participants reported never using the resistance bands before and one of them said to having been afraid to using them. In addition, a few participants expressed liking the bands and one thought they were convenient.

> "P: Using the bands were terrifying, because, especially when you use it for the first couple of times, you think they don't work. I don't know if you've ever used the bands?
>
> I: No.
>
> P: You don't kind of instantly, they don't stretch. Then you realise you just have to put in a lot of work, and then finally you're really beginning to feel them. So, I think that was a real positive for me, having never done the bands. If I'd have bought them myself, and watched maybe videos, I don't think I'd have stuck at it, because I think I'd have chickened out to think, I just can't manage with these. I liked the ones with the bands. Again, same reason, because I felt, when you changed to a new colour, it was almost like, hey, look at this, I'm going up a band." (RE group, younger than 35 years old, male, completer)
>
> "I generally quite enjoyed the ones with the resistance bands, they were good. Personally, I didn't enjoy doing things like lunges and that, but that's just me, I've never liked them much. The resistance bands were good." (RE group, over than 50 years old, female, completer)

2) **Competence:**

In general, there were more comments about competence from the resistance group than the flexibility group. Also, there were more reports from the completers group than from the non-completers about competence.

A couple of participants reported that having scoliosis in their lower back and their stomach got in the way of doing some of the exercises. In addition, a couple of participants from the flexibility group expressed having poor flexibility in their arms or legs, while only one participant from the resistance group reported having low strength in her arms.

> "Then there was the sitting down stretches and leg stretches, again all of those I think were fine for me apart from one, which was lying on my front and extending my back, pushing up with my arms and stretching up with my torso. I have very slight scoliosis at the base of my spine and that causes me a little bit of difficulty." (FLEX group, over 50 years old, female, completer)

> "My flexibility with my arms, it was just very, very poor but I mean, that's something I can try and work on…Well, the one with one knee to the chest was fine, that was one of my favourites but it was the one with both knees to the chest, I found that quite difficult to get in the position you did and I think my stomach got in the way. I can remember thinking to myself, goodness me, you're going to have to do something about the stomach, because…and I do remember thinking that if anybody had, you know, was perhaps severely overweight, they might find that one quite uncomfortable." (FLEX group, over 50 years old, female, completer)

A couple of participants from the resistance group expressed that their body shape, like having long legs and arms and a short body, affected how they did some exercises and how they felt while doing them. Additionally, a couple of participants mentioned having poor knees which affected their squats and lunges.

> "There was none that I thought I didn't like. Some of the big lunges, the single lunges, I'm not a big fan of those. When you're tall to begin with, jumping up even higher doesn't make it more pleasurable." (RE group, younger than 35 years old, male, completer)

> "P: I didn't like lunges, I've never liked lunges. I don't particularly like squats either. What else was there for legs? Hmm.
>
> I: Why?
>
> P: I suppose the one with the bands that was alright.
>
> I: Why don't you like them?
>
> P: I don't know, I just…well, probably partly because my knee doesn't like them. And I just find squats…I don't like lunges because of my knee. Squats? I don't know, I just always have found them a bit tricky.
>
> I: In what sense, can you explain it to me?
>
> P: I don't know, just that I feel like I lean forward too much when I'm doing them and I don't feel I do them very well. So I

> suppose because I don't think I do them very well I don't like them whereas there are some exercises I really enjoy doing. It is partly because of the shape of people as well. I've got long legs and a short body and very long arms and some exercises other people find very easy, I just think, this is really weird and I can't do it – whereas other exercises that they can't do so well, I can do alright. So I suppose it's just your body likes some exercises, doesn't it, and doesn't like others, and my body doesn't seem to like squats and definitely not lunges." (RE group, over 50 years old, female, completer)

It was reported by one participant that a night of poor sleep or a change in the order of the exercises changed his performance in the exercises.

> "I think what surprised me was one week, I did maybe 19, I then went to aim for the full 20, and I only got 14 on the same band. So, again, it just showed that you weren't just keeping on building and building, but if I was tired, like if the wee one had been crying all night, and I hadn't slept much, that had a major impact on me. I also varied the order I did things, which probably had an impact on it." (RE group, younger than 35 years old, male, completer)

3) Convenience:

There was only one report participant from the flexibility group. The participant reported that the standing exercises (stretches) are convenient because she can do them in front of her desk quickly during working hours.

> "I think I preferred the standing exercises, because if you're at your desk all day, you can just jump up and quickly do a quick exercise. Whereas, if you need to do any kind of floor-based exercises, you need to go and find somewhere to do it. But that's only because I was fitting things in with working from home while I'm at my desk." (FLEX group, between 35-50 years old, female, completer)

One participant from the resistance group made a similar statement regarding the convenience of standing exercises. In addition, participants stated that the exercises were handy, because of being quick to do and that they could be done in a motorhome.

> "So I feel like most of the time I would do them in my office, because that's where my computer is, so I can watch the videos and just do them in the space I've got at my desk. But if I was travelling, not home, I'd just have some time to do them at [inaudible 10:53], I wouldn't necessarily do all six at the same time. I'd do some on some days then I would just do them wherever. You can do lunges and press

anywhere." (RE group, between 35-50 years old, female, non-completer)

"I actually quite enjoyed the exercises and they're really quick to do, which was really, really handy. So, even if it got to Tuesday night and I was thinking, right, easy to get them done. It was easy enough to do them." (RE group, between 35-50 years old, female, non-completer)

Squats, upright row and seated row were convenient exercises due to only counting once, being able to do them next to their children while watching television and because you only need a resistance band.

4) Hard or Easy to do:

Flexibility group:

A few participants from the flexibility group expressed that the flexibility exercises were easy to do. One of them said that it felt like meditation.

"I think they were easy to do so I did them but also they were less demanding on my body and they were verging on doing meditation in a way for me. It wasn't necessarily pushing my body but more my mind and getting in a space of doing an exercise." (FLEX group, younger than 35 years old, female, completer)

On the contrary, other participants reported that the arm stretches, leg stretches, abdominal stretch, knees to chest stretch and chest stretch were difficult to perform, being the chest one mentioned by two different participants. The claims were made by mainly participants over 35 years old and completers.

"P: You know the chest when you put your arm and turn?

I: Uh-huh.

P: [Voices overlap 04:06] good with that to start with, I thought, I can't, I don't understand how that works that exercise. But after a while I got to understand how that one..." (FLEX group, between 35-50 years old, female, non-completer)

"And actually out of all the exercises that was the one that I found most difficult for the simple reason that, although it was explained very well, when you watch the video it's not really quite clear

> how…whether you're doing it correctly or not. So I was never really quite sure whether I was doing that one correctly or not. It does say in the video you should feel this bit of your body stretching, whatever, but to be honest, with me, because I have quite tight muscles and I'm not young and fit as she is, it's not always the obvious place that you feel the stretch, so that doesn't really help you to know that you're stretching in the right way...Well, the chest stretch wasn't the one I enjoyed the least, it was just that was the one I found the most difficult to know whether I was doing it correctly." (FLEX group, over 50 years old, female, completer)

Resistance group:

A couple of participants from the resistance group reported the plank as an easy exercise, but another couple referred to it as hard to do. Additionally, push ups, lunges, squats, seated row, lateral raise and crunches were mentioned as being hard to do.

> "There was an exercise, I think, because I do…I don't have much strength in my arm, so I recognise that, there was…I don't know what it's called but your band and you're standing there and you're kind of going out to the side. Is it called lateral raise? I can't remember, but I know I didn't do that as often, plus avoided because it's harder." (RE group, between 35-50 years old, female, completer)

One participant reported preferring the easy exercises and choosing them every week.

> "There was a set of exercises for different body parts. So when I went onto the website, I selected one for your arms, one for your back, one for your legs – and there were other categories, I can't quite remember – and as long as they had like four or five different exercises that was the quota for the week. And I basically discovered there were ones I preferred or that I found it easier to do. So the following week I would kind of opt for those just because, as I say, they were easier to do." (RE group, over 50 years old, male, non-completer)

5) Progress or improvement:

One participant from the flexibility group reported not having levels in the exercise programme. Additionally, a few participants reported different things such as improvement in their shoulder thanks to the exercises, having improved in their back and abdominal stretches and improvement in general. All these

reports were made by participants in the over 50 years old group and in the completers group.

> "There was the…funnily enough, there was a chest exercise where you had to put your hand against the wall and I'm still doing that one but that's probably the only one that I'm still doing because I've had a bit of a dicky shoulder and I didn't know what was wrong with it and that exercise seemed to actually help it and improve it so I'm still using that one." (FLEX group, over 50 years old, female, completer)

> "I did the knee to chest stretch and the one knee to chest stretch and also the back exercises, the cat and dog and the back…I think it's a back stretch where you spread out because I found that very beneficial as well, actually. Yes, I felt a bit of an improvement in myself with some of the back exercises. Oh, and the other one, the abdominal stretch I think it is where you lie on the floor, you lever yourself up and you pull yourself up, yes." (FLEX group, over 50 years old, female, completer)

Some participants from the resistance group reported to have improved in some of the band exercises. In addition, some participants mentioned to have improved in lateral raise, push ups, squats, deadlift, plank and leg exercises. These were made mainly by participants between 35-50 years old and completers.

> "So I did a lot of the press ups ones, and I went from, I can't remember my initial, maybe ten or 11, I think it was, and I felt myself really building up. So, I got right to the very end of the press ups ones, oh no, the one before where I had to have my feet up on a chair. And if I'd been doing one more week, I would have been onto the final one where I would have been clapping. So that's now one that I'm doing myself, now that the programme's finished. That was good, because it gives a true estimation of me progressing. I could see myself getting better. The better I got, the better I felt, and so the more confident I felt about going for it. So yeah, that one was good." (RE group, younger than 35 years old, male, completer)

> "So, there was squats, I moved through a few levels of that one. So, that went from the…a sitting one, or one where there was a chair that you could sit down on, or sit on that level, and that got up to the dynamic one, where there was a jump involved in it. The other leg one I did was the deadlift one with the resistance bands, and then for…I can't remember if it was arms or back, it was rowing, there was a wide row and then a narrow row. Chest was always push ups. I didn't get past doing push ups on my knees. But I did get them better, but I didn't get past doing push ups on my knees. Plank, I did progress in plank for core.

> So, I tended to do plank more than…the other option for that was the crunches, but I did more of the plank. So, I went up the levels with that and had just about got to the dynamic plank when the twelve weeks was up. And there was lateral press, the folder ones, so they were quite good with that. I actually quite enjoyed the exercises and they're really quick to do, which was really, really handy. So, even if it got to Tuesday night and I was thinking, right, easy to get them done. It was easy enough to do them. Occasionally, if I was doing them, my children wanted to join in." (RE group, between 35-50 years old, female, non-completer)

6) Pain or discomfort:

A few participants in the flexibility group reported experiencing pain during the abdominal stretch and being uncomfortable with their stomach during some exercises. On the contrary, one participant reported to have experienced less pain in her knees thanks to the exercises.

> "I didn't particularly like the abdominal one where you had to lie on the floor and then lift yourself up off the floor, I didn't like that one. That one was quite sore" (FLEX group, over 50 years old, female, completer)

> "Well, the one with one knee to the chest was fine, that was one of my favourites but it was the one with both knees to the chest, I found that quite difficult to get in the position you did and I think my stomach got in the way. I can remember thinking to myself, goodness me, you're going to have to do something about the stomach, because…and I do remember thinking that if anybody had, you know, was perhaps severely overweight, they might find that one quite uncomfortable." (FLEX group, over 50 years old, female, completer)

Participants in the resistance exercise group reported experiencing pain in their neck during crunches, pain in their knees once they moved up levels and pain in their arms during the plank, though the last one was not due to the exercise but due to a fall outside the exercise programme. In addition, some participants in the resistance group experienced discomfort with the thicker bands while pulling, in their knees during squats and lunges, and during planks.

> "I: Okay. Was it too thick, like a very thick band to kind of just pull yourself up?

> P: Yeah, I think it's because it doesn't have a handle, the band kind of pulls unevenly on the hand and it's a bit uncomfortable. I think you can get handles for exercise bands but I never got round. I

thought it was becoming a step too far to get a handle, but I might do that now." (RE group, between 35-50 years old, male, completer)

7) Variety or not variety:

Participants in the flexibility group reported not having levels in their exercise programme and wanting more variety. On the contrary other participants in this group reported having a variety of exercises and trying different exercises every week to keep a good variety.

"Yes, I would have liked to have more diversity or a level up at one point but probably this wasn't the aim of the programme itself but for the future probably it would be interesting to have different levels of improving or more...we function this way that we like rewards and achievement and I think it would have been nice to have the goal itself moving forward and did this, good, let's move on." (FLEX group, younger than 35 years, female, completer)

"Yes. It almost seemed too easy. Because you were holding the poses for 30 seconds. But there was a good mix of poses. And some of them were a bit too strenuous for me, but there were alternatives there. So, I could go for an easier option." (FLEX group, between 35-50 years old, female, completer)

On the other hand, participants in the resistance exercise group reported choosing different exercises every week, liking the variety of exercises and having a good selection of exercises. However, one participant reported not having a good variety of leg exercises and wanting more.

"I generally chose them when I was doing them based on, kind of, just trying to have some variety in what I was doing, and they're all ones that I really referred or ones that I found particularly difficult, so I wanted to do them." (RE group, younger than 35 years old, female, completer)

"I liked them all. I thought it was a really good selection of exercises. I found some more tiring than others." (RE group, between 35-50 years old, male, completer)

8) Volume of exercise:

Overall, the majority of the participants reported doing one set per muscle group (six muscle groups) per week. This was the same between exercise groups, age groups and completion groups. Only one participant reported doing two sets

and only one reported doing three sets. A few participants reported having done between 1 and 2 sets for some muscle groups.

> "I did one each day, yeah. That worked best for me. And then I had a rest day as well. So there are six exercises, I think, in a week, so had one day when we didn't do any. Sometimes I'd do a little bit more of one exercise than the set time, but, yeah, I stuck to one exercise per day." (FLEX group, over 50 years old, female, completer)

A couple of participants reported starting with two sets and decreasing to one set due to different reasons.

> "So I used the app on my phone to set up the programme, doing two leg-based stretches each session and then other parts of the body, just one exercise each session. I think there were sort of six to eight exercises in each session and I did it. Initially, I was able to do two sessions a week but in the end I ended up just doing one session a week towards the end of the study." (FLEX group, over 50 years old, male, completer)

Appendix AO: Descriptive Summary Progression

1) **Flexibility group**

   a. Lack of progression

A few participants from the flexibility group reported not having any progression in the flexibility exercise programme. Some claimed to get bored and being disappointed because of the lack of progression.

> "I also got probably bored at one point. I was hoping that maybe midway requirements would change and things would get a bit more intense. I felt like it was a bit less demanding on my body." (FLEX group, younger than 35 years old, female, completer)

> "I remember thinking when I went on to the programme and its levels, and then there was only one level, that was a bit disappointing, I guess, at the time." (FLEX group, over 50 years old, female, non-completer)

One participant of the flexibility group reported noticing some improvement at the beginning, but not at the end of the programme.

> "Yes, certainly some of them seemed to… I was conscious of some improvement with some of them, and others not. So in particular, the exercise where you're sitting and you stretch forward to touch your toes, that was actually used as one of the base measurements for the study and it was also one of the exercises in the programme. Now I find doing that exercise, which I was familiar with, doesn't produce any improvement unless you introduce a resistance band or somebody pushes against your back to actually help you get further than you can. Whilst I did that exercise, I was conscious that I wasn't seeing any improvement throughout the period." (FLEX group, over 50 years old, male, completer)

2) **Resistance group**

Several participants reported improvement during the exercise programme. Some reported to increase in the number of repetitions, but not progressing to the next level.

> "I was more than comfortable at entry level. Apart from legs where I did move up to level two of the videos, I never progressed beyond one

and I've never progressed to the advanced bands. But, again, time, I'd like to." (RE group, between 35-50 years old, female, non-completer)

"So, on the…when you record it, it will say, what did you get…what did you do last time? So, you could see that you got…you managed to do 12 of the four. And so it was quite encouraging to see that you could do 14, and then it would kind of increase. So, I…so I suppose, yeah, I could see that those exercises were…I was becoming stronger I guess. It felt like that anyway. But I know it's a very gradual thing but I could see that progress." (RE group, between 35-50 years old, female, completer)

Some others increased their repetition number and progressed to the next level.

I: "Did you notice any changes as a result of the programme?

P: Not huge ones, no. I noticed that I could do more reps or the stronger bands than when I started, but not really apart from that.

I: Which band and what exercise were you referring to?

P: All of them I think. Every single exercise I started off with x reps and I can now do more reps, or the same number with a stronger band. (RE group, between 35-50 years old, male, completer)

A few participants reported that when they moved up a level the number of repetitions they could do decreased. In addition, some participants thought that there was not a good transition between some bands, while another participant found this interesting and a good transition between the bands.

"P: And it's the same with the bands, I was getting better and better with one band and then when I hit the upper limit I moved to a different band. One issue was that it was simply thicker in my hand and gripping it was, you know…it just didn't feel as comfortable in my hand as the lighter, thinner one. So I felt if there was an exercise…I couldn't do that, sort of thing. And I found it a lot easier with the thinner band and then with the other one it was like no, I'm struggling to even get up to level with that for one, where I was getting to 20 with the other one. The increment between the bands, between the exercises, was just maybe a wee bit…

I: Too much?

P: …u-huh. With 20 as the limit, that's what I found." (RE group, over 50 years old, male, non-completer)

"I: Did you change bands during the programme in different exercises?

P: Yes, I started off quite light to make sure I was getting good form and things, and then worked up through the bands. The one thing I'd say that's not as good about bands is sometimes the step from one band to the next is quite big. So, with exercises like lateral raises I could do 20 on the smallest one, but then like just about one on the next band up." (RE group, between 35-50 years old, male, completer)

"I really don't like exercise very much. And so I was like, well, you know, I'll just do kind of…not the bare minimum because I did try to do as many repetitions as I could do, you know. But sometimes it can feel discouraging when you move up a level and then you, you know, you were doing like 15 or whatever and now you're doing two." (RE group, younger than 35 years old, female, completer)

"I: So how did you find changing from one band to the next?

P: Tougher, but obviously it was very interesting. If I could manage 20 of, say band two, I could obviously do more than six on band three, but not necessarily hugely more than that.

I: Yeah.

P: So it was cleverly done, you had to reach 20 in order to go up, but you had to a minimum of six, in order to stay up there.

I: Okay.

P: So it was progressed naturally, yeah." (RE group, younger than 35 years old, male, completer)

A couple of participants reported finding it good to have several levels for the exercises.

"I: And what did you think about the different exercise levels?

P: I thought it was really good. It…especially for things like push ups, which I would say I would find a bit daunting. It's really good that there were some…that there were lots of different levels, and that you were able to take the time to work out which one to start on for yourself. And for me, there was always a level that I could start on." (RE group, between 35-50 years old, female, non-completer)

Some participants reported having progressed to the following level in general after 3-4 weeks or 7-8 weeks, or that their progress depended on the specific exercise.

> "I: When was that, after how many weeks did you move to level two, if you can remember?
>
> P: I'm not 100 per cent sure. Probably, yes, maybe like three or four weeks I moved up to the second level band." (RE group, younger than 35 years old, female, completer)

> "I think I started at maybe level 2, because level 1 felt too easy. The first day I tried level 1 and it felt too easy, so I started at level 2 and then I changed to level 3 about two thirds of the way through, so maybe seven or eight weeks." (RE group, 35-50 years old, female, non-completer)

A couple of participants commented never having used the resistance bands before the exercise programme, but liking them after using them.

> "I: And how did it go with the bands, how…?
>
> P: I quite liked them, they were…my children really enjoyed seeing them as well. But I'd never used resistance bands before, so I didn't really know very much about them. I'd heard about them, but I didn't really know how to use them. So, the videos were really good for that point of view, and just to see how they are used in exercise and different ways to use them. I actually quite enjoyed it, and it was an exercise that I hadn't done before. So yes, I thought they were really…with the videos, they were really straightforward to use. I think if I hadn't had the videos, I wouldn't have really known what I was doing with them." (RE group, between 35-50 years old, female, non-completer)

One participant noticed a problem in the webapp. She reported having received five resistance bands and having only four levels in the webapp for the band exercises, though this didn't actually affect her programme since she didn't progress until the last band.

> "One thing I did notice on the app, although I was sent five resistance bands, I never felt confident to go up to the number five, but you couldn't record it on the app as number five. If you went into the exercises, it only gave you one to four, so some people were a lot stronger than I am. They might have got to five a lot earlier. But it didn't even bother me, that was just one thing I noted" (RE group, over 50 years old, female, completer)

Overall, participants reported improvement in band exercises, leg exercises, squats, planks, lateral raise, lunges and push ups. Some participants found it hard to improve in push ups, arm and body weight exercises.

> "I don't think I was able to move levels in the push up. I think I moved levels in the squat and the lunging and most of the other…most of the resistance bands I moved up in apart from perhaps the exercise where you were raising your arm to the side because I found that was just like really challenging for me." (RE group, younger than 35 years old, female, completer)

> "I did notice that I was able to increase my repetitions. But then when it came to a press-up…push-up I'd done the maximum of one level but I just couldn't do the next one, like I couldn't even do one. So, I don't know that it necessarily followed. I know that push-ups are hard for women like with…and there's…and I haven't got much upper body strength, but apart from that the others I felt I could…I did see improvement in the number I could do from the beginning." (RE group, between 35-50 years old, female, completer)

> "I: Can you describe to me a couple of the…some exercise that you did?
>
> P: So, there was squats, I moved through a few levels of that one... Chest was always push ups. I didn't get past doing push ups on my knees. But I did get them better, but I didn't get past doing push ups on my knees. Plank, I did progress in plank for core." (RE group, between 35-50 years old, female, non-completer)

One participant referred to not wanting to progress to the following level in lunges or squats due to being afraid of an ankle injury.

> "Some of them felt like…I don't know, like the lunges and the squats, I was never really willing to work at jumping, so I was not willing to go to the next level, because I just, I don't know, I was afraid I was going to break my ankle or… I just don't feel like confident enough, so I was fine just doing 20 of the level I was because, yeah, I didn't feel comfortable [inaudible 07:47] jump, they were hard." (RE group, between 35-50 years old, female, non-completer)

Appendix AP: Descriptive Summary Experience of doing the exercises

1) **Subcode “Doing the exercise right and concerns”:**

Overall, a few participants reported being worried about how to do the exercises properly during the exercise programme. There was no difference between exercise groups, age groups and completion groups, though only female participants reported this. Only one participant from the resistance group mentioned being worried about injuring herself if she did not perform the exercises properly.

> "I found that a lot of the ones where I was standing I worried a lot about form. So, I worried a lot about form and lunges thinking about whether my knee was going passed my toes and squats and, kind of, thinking about that. So, I enjoyed the floor based ones more, and I think that just reflects like my general sense of these types of strength exercises is that I worry a lot that I’m going to injure myself or something." (RE group, younger than 35 years old, female, completer)

> "I felt the stretching, all the pulling in the areas that you described and if I didn’t, as I said, I stopped and watched the video again." (FLEX group, over 50 years old, female, completer)

In addition, a couple of participants mentioned having learned how to do the exercises properly as the programme progressed.

> "I still used the mirror, just because it happened to be in one of the rooms that I was doing them in. So, I did use it, just to check, especially for squats, that my knees weren’t going too far forward, and for the lunges, again, that my knees weren’t going too far forward. But I didn't…after a while, I didn't use it for the planks and I didn't use it for the push ups. ...I think that my body knew what shapes it should be making and how it should feel. So, I think once I was more comfortable in knowing, for example, in a plank, where my hips were, and making sure I wasn't sticking my bottom up in the air, what have you. Once I knew what that felt like, then I didn't need it." (RE group, between 35-50 years old, female, non-completer)

Some participants disclosed finding some exercises difficult to follow and not knowing if they were doing them properly, especially squats and lunges for the resistance exercise programme and the chest stretch for the flexibility programme.

Finally, a couple of participants reported being cautious while doing the exercise, due to poor balance, health conditions, family history and a friend's experience.

> “I: Why were you cautious?
>
> P: A combination of a lack of exercise over time, so erring on the side of caution. My age - I’m 51 and one of my good friends two weeks ago was out running, he’s training for the London Half Marathon, he felt unwell and he went to see his doctor and last week he was fitted with three stents. And he is healthy, he eats well, he’s not overweight and he runs. He’s running at a level for 13 miles, sort of thing. And it turns out he has three blockages in the arteries leading to his heart and he had to have three stents fitted.
>
> So I’m aware of my age and the kind of…again, family history. My father has had a triple bypass, there’s been angina in the family. And during lockdown you can't really get to see doctors. That kind of caution was over, I’m doing a bit of exercise for the first time in a long time, so I’m erring on the side of caution in terms of not pushing myself, not making myself overly uncomfortable. So that was part of the reasoning was just being careful." (RE group, over 50 years old, male, non-completer)
>
> "Some of them felt like…I don’t know, like the lunges and the squats, I was never really willing to work at jumping, so I was not willing to go to the next level, because I just, I don’t know, I was afraid I was going to break my ankle or… I just don’t feel like confident enough, so I was fine just doing 20 of the level I was because, yeah, I didn’t feel comfortable [inaudible 07:47] jump, they were hard." (RE group, between 35-50 years old, female, non-completer)

2) **Subcode “Perception of ability”:**

There were some participants that mentioned their body getting in the way of doing the exercises, like having scoliosis or their stomach getting in the way. Also, a couple of participants reported having their bodies changed previous to the study and that affected their ability to perform exercise., like having a baby or gaining weight.

Several participants reported having low fitness, low flexibility in their arms, legs or ankles, low strength in their arms and not having a good balance. Some even reported feeling ashamed or horrified of their fitness at the beginning of the programme.

"I: Did you have some that you enjoyed more and others that you least enjoyed?

P: Well, to be fair, because it was stretching, I'm quite tight in my legs so it was quite good to do them although they're hard but I find them probably something I should be doing more of but, yes." (FLEX group, between 35-50 years old, male, non-completer)

"I think is it the quad stretch where you stand on one leg and you get the other leg by the ankle, the first time I attempted that it was embarrassing and I was actually…I actually felt quite ashamed of myself. I thought, how could you get in such a state that you can't stand on one leg and comfortably pull the other leg and get in that position, but after about three or four weeks there was a…just doing that exercise with the required repetitions I found there was an improvement in me being able to do that exercise." (FLEX group, over 50 years old, female, completer).

"At the start of the study it was just that horrification of how your body can just go to being ineffective in such a few number of months, and literally I last went running the end of September, very early October through to…no, that's not true, I went out just before October half term, so mid October, so mid October to June, how you could have just lost everything but without noticing that you've lost it." (RE group, between 35-50 years old, female, non-completer).

In addition, a few participants reported that the exercises were within their capabilities, that they were not demanding, felt confident during the programme and a couple reported having previous knowledge of the exercises due to having previously done yoga or going to the gym.

Some participants reported an improvement during the programme, for example in their flexibility, learning the exercises and feeling less aches as the programme progressed. On the contrary, one participant in the flexibility group reported not being sure of any progress in her ability to perform the exercises.

"I think is it the quad stretch where you stand on one leg and you get the other leg by the ankle, the first time I attempted that it was embarrassing and I was actually…I actually felt quite ashamed of myself. I thought, how could you get in such a state that you can't stand on one leg and comfortably pull the other leg and get in that position, but after about three or four weeks there was a…just doing that exercise with the required repetitions I found there was an improvement in me being able to do that exercise." (FLEX group, over 50 years old, female, completer)

A couple of participants reported not having used bands before and not knowing how to use them. One of them found them difficult to use while the other participant reported an improvement in his confidence while using them.

Several participants from the resistance group reported some exercises to be specifically difficult. Push-ups and lunges had three hit each, squats two hits, shoulder press and crunches one hit each.

3) Subcode "Immediate response to exercise":

a. Physical response to exercise:

Overall participants reported feeling invigorated, an endorphin buzz, comfortable, relaxed, not being out of breath, exhausted, sore or achy, uncomfortable, flashed or hot, nauseous, tired and elevated heart rate.

> "I think sometimes I felt a bit more calm, because I think sometimes the reason you want to get up and go is because you're feeling stressed or you're doing a task that's quite complicated or you think a lot and you're like, oh I just need a bit of a break. And then you do that and come back and feel a bit invigorated, ready to do it, ready to carry on more .. No, I think you just felt better for, like, moving, like you said." (FLEX group, between 35-50 years old, female, non-completer)

Only participants from the resistance exercise group reported feeling exhausted, flashed or hot, nauseous, tired and having an elevated heart rate.

> "Most of the time I would kind of feel like [interruption from child] feel kind of bored mostly and then also, then like in a lot of pain. Because primarily I'm doing it during my free time and I don't really get that much free time, and so I'm always like, oh my God, I'd rather not be doing this, kind of thing.
>
> And then, it's also, you know, kind of painful [interruption from child]. Kind of, you know, it's also like painful I'm going to say. Like, oh my God, oh, my leg hurts. Like, this is really hard." (RE group, younger than 35 years old, female, completer)

A similar amount of participants from the flexibility group and the resistance group reported feeling pain during the exercises. But, if we compare the different group ages, more participants from the group over 50 years old

reported feeling pain compared to the other two age groups. In addition, there were no differences between completers and non-completers for this either.

> "Most of the time I would kind of feel like [interruption from child] feel kind of bored mostly and then also, then like in a lot of pain. Because primarily I'm doing it during my free time and I don't really get that much free time, and so I'm always like, oh my God, I'd rather not be doing this, kind of thing. And then, it's also, you know, kind of painful [interruption from child]. Kind of, you know, it's also like painful I'm going to say. Like, oh my God, oh, my leg hurts. Like, this is really hard." (RE group, younger than 35 years old, female, completer)

> "To be honest, I think there were some I didn't like in terms of where you're sitting back on your legs. So you're in a kneeling position and when I sat back, I think it was just a case of my build, as such, that my ankles didn't have the flexibility to be, sort of, sat on, and that was a bit painful and so I, sort of, didn't like to do those ones. And, also, on the kneeling I found I had a bit of a problem on my right knee. I can't kneel comfortably on it unless I got something padded underneath, I get, sort of, a pain." (FLEX group, over 50 years old, male, non-completer)

In addition, some participants commented feeling sore or achy while doing the exercises or after doing them. Looking at the exercise groups, there were more people from the resistance group than the flexibility, no relevant differences between groups and more completers than non-completers.

> "To begin with, the first couple of weeks, not right afterwards, but the next day, I was a bit achy, but then that went away and it didn't seem too long. But I was definitely a bit achy, especially with the first couple of weeks, because I'd done a couple more sets where I'd tried maybe the easy level, but then also done the next level. So, I was more achy those weeks, but not laterally." (RE group, between 35-50 years old, female, non-completer)

> "No, no it was just if…yeah, I think it changed when I changed the lunge from a short one to a long one, that helped. I got more…I wouldn't say stiffness, more a, you think you've used that muscle. I mean I didn't take any painkillers or any anti-inflammatories, nothing like that. It was just you think, oh…as if you'd been on a long walk and you thought, oh gosh, I've definitely exercised my muscles today, yeah." (RE group, over 50 years old, female, completer)

One participant reported during the exercises feeling her heart rate to raise.

> "Some of the ones it did raise my heart rate considerably, which was interesting because you don't think you're doing a huge amount. It's not as if you're running. Which I suppose is good, I think. I suppose generally I felt quite good doing them. I felt it was making an improvement, so I suppose I felt quite good doing them." (RE group, over 50 years old, female, completer)

b. Mental response to exercise:

Several participants commented to have felt a sense of achievement, encouraged, satisfied, pleased with themselves, proactive, good, happy, calm, a boost in the mood and having fun while exercising or after it. There were considerably more people reporting feeling a sense of achievement in the resistance group compared to the flexibility group. There were no relevant differences between age groups or completion groups for this.

> "I do like stretching out. I think it's good to stretch your muscles and whatnot so it is…yes, I guess it's quite satisfying when you've completed the set of stretches." (FLEX group, over 50 years old, female, non-completer)

> " think that I noticed, you know, whenever I was doing them there would be a boost in my mood which was helpful, which I was kind of aware of anyway. That doing physical activities especially something that kind of was making me sweat would be helpful for my mood. So, yeah, that was helpful." (RE group, younger than 35 years old, female, completer).

> "I always felt a bit of a sense of achievement actually, especially when you could see your personal best and you were able to see what you'd done the last time. There were times when I wasn't as good as I had been before, and that always felt a little bit disappointing. But otherwise, there's definitely a sense of achievement afterwards." (RE group, between 35-50 years old, female, non-completer)

In contrast with the previous reports, some participants commented feeling neutral, confused with the instructions, bored, distracted and disappointed. These were made by almost only participants in the resistant group, while only one participant from the flexibility group reported being bored. Also, these comments were only made by participants younger than 35 years old and between 35-50 years old. There were no differences between completion groups.

> "I think they were easy to do so I did them but also they were less demanding on my body and they were verging on doing meditation in a way for me. It wasn't necessarily pushing my body but more my mind and getting in a space of doing an exercise…also got probably bored at one point. I was hoping that maybe midway requirements would change and things would get a bit more intense. I felt like it was a bit less demanding on my body." (FLEX group, younger than 35 years old, female, completer).

> "Most of the time I would kind of feel like [interruption from child] feel kind of bored mostly and then also, then like in a lot of pain. Because primarily I'm doing it during my free time and I don't really get that much free time, and so I'm always like, oh my God, I'd rather not be doing this, kind of thing." (RE group, younger than 35 years, female, completer)

Finally, several participants reported having enjoyed doing the exercises, with no difference between exercise groups. On the contrary, more than half of the participants between 35-50 years old and over 50 years old reported enjoying the exercise, while only one participant younger than 35 years old reported enjoying it. Adding to this, there were also more completers that enjoyed the exercises than non-completers.

> I generally quite enjoyed the ones with the resistance bands, they were good. Personally, I didn't enjoy doing things like lunges and that, but that's just me, I've never liked them much. The resistance bands were good. The plank was good because it made me try and do a few every week. And it was only them…what do you call them, press-ups, I hate press-ups, but I did try and do them, not with much success but, you know, just doing them once a week it did make you get a wee bit better. (RE group, over 50 years old, female, completer)

> So, in general, I found it enjoyable, very enjoyable actually. It was a little bit confusing to know was I allowed to do just that one exercise from the group or could I do multiple from the group? And in the chaotic world I'm in I never got around to questioning it with you so I ended up just doing one because I felt that was…I wouldn't be compromising your results by doing that if you weren't allowed to do. (RE group, between 35-50 years old, female, non-completer)

Appendix AQ: Descriptive Summary Experience of the web app

1) General thoughts on the web app

Several participants expressed linking the web app and finding it good. In addition, several participants reported the web app to be helpful, handy, straightforward, easy, simple, easy to use, clear and very user-friendly. However, one participant found the web app not helpful and confusing.

> "I: Yeah, I was asking what did you think about the web app?
>
> P: Yeah, I thought it was good. I liked the videos, I liked the ability to see what my previous…I don't know, one thing that I would say, when I got to select the exercises for the week, I wouldn't always remember which one I'd done the previous time, so I'd like it to have the history there so I could refresh my memory. So I liked that, like the little videos, I feel like I watched the videos, I think every time, even once I…because I [would switch on 03:16] which ones I would select, so I liked watching the videos to help me remember the right form and things like that, so I did find it helpful" (RE group, between 35-50 years old, female, non-completer)

> "I: So tell me about the online programme that you did?
>
> P: I found it very straightforward actually, just logging in every day. Every week I would choose my week's worth of exercises and then the videos were very clear and then it was just a case of setting up the timer on my phone, making space for myself and doing the exercise. I found it very, very straightforward, very easy." (FLEX group, over 50 years old, female, completer)

> "P: I think I just ended up getting confused and I thought, I want to do different ones each week, but then I can't remember which one was which, and then, had I done that before and things? And I think I just ended up quite muddled up with it, that I just ended up taking pictures of each exercise from the demonstration and then knowing in my mind, these are the ones that you need to do. And doing it that way so, like, taking it away from the logging in part and just knowing in my own mind what I needed to do.
>
> I: Okay, yeah, I know what you mean. So, like, the website itself was not very helpful then?
>
> P: No, not for me" (FLEX group, between 35-50 years old, female, non-completer)

In addition, participants reported that the web app did exactly what they needed, it was good that it remembered the exercises selected each week and that it had good exercise videos. Participants reported using their phones and their laptops to navigate the web app. One participant expressed that it was always accessible on her phone.

> "It was quite good and handy that I could have it on my phone, or I could log in to the PC, depending where I was. So, I thought it was quite clear to follow, and I liked that it had the history, so I could go back and check what I'd done and how I was getting on, I liked that as well." (RE group, between 35-50 years old, female, non-completer)

> "I thought it was brilliant to have that as a place. I thought it was much better to have an app than to say, just have a website or something because, you know, I think most of us now you live with your…you have your phone with you a lot. So it was helpful just to have the app there, and I just put it on my front screen, so it was always accessible." (RE group, younger than 35 years old, female completer)

On the other hand, some participants expressed that it was frustrating having to choose the exercises each week and to go back to the exercise videos, the app did not remember which band they were using previously and that it would be easier to use it if it was an actual mobile app.

> "I: So what did you think about the webapp in general?
>
> P: It's reasonably good in terms of design, but one thing that was frustrating was that every time I was…each week, I had to restart all the exercises. And for some of them, there was no choice, and for all of them, there was no choice of resistance levels but you still had to go through and select it each time. So after 12 weeks, that was annoying, every week having to reset the programme." (FLEX group, over 50 years old, male, completer)

> "But with the reflex bands, because there's so many and then you're doing probably different bands on different exercises, I don't always remember which band I was on with which exercise. And so, she told me, well, just go back to the history. But it would make more sense I think if the app told you when you chose it. It was like, you've already done 20. Because it will tell you that but only after you've picked it." (RE group, younger than 35 years old, female, completer)

2) General thoughts exercise diary

Overall, several participants expressed liking the exercise diary. The reasons reported were that it was helpful without being complicated, it as accessible, they could see what they had done before, could use it to keep a variety of exercise through the weeks, it pushed the participant to do as many repetitions as the previous week and it was easy to follow and record the exercise.

> "Yeah, I thought it was brilliant to have that as a place. I thought it was much better to have an app than to say, just have a website or something because, you know, I think most of us now you live with your…you have your phone with you a lot. So it was helpful just to have the app there, and I just put it on my front screen, so it was always accessible." (RE group, younger than 35 years old, female, completer)

> "I: What did you think about the exercise diary in particular, the bit that you could see your feedback, what you have done before? What did you think about that?
>
> P: I really liked it. Again, it was helpful without being too complicated. I think a lot of exercise programmes that I've seen in the past over-complicate things in that they either get too difficult too quickly, or they take too long, or they're just too complicated. I really liked the fact that you could go onto the app and it would say like last week you did 16 push-ups, and it was as simple as that. You could see the chart of how many you've done over the last few sessions." (RE group, between 35-50 years old, male, completer)

> "I liked that it had the history, so I could go back and check what I'd done and how I was getting on, I liked that as well. And the little bit that gave you what your personal best was, because obviously, some weeks, I wasn't as good as other weeks. So, that was quite good, being able to see that and see what your personal best was, and a little reminder that if you were managing to do the twenty repetitions, that it might be time to move up to the next level and things like that [inaudible 04:08] that that was all in it as well." (RE group, between 35-50 years old, female, non-completer)

On the other hand, some participants thought the exercise diary was not helpful, it was confusing, unclear and hard. Moreover, a couple of participants did not know the existence of the exercise diary and one did not use it.

> "I found it really hard to remember to sort of, like, log in and say I'd done the certain weeks, because obviously I saw the different exercises and they were all of one level all the time so I had an idea

what they were. So what I tended to do was just to have them in my mind and sometimes I'd just think, oh I'll do that one for so long and then change it round, and then logging in one at a time and I found my diary a bit hard to do and to remember to go in. One week I thought I'd picked exercises and then I realised I hadn't and it'd gone to the next week and it all confused me. So I just thought, well, if I just keep doing them when I remember, it might be better." (FLEX group, between 35-50 years old, female, non-completer)

"Also, the website wasn't such that it was, sort of, easy to allow you to record what you were doing. Whilst it had a diary function, I just basically ignored it because it was just literally you click on it and you can go back into the diary function and there was no follow up whether I had to fill it in or not. (FLEX group, over 50 years old, male, non-complete)

"I: Then what did you think about the exercise diary?

P: I don't know that I used it, to be honest. I just went in every day and used the…went in and did my exercise, I didn't really look around the app any more than that, to be honest." (FLEX group, over 50 years old, female, completer)

3) Specific problems with the web app and diary

Several participants experienced a range of problems with the web app during the exercise programme. The problems presented by the participants can be divided into the following categories:

a. Web app interface problems

It was reported that the web app had a glitch, it was clunky to select the exercise, had problems with the exercise recording system, it did not tell when the exercises were completed each week, the resistance programme band exercises did not have level 5 despite having 5 bands and that it did not work well on a phone.

"I: And what did you think about the web app?

P: I think it took me one attempt to navigate it. It was a wee bit clunky when you were selecting the exercise you were doing, but once I knew how I had to do it, what clicks I needed, it was fine" (FLEX group, between 35-50 years old, female, completer)

> "I'm not sure. One thing I did notice on the app, although I was sent five resistance bands, I never felt confident to go up to the number five, but you couldn't record it on the app as number five. If you went into the exercises, it only gave you one to four, so some people were a lot stronger than I am. They might have got to five a lot earlier. But it didn't even bother me, that was just one thing I noted." (RE group, over 50 years old, female, completer)

b. Log in problems

Some participants reported having problems with the web app login system. A couple of participants couldn't log in to the app and had to do a few password resets over the exercise programme to be able to access it. Another two participants reported that the web app did not remember their login details and had to log in several times or every time they used the app.

> "I found it slightly inconvenient that I had to log in every time I used it. I think if it was an app rather than a website, or it remembered the login it would be slightly quicker to use." (RE group, between 35-50 years old, male, completer)

c. Video problems

Some participants reported a few problems with the videos in the web app. The problems reported were not being able to watch the videos well on their phone, one exercise in the resistance exercise programme had the wrong video and the flexibility exercise videos audio was very low.

> "I: What did you think about the website itself?
>
> P: I thought it was good with the videos. But I think sometimes you'd watch the video and you'd realise what that was and then next week you'd come back and certain exercises you would remember because they were in, like, little blocks. Like, obviously the chest one had less, the leg one had different ones and then… So you'd be trying to watch the video again, but I couldn't get them on my phone very well, so I was having to go on a laptop to see what it was and try and remember each one that way." (FLEX group, between 35-50 years old, female, non-completer)
>
> "Regarding the videos, I found them, whilst instructive, the audio was quiet. It was occasionally have instructions given to you, but luckily they had also typed up what they were saying so it allowed me to read afterwards. But then when they were showing exercise, the volume increased for the background music. It was actually louder than the

people telling me, so I felt they should have flipped that. They should have had the people telling me louder so I could actually hear it instead of sitting there with my ears like this so I could ear. I couldn't turn it up. I had it maximum on my PC. So that was, if you like, the criticism." (FLEX group, over 50 years old, male, non-completer)

4) Expectations of the web app

A participant from the resistant group reported expecting the app to remind her to do the exercise. A couple of participants from the flexibility group reported expecting the web app to time their exercises and to track their exercise in a different way.

"I think a couple of things; I expected with the app to remind you when the end of your week was coming up, because what I found is I just kept it in my mind that I had signed up on a certain day for the programme, so I had to do stuff by the end of this day, but sometimes I found myself, like, worrying like have I got it wrong and have I missed my week or something." (RE group, younger than 35 years old, female, completer)

"I: What did you think about the exercise diary? In the programme online there was a bit of a feedback I think it is called option that you could go back and see what you have done before. Did you go in there?

P: I think I went only a couple of times. But I felt that it didn't track the way I expected it to track. I was expecting to have the time when I did it and it didn't appear or for how long. I feel that it didn't record the time itself. You know when you do those apps on the phone and when you do it together then it records how much time you spend." (FLEX group, younger than 35 years old, female, completer)

5) Suggestions for the web app and exercise dairy

A couple of participants suggested that it would be better to have an app and not a web app for the phone and a better integration with the phone.

"I think it was the case that knowing I only had to do one exercise once a week, I wasn't really that bothered to go and fill it in because it's just the fact is it will take me longer to log in, pull up everything than to do the exercise. I felt if the diary was, I didn't try and access it on my phone, I was doing it all through on the laptop. So maybe if it was an app more suitable for a phone, then it would have easy to scroll and pick because you had to, sort of, go and find the exercise

> you were wanting." (FLEX group, over 50 years old, male, non-completer)

A couple of participants suggested to have a reminder in the app to remind people to do their exercise. On person suggested to have a reminder to remind people to fill in the exercise once completed.

> "What it could have done is and I missed quite a few because sometimes you forget, it could do with a reminder, I think, to reminder you. I don't know if they could build in an alarm to remind you." (FLEX group, between 35-50 years old, male, non-completer)

One participant suggested to have a time built in the app.

> "It would have been useful to have a timer built into the app. I just purchased a little separate timer to make sure I was doing the exercises for the right amount of time." (FLEX group, over 50 years old, male, completer)

A few participants suggested some changes for the web app and exercise diary interface, such as having a faster way of selecting and completing the exercises, being able to see the history while choosing the exercises, having a level summary when choosing the exercises and not having to choose the exercises every week.

> "I think if the app had actually been easier to set up each time. So at the beginning of each week, the fact is that I had this rolling weekly schedule, it was a bit frustrating. There were some times when, because of the time I started, I think it was three o'clock on a Friday afternoon, so there was one week when I went to a second session and it was four o'clock on the Friday afternoon and it said, your week has expired" (FLEX group, over 50 years old, male, completer)

Another participant suggested for the exercise diary have the history of all levels completed for one exercise in the same graph.

> "I: So what did you think about the exercise diary?
>
> P: So it had its flow chart which was good, it meant I could see where I was progressing. I would have liked, if I could have seen on one page, all of my flow charts, so I could see a line of all my press ups, all this, because I think that would have helped me choose the next week. I might have said, well, I've done press ups for the last three weeks, I'll now do planks.

I: Okay, anything else that would have helped?

P: I suppose just the layout. The history was fine, but you had to go into, into, into. And I think the other problem is, when you went up a level, there was nothing to show your progression. So the flow chart didn't say, band one, band three, so it didn't change colour, it was just like, that's band one, a completely separate flow chart for band two." (RE group, younger than 35 years old, male, completer)

Appendix AR: Descriptive Summary Information

1) **Initial Instructions videos:**

Several participants reported that the initial instruction videos were clear and straightforward and that they understood the instructions.

> "I: What did you think about the instructions at the beginning of the programme? The ones that show you how to navigate the programme and the programme itself it tells you what to do?
>
> P: The videos?
>
> I: Not the exercise videos but the two videos on the beginning.
>
> P: Things were quite clear at that point from what I remember. I had no questions and I knew what I was getting myself into." (FLEX group, younger than 35 years old, female, completer)

On the other hand, there were a few participants who did not understand the instructions, which affected their exercise programme and exercise diary. Additionally, a couple of participants were not able to recall watching these and one person did not feel the need to watch them due to understanding the instructions given by the researcher during the previous appointment.

> "I: Did you watch the videos for, like, instructions of the website and the programme itself, the instructions – not the exercise videos but the instructions of the programme of the website?
>
> P: I don't know, no. Well, I knew what I had to…no, I don't think I did because you told me what to do so I just did it, well, I knew anyway. I didn't go fiddling in the website at all. I just found the bit where you put the exercise in and you chose your exercises and I put that in and I think that was all.
>
> I: Why do you think you didn't go and explore and kind of have a look around and…why do you think that didn't happen?
>
> P: I don't know, I thought you'd explained it to me and I knew what I was meant to be doing so I just did it." (RE group, over 50 years old, female, completer)

Finally, one participant reported not being clear on how long the rest between sets should be.

2) Exercise videos:

Several participants reported that the exercise videos were good, clear, easy to follow and understand, had good instructions and were useful. One participant mentioned that she would watch the video of each exercise she did every time.

> "I thought the exercise videos were really clear, instruction wise, yes, I could follow them really easily." (FLEX group, over 50 years old, female, non-completer)

> "I: What did you think about the video instructions?
>
> P: I thought they were really clear, actually. They were really…and it was really good to have them, so that when I decided to change an exercise, if maybe I hadn't done it for a few weeks, it was there, just as a refresher, to make sure that I was doing it correctly and to check my form and things as well and…because it's easy to think that you're doing it right, if you're not actually looking and doublechecking. So, I actually thought that was really good. And the different variations for the different levels and things, the explanation of that was really good as well. So, I found it really useful, having the video instructions. And I think I watched them actually every week, just to remind myself what I was doing." (RE group, between 35-50 years old, female, non-completer)

A couple of participants mentioned that the written instructions at the end of the video were good and that they would read them instead of watching the video.

On the other hand, some participants reported some issues with the exercise videos during the programmes. It was reported by one person that they couldn't watch the videos on their phone and another reported that it was difficult to get back to them on the web app. Additionally, one flexibility video did not match its audio description and one resistance exercise had the wrong video. Another participant in the flexibility programme expressed that the audio description was very quiet and the background music was really loud.

> "I couldn't get them on my phone very well, so I was having to go on a laptop to see what it was and try and remember each one that way." (FLEX group, between 35-50 years old, female, non-completer)

> "Regarding the videos, I found them, whilst instructive, the audio was quiet. It was occasionally have instructions given to you, but luckily they had also typed up what they were saying so it allowed me to read

> afterwards. But then when they were showing exercise, the volume increased for the background music. It was actually louder than the people telling me, so I felt they should have flipped that. They should have had the people telling me louder so I could actually hear it instead of sitting there with my ears like this so I could ear." (FLEX group, over 50 years old, male, non-completer)

Finally, a few participants recommended some changes in the exercise videos. One person said that it would be good to have a graphic summary of the level of difficulty in the video. Another two participants recommended mentioning and emphasising details of the exercise during the video and the differences between other similar exercises. Finally, one participant, suggested that it would be better to have the exercise in the video to last exactly the length of the stretch to be able to do the exercise alongside it.

> "So, the, yeah, so the videos were good and the instructions, like, the written instructions were good too. I think sometimes, yeah, it might just be useful to be like, make sure your hands look like this, or are like this. Or make sure your hands are like…or whatever. If it's just something that's…I guess, if that's the important part of the exercise, that's like, the…the, because I feel like sometimes it's the detail that might be missed. If you're just, if you don't know very much about exercises or whatever and you're just watching it, you're like, okay. And you're just like, it doesn't matter what my hands are like, or whatever, you know." (RE group, younger than 35 years old, female, completer)

Appendix AS: Descriptive Summary Programme of daily life

1) Time of day and reasons subcode

Participants chose to do the exercises at different times of the day – including immediately after waking up, mid-morning, afternoon, evening, and/or night. Some participants reported doing their exercise during working hours; others did not have a specific time of the day but fitted it around their daily activities.

> "I wouldn't specifically do it all in a one-er. I'd spread it through the day, just depending on what happens. I think that's because I do different things every day and I don't have a set routine." (RE group, over 50 years old, female, completer)

Almost half of 35-50y participants chose the evening because after their children went to bed was a convenient time to do their exercises.

> "I'd often do them in the evening like when my children had gone to bed. So, I'd kind of think, if I've got to do that thing, I've got to do the exercises. But, no, I found I could do them all…I could do them as…you know, I feel…I didn't miss a session." (RE group, 35-50 years old, female, completer)

> "So, I chose the evenings because I have two small children, so it was easier for me to do them undisturbed once they were in their beds. And because of marking during the day, it was…I couldn't fit it in then. And once I get home from work, it's just a very busy time, dinner and bath time and bedtime. So, that was probably the time of day that I have that bit of time to myself that I can get my head into doing it." (RE group, 35-50 years old, female, non-completer)

The other half of this group chose the morning giving as a reason for being a morning person. Half of 50+y participants did their exercises randomly fitting them along with their daily activities (e.g. work) or simply when they would remember to do them. A quarter of 50+y participants chose the evening. A participant in this group reported choosing that time of the day because it was time for herself. Just one participant in this age group chose the morning because it was easier to do the exercises at that time of the schedule.

> "Because I've been working during the day, doing things for the family and it's a bit of my time in the evenings." (FLEX group, over 50 years old, female, non-completer)

There were no differences in time of the day between the flexibility group and the resistance group. In both groups around half of the participants chose the morning and the other half the evening.

There were more men doing exercise in the morning, while there were more women doing exercise in the evening. There were no relevant differences between completers and non-completers. Both groups chose the morning and evening primarily.

2) Place of exercise and reasons

Participants chose different places to do their exercises such as next to their work desk, living room, kitchen, dining room, study, spare room, bedroom and bathroom. Across all participants, the most popular place was the living room because there was more space, was the biggest room in the house or it would break working times.

> I: where did you do the exercises?
>
> P: So, the stand-up ones were close to my desk. So, it depended on what surface area, because some of them needed a specific surface area. So, that would be…most likely, it was in the hall, I did a lot of them, with the surfaces that I had for the [voices overlap 05:22]. And the floor exercises, I tended to do in the living room, because there's more floor space there. (FLEX group, between 35-50 years old, female, completer)

Across the different age groups, the living room was also the most popular among participants. The second most popular room for the group between 35 – 50 years old was next to their work desk, while in the group over 50 years old was the kitchen and the bedroom.

> "So I feel like most of the time I would do them in my office, because that's where my computer is, so I can watch the videos and just do them in the space I've got at my desk." (RE group, 35-50 years old, female, non-completer)

Both exercise groups had as well the living room as the most used room for their exercises. The flexibility group also chose their bedroom as the second most popular room, while the resistance group chose the kitchen and the spare room.

> "Just in my room, I have plenty of space to do it." (FLEX group, younger than 35 years old, female, completer)

> "I'd fit them in…sometimes if I was cooking the tea, I'd think oh I'll just do a couple now. You could be in the kitchen, and you could do a couple now. I do quite like that kind of thing because I'm not really a gym person. You can probably see by my note, how I did and things, I'm not that. It was good that you can fit it into your day-to-day activity." (RE group, over 50 years old, female, completer)

There were no differences between completion groups.

3) Clothing and equipment and reasons

a. Clothes changing

Participants reported having changed into different clothes and not needing to change. Overall, younger participants tended to change more than the older participants.

Most of the flexibility group decided not to get changed into different clothes because they were already wearing comfortable ones. While the resistance group was divided between changing and not changing.

> "No, because I'm working at home I'm probably in leggings and a t-shirt anyway most of the day so that was quite useful." (FLEX group, 35-50 years old, female, non-completer)

> "I: …So were you wearing just normal clothes?

> P: Oh well, what did I put on? Well, generally it'd be…some days I did it in my pyjamas in the morning or some days I put on, like, leggings and things.

> I: And that would depend on?

> P: Well, it would depend on, well, what I was, what I'd been doing beforehand. Sometimes if I was doing the arm ones and I just had a t-shirt on I might have been…I mean, I might have jeans or

> something on but as long as it was a flexible T-shirt, I just carried on like that. I didn't particularly put gym clothes on for it all the time, sometimes I did, if it was for the leg ones more." (RE group, older than 50, female, completer).

There were no relevant differences between male and female participants and between completers and non-completers.

b. Type of clothes used during exercise

Firstly, the majority of the participants reported wearing comfortable clothes during their exercise sessions. Several of them did not change their outfits because they have been wearing comfortable clothes already due to what they were doing previously, clothing preferences, their lifestyle and working from home.

> "I tended to wear…I've kind of been wearing kind of yoga trousers for most of the last year anyway. So I would just wear, yeah like some stretchy yoga leggings and a t-shirt which is I would wear anyway…"(RE group, younger than 35 years old, female, completer).

Just one participant reported wearing their regular clothes because they did not find the need to change.

> "No. Pretty much…no, I didn't change into any specific exercise clothes. I didn't use any mats. I would wear jeans and that…not jeans, wearing trousers and a T-shirt I would do the exercise. Partly because I didn't feel they were…I wasn't getting out of breath and I wasn't working up a sweat with them, so I didn't feel as if I needed to sort of change into any physical education clothes." (RE Group, over 50 years old, male, non-completer)

One participant reported changing to comfortable at the beginning of the programme but stopped because she realised that it was a big effort.

> "At the beginning, I think I was changing into more relaxed clothing, at the beginning. And then I thought, this is a faff, I'll just do it in whatever I'm wearing." (FLEX group, between 35–50 years old, female, completer)

Secondly, almost all participants reported using trainers or being bare feet. Female participants tended to be divided by almost half, though the male

participants tended to prefer being bare feet. All of the age groups were divided between wearing trainers and being bare feet.

> "… because I'm working from home, I'm, generally speaking, in pretty comfy clothes so I didn't really have to change clothes and generally speaking I just did them all in my bare feet whereas when I'm in around the house, I just knock about in my bare feet." (FLEX group, over 50 years old, female, completer)

> "Because the clothing, tracksuit bottoms and the training shoes were far more comfortable and also, I think for a couple of the exercises, I think it's the calf stretch, really, it's impractical to do that in most footwear, apart from trainers." (FLEX group, over 50 years old, female, completer)

The same pattern was found for both exercise groups and completion groups. Some participants in the resistance exercise group reported using trainers because it was uncomfortable and painful to pull the band under their bare feet while one participant reported using flip-flops or slippers with a hard sole for the band exercises.

> "I've got a pair of trainers that I save for indoor exercise, so I put those on because I found, like, just having the bands under your feet it's more comfortable with shoes on. So, yeah, I put on the trainers to do most things." (RE group, younger than 35 years old, Female, completer)

> "I had to have my trainers. Again, I started barefoot but for those where you're pulling it actually hurt underneath your foot. So, again, that was strange having trainers in the house but, no, I did wear trainers." (RE group, between 35-50 years old, female, non-completer)

c. Equipment

The most popular extra equipment used by the participants was an exercise and the second most used was a rug. Within the different age groups, the group between 35-50 years old was the one that had more participants using a mat or a rug. Whether between the flexibility and resistance groups, there was no difference. Women and completers tended to use an exercise mat or a rug.

A couple of female participants from the flexibility group reported using a timer on their phone to time their exercise.

> "And I think counting to 30 seconds took forever. That was one thing I used, I had to find a timer because I couldn't work out what 30 seconds was. Because you think you know what 30 seconds is in your head, but it's not, your head is much faster than an actual timer. So, that's what I did, initially, I was trying to…so, I think I used my phone with a timer on." (FLEX group, between 35-50 years old, female, completer)

One person reported using a towel for the flexibility exercises and another used music during the exercises.

4) Pattern of exercise during the week:

In general, more participants reporting being stable and consistent in their pattern of exercise sessions per week throughout the programme. Only a few participants reported to have reduced their exercise sessions per week as the programme progressed. This was similar if age groups, exercise programmes, genders and completion groups were compared. Some reasons reported by the participants was being busier and because of time.

> "I: So how many days did you do them, if you did two at a time?
>
> P: Oh, three days in that week.
>
> I: Three days in that week, okay. And did this change as the 12 weeks went along?
>
> P: No, not really. It was pretty consistent." (RE group, between 35-50 years old, female, non-completer)

> "I: Right. How many sets were you doing every week, do you know, you remember?
>
> P: Mainly just one set. At the beginning, I did do more sets, but towards the end, I was…it was the evening, so I had to get…I just took…I'll just do one set before I can go to my bed.
>
> I: No worries. Why did you decrease to the minimum?
>
> P: I think it was just time, just trying to fit in." (RE group, between 35-50 years old, female, non-completer)

Some participants did their exercises randomly depending on their daily activities or around work spreading them across the week with no established

pattern. Only female and completer participants (separately) reported doing their exercise randomly. There were slightly more participants over 50 years old reporting doing their exercise randomly in comparison to the other two age groups. There were no relevant differences between exercise programmes.

> "I was really flexible, it just depended, again, what I was doing. I tried to do it over a few days, but there were probably a couple of days where it got to the end of the week and I thought, oh I haven't done them, I'd better do them. So I might've done them all in the day – probably not all at the same time, I might've done some in the morning and some later on, but it varied… That was good, it was perfect for me because if I've had to do it at the same time every day or every week, I probably wouldn't have managed to do it every week, so for me that was perfect." (RE group, over 50 years old, female, completer)

On the other hand, considering the participants that have reported a specific and steady pattern of exercise throughout their programme we found that participants decided to do their exercise between one and six days a week.

In the group younger than 35 years old, participants tended to do their exercise between one and two days a week, while the group between 35-50 years did not have a clear preference between one and six days a week. Finally, the group of over 50 years old tended to do their exercise on one day a week or six days a week.

> "Most of the time I did them all on one day, sometimes I did them in two days." (RE group, younger than 35 years old, female, completer)

> "I did one each day, yeah. That worked best for me. And then I had a rest day as well. So there are six exercises, I think, in a week, so had one day when we didn't do any. Sometimes I'd do a little bit more of one exercise than the set time, but, yeah, I stuck to one exercise per day." (FLEX group, over 50 years old, female, completer)

Almost half of the flexibility group preferred to do their exercise on one day a week, while the other half preferences were between two and six days a week. Similar to this group, also half of the the resistant group preferred to do their exercise on one day a week, whilst the other half chose to do their exercise on three or six days a week.

> "I: How many times a week did you do the exercises?

P: Generally once, sometimes twice a week.

I: Once or twice a week.

P: I used to do them in a one block. I'd do all the exercises together.

I: Okay.

P: One after the other. So I'd do that once a week or maybe twice a week.

I: Okay, so you do all the six in one day.

P: Yes, all six together, yes." (FLEX group, between 35-50 years old, male, non-completer)

"I mean it varies, in the early days I was super keen so I was managing six times a week, once school holidays crept in and we're going through major change with our teaching programme and standards and things, so the worst thinking of this was three times a week and the best was six." (RE group, between 35-50 years old, female, non-completer)

Almost all male participants preferred to do their exercise on one session per week. On the contrary. The female group preferences were more scattered, but three days a week was the most popular option.

"In my living room, usually the night before it was due." (RE group, younger than 35, male, completer)

"I: So how many days did you do them, if you did two at a time?

P: Oh, three days in that week.

I: Three days in that week, okay. And did this change as the 12 weeks went along?

P: No, not really. It was pretty consistent." (RE group, between 35-50 years old, female, non-completer)

Non-completers chose to do their exercise between one and three days a week. In comparison, the completers group did their exercise between one and six days a week.

5) Routine

A couple of participants reported having a reminder in their phone calendar to do their exercise. Other participants chose a specific time during the day, for example, one participant reported putting a reminder on her phone.

> "I: And you have mentioned that you did your exercises in the evening. Was this the case for the 12 weeks or did this did change during the programme?
>
> P: No, I did that consistently, that was when I knew I would have some time to myself to be able to come and do that. So, yeah, I did that consistently. It helps also just to work it into your day and make sure you remember to do it if you have it at the same time, I found. So I set a reminder on my phone and I'd come do my exercises." (FLEX group, over 50 years old, female, completer)

Two participants mentioned having the aim to establish a routine to do their exercise but failed to follow it. The reasons given by them were to have lost the routines since working from home and that the previously chosen time for the exercise never seemed the right one on a daily basis.

> "I think, so I set up a reminder on my phone to say, like do the exercises now but what I found is that I just…I don't know how to say it, because the thing is they don't take long. So, it's not as if it was difficult to fit them in. I think that the thing was that whenever I got the reminder just seemed to be not a good time for certain reasons. So, I set it about six o'clock which I thought is after the work day, but before I would usually have dinner, but sometimes I was out of the house or I was so hungry that I couldn't do them." (RE group, younger than 35 years old, female, completer)

On the other hand, there was one participant who referred to intentionally not developing a routine with their exercise programme and that arrangement suited her perfectly.

> "I: And do you remember how many times a week more or less you did them or, like, was it something that you decided previously or just really flexible?
>
> P: No, I was really flexible, it just depended, again, what I was doing. I tried to do it over a few days, but there were probably a couple of days where it got to the end of the week and I thought, oh I haven't done them, I'd better do them. So I might've done them all in

the day – probably not all at the same time, I might've done some in the morning and some later on, but it varied.

I: Right, and what did you think about the flexibility to be able to distribute everything however you wanted…

P: That was good, it was perfect for me because if I've had to do it at the same time every day or every week, I probably wouldn't have managed to do it every week, so for me that was perfect." (RE group, over 50 years old, female, completer)

6) Priorities

Participants reported several competing priorities during the exercise programmes, like work, family, children, house chores, personal well-being, other people and having a dog. The ones that were mentioned the most by the participants were family, children, and work. In the age group younger than 35 years old children was the most mentioned priority. A participant in this group also mentioned having a dog as another priority. In the group between 35-50 years old children was also the most mentioned priority but also work was mentioned as the second one. On the other hand, the group of over 50 years old, children were not a priority at all, but work was the main one and family the second one. Some participants in this group mentioned other priorities like being the carer of their father, other people needs and their wellbeing.

"P: There might have been a couple of times I did them during the day but I think the majority of them were in the evening.

I: Why is that?

P: Because I've been working during the day, doing things for the family and it's a bit of my time in the evenings." (FLEX group, over 50 years old, female, non-completer).

"I chose the evenings because I have two small children, so it was easier for me to do them undisturbed once they were in their beds. And because of marking during the day, it was…I couldn't fit it in then. And once I get home from work, it's just a very busy time, dinner and bath time and bedtime. So, that was probably the time of day that I have that bit of time to myself that I can get my head into doing it." (RE group, between 35-50 years old, female, non-completer)

But I suppose that's indicative of our life for this past couple of months, with having the wee one. But yeah, if I did this all again, I

> would try and get into the habit of maybe doing it before tea, but time's not my own. So that meant that I then had to panic and try and shove it into the last minute, which is why if, I don't know if it says the times that I do it on my schedules that you guys have, but you'll see that they were often late at night and kind of in a panic. (RE group, younger than 35 years old, male, completer)

7) Disruptions

Overall, the most reported disruption during the exercise programmes was participants going on holiday. Some participants in the resistance group had to change slightly their set up and reported doing the exercises that required the exercise bands at home and the other ones during their holiday away. Another couple of participants from this group reported just taking the bands with them and not changing anything.

> "If I was travelling, not home, I'd just have some time to do them at [inaudible 10:53], I wouldn't necessarily do all six at the same time. I'd do some on some days then I would just do them wherever. You can do lunges and press anywhere." (RE group, 35-50 years old, female, non-completer).

> "I went on holiday during the three months, 12 weeks, and I could just take the bands with me because they don't weigh anything and they're not very big." (RE group, 35-50 years old, male, completer)

A participant from the flexibility group reported condensing her exercises over two days because of going on holiday. In addition, a couple of participants of this group had their programmes interrupted during holiday because of poor phone reception and not being able to access the webapp and exercise videos, or because their holiday got extended. On the contrary, one participant from this group did not see his programme interrupted because the exercises did not need a lot of space.

> "To be honest, with the stretching ones I could do it wherever, wherever I was so bedroom or in the living room. In fact we were on holiday for one of them so I didn't need a lot of space so it was fine." (FLEX group, between 35-50 years old, male, non-completer).

> "P: I had a couple of weeks away where we were away on holiday and it was difficult to do them at all there. So I tried to make sure I caught up the following week when I was back home.

I: And then you mentioned about holiday and you were not able to do them while on holiday. Why was that?

P: Just due to poor phone reception and no internet, so I couldn't use the app." (FLEX group, over 50 years old, male, completer)

8) Weekdays vs weekends:

Just one participant reported differences between weekdays and weekends. He reported to go away every weekend to his holiday flat and taking the bands with him to do the exercises but ended up cramming the exercises just before their deadline.

Appendix AT: Descriptive Summary Barriers and facilitators

1) Accountability

A few participants reported that being accountable and having someone checking up on them helped them to do the exercise.

> "So for me it was perfect because it gave me that, got to do this, and that was my only apprehension of doing it. So, again, it was good because it made me time accountable so I had to do it. Part of the reason that I chose to do it before work is I fall into very bad habits but work doesn't stop because you're at your house, there is no packing it away. So I was just concerned that if it was left until the evening when the kids are in school you get pulled into, have you done this, have you got that, whereas in the morning neither of them wake up so it's my time." (RE group, 35-50 years old, female, non-completer)

> "I think it was helpful that it was part of a structured study. If I'd just downloaded that app by myself I would have found it more difficult psychologically to make sure I did it every day I was supposed to do it. The fact that I was going to be tested on my results, and I guess you could see whether I'd done it properly or not, is a good motivator for doing it thoroughly." (Re group, between 35-50 years old, male, completer)

However, one participant reported that her own commitment to do the exercises helped her to do them.

> "I: And do you think there might be anything that could have helped you to do the exercises, like, more than one…?
>
> P: No, I don't think so. I mean, I made sure I did them every week (a) because I thought it was doing me good and (b) because I said I would do it. But no, I mean, I made sure I did fit it in while I was doing the programme." (RE group, over 50 years old, female, completer)

2) Competing Priorities

Overall participants reported different priorities that competed against the exercise, such as children and family, home, work and other things. This last one was the one most mentioned followed by children and family.

> "Well, my kids are up early so you're up early with the kids to get them ready for school, then I've normally got meetings on here and I don't move from here until 5:30, six o'clock and then halfway through you don't really think about, oh, I'll get up and do an exercise, because you're always constantly…it depends how busy you are but I'm pretty busy so, yes." (FLEX group, between 35-50 years old, male, non-completer)

> "I would, in theory, I would like to spread that out more, or do more exercises. But I…like, all day I've got the kids and then in the evening I'm tired and…so, it's hard for me to find the motivation to do it. Like, oh, I can just do it later kind of thing." (RE group, younger than 35 years old, female, completer)

3) Convenience

Several participants reported that the exercise was quick to do, it was easy to fit them, could do them anywhere and did not need to change clothes.

> "As I say, initially the curiosity motivated me and I did them when it was convenient and it was like, I could squeeze this in here. And my thinking was eventually, 'cause doing 15 arm raises or whatever doesn't take more than 30 seconds to do and I found I didn't have to transition into gym wear to do them." (RE group, over 50 years old, male, non-completer)

> "I: Is there anything that got in the way of doing the exercises?

> P: No, not for me because I could do them anywhere, even when we went up, we've got a cottage in Cumbria we're renovating and it's in a pretty awful state but even there, I could go up to one room which was the only carpeted room left and we've got Wi-Fi so I could easily do the exercises there and some of the leg exercises I could do outside using the house wall as a support. So I mean, you could do them in a hotel room, anywhere really, as long as there is enough floor space then you're not particularly tied to equipment or anything or any sort of huge space or whatever. As long as you've got a bit of privacy, a bit of floor space and you know what you're doing then they're pretty easy to do, pretty easy to fit in anywhere." (FLEX group, over 50 years old, female, completer)

On the other hand, one participant reported that the exercises were not very convenient because it was difficult to do them anywhere.

> "I'd say we were away a few times in our motorhome so that made it more difficult to do them. You can do some of them. So I'd try and put some of them in. But not so easy other days to do that. So if I was away for weeks at a time I'd have to think about…it's not as if

> we've been away weeks at a time. I'd have to think of different ways of doing that." (RE group, over 50 years old, female, completer).

Additionally, one participant did not find the web app convenient.

> "I found that it was brilliant to have an app because it was a focused place to look, but I found that once I'd got into a routine of what I wanted to do I would have found it easier to do them if I had a way of accessing, like the exercises altogether, because when I was going into the app, like there were quite a lot of stages to go through before you could add your exercises. So, like sometimes I would kind of be trying to get through and be like, yeah, okay" (RE group, younger than 35 years old, female, completer)

4) Exercise Intensity and Volume

One participant mentioned that due to the low intensity and the low volume of the exercise programme she did not set time aside for the exercises and that if it was more intense, she would have done more.

> "And in a strange way I think if it had been a longer period of time I might have scheduled it differently into my…I think I'd imagined that I was going to do this programme and that I would maybe be doing it first thing in the morning, or I'd be setting [audio breaks up 00:23:41] in there, you know, where my husband would have the kids and…whereas actually it ended up being like something I just like slotted in very quickly and easily. So, [voices overlap 00:23:49] but your question about what would have made it easier that doesn't really answer the question, sorry……I guess…so I may have had a preference for it being more intensive because I knew that I was motivated to take part and so had it been more intensive I think I would have done it and it would have had an even bigger benefit, if that makes sense?" (RE group, between 35-50 years old, female, completer)

Additionally, a participant found the exercise programme minimal and thought she was in the control group, therefore she aimed for the minimum required.

> "I don't know, really. Maybe I didn't feel that it was…maybe I felt…I think probably I felt I was in the control, in the control arm and that wouldn't actually affect my outcomes that much. So, yes, that's probably why I didn't go full on that." (FLEX group, over 50 years old, female, non-completer)

5) Identity

One participant reported that having a history of chronic illness made her feel inadequate to perform physical activity and that gets in the way of her doing exercise.

> "P: I think just because in my own history with physical activity. So, like I have a history of chronic illness and I haven't really found it easy to engage in a lot of physical activity because I was always unwell. So, I have a lot of, kind of, feelings of being inadequate and being not good at those kind of activities." (RE group, younger than 35 years old, female, completer)

One participant reported that knowing the benefits of the exercise that she was getting helped her do the exercises. On the contrary, another participant reported not liking exercise as a barrier to perform the exercises.

Quite a few participants reported forgetting to do the exercise as a barrier. On the other hand, one participant reported not finding the exercise difficult to remember.

> "Well, most of the time I would forget. And so, then I would remember like, oh, like it runs over on Wednesday, so I'd better do it now. Sometimes I would even do it…so, five at my time is when it would turn over, and so sometimes I would…normally, if I'm going to exercise, I exercise in the evening, so my kids are asleep. But, sometimes I'd be like, oh my gosh, I forgot until like today and it's going to expire in five hours so I'd better do it right now kind of thing." (RE group, younger than 35 years old, female, completer)

> "The latter stages of the time period when I was kind of squeezing it in because I'd forgotten about it, you know, it hadn't been at the front of my mind, kind of thing." (RE group, over 50 years old, male, non-completer)

6) Laziness and Tiredness

A couple of participants reported that tiredness got in their way of doing the exercises, due to being a new parent or suffering from fatigue. Only one reported laziness as a barrier.

> "Tiredness, actually, because I do suffer from fatigue, so sometimes it would be time to do the exercise and I would just think, oh, you

know. That didn't happen very often, but once or twice I would be too tired to do it or just would not want to do them but did it anyway. And then just needing to do things for other people if they needed things. It's hard to not put their needs aside and I'd have to do something for somebody else rather than have my exercise time. But generally, because I had it in my diary and I was doing it at a consistent time, that didn't happen very often." (FLEX group, over 50 years old, female, completer)

7) Life events

Some participants reported different life events that got in their way of performing the exercise, such as becoming a new parent, getting ill with a cold, holidays and an unexpected event with their children.

"So I did the stretching programme which was once a week although I think I probably missed a few sessions, two or three in the 12-week programme. The first one, I must say, I was at…I went on a working holiday up to Cumbria because my parents are changing their house into a holiday cottage and it's kind of all hands-on deck. So on that Tuesday when I…I think I was planning to do my exercises on the Tuesday but on the Tuesday morning my brother's farm caught on fire and it was right opposite my mum and dad's place so we just…we saw it. It was a big silage shed went up and his building next to it so it was just a…yes, everything went out the window that day. Then I ended up staying up there for two weeks because there was so much work to do so I wasn't great with it but I was still continuing my walking and whatnot." (FLEX group, over 50 years old, female, non-completer)

"P: So, there were a couple of weeks where I wasn't feeling very well when I did do them, just because I wasn't feeling good, or the night that I'd planned to do them, something else happened with the children, or something else happened at home, so those…there were a couple of weeks that I missed it, or missed doing it. Because I thought, I'll do it that night, and then something happened, and I thought, it's okay, I'll do it on the next set, and then something else happens and then I was out of time for that week.

I: Yes. What happened to you within those weeks that you weren't feeling well?

P: So, it was just more like a cold, or a bit rundown, it was nothing serious. But I didn't do those weeks." (RE group, between 35-50 years old, female, non-completer)

One participant reported going on holiday but not having his exercise programme interrupted.

> "I just did them anyway. As I said, I took my bands with me. I think I picked exercises such that I only needed to take a couple of bands, so it was a bit easier. And then I could do the ones that didn't need them at all, like press-ups. So, I just carried on while I was on holiday." (RE group, between 35-50 years old, male, completer)

8) Online exercise programme

A couple of participants reported having problems with the web app which got in their way of doing the exercise.

> "I: Is there anything else that got into the way of doing the exercises?
>
> P: Only the odd occasions where I couldn't get into the app to log.
>
> I: That is during the holiday?
>
> P: No, there were times when I couldn't log-in and I had to do a password reset, so that happened on three occasions on the 12 weeks. So M helped me the first time and suggested I do the web reset rather than the app, so I was able to do that myself when it happened again. But it did mean that if I went when I had 15 minutes available, if I went to try and do it and couldn't log-in, then I would have to miss that session." (FLEX group, over 50 years old, male completer)

9) Other people

Participants mentioned other people, family members, as a barrier to performing their exercises. Children were the most mentioned, followed by spouses.

> "I would, in theory, I would like to spread that out more, or do more exercises. But I…like, all day I've got the kids and then in the evening I'm tired and…so, it's hard for me to find the motivation to do it. Like, oh, I can just do it later kind of thing." (RE group, younger than 35 years old, female, completer)

> "Initially there were a couple of times when my husband disturbed me but I was in the middle of them and said…and he'd forgotten, he'd basically forgotten and after that, I let him or when my stepdaughters are here, I'd let them know, I'm going to do my exercises, I'll be ten minutes and I can't be disturbed, so that was it." (FLEX group, over 50 years old, female, completer)

10) Routine and Scheduling

A couple of participants mentioned wanting to set up a reminder in their calendar to do the exercise but did not do it. Another participant set up a reminder, but it was always the wrong time and that got in her way of doing the exercises.

> "Oh, do you know, I kept meaning to put in on my calendar on my phone, to remind me, but it didn't." (RE group, younger than 35 years old, male, completer)

> "I: Is there anything else that could have helped you to do the exercises that was not in the programme and maybe it would have contributed to you doing the exercises better or more?
>
> P: If I'd thought about it at the beginning I should have like set up a notification on my phone or something like that to remind me, I should have just done that, but I never bothered to. If there were an app it would be great to have the app, it would be like, hey, it's been eight days since you've done this one or something like that, that would be helpful. But again I could have just done it myself on my calendar, I just didn't for whatever reason." (RE group, between 35-50 years old, female, non-completer)

One participant reported not having dedicated a specific time for the exercise as a barrier.

> "As I say, initially the curiosity motivated me and I did them when it was convenient and it was like, I could squeeze this in here. And my thinking was eventually, 'cause doing 15 arm raises or whatever doesn't take more than 30 seconds to do and I found I didn't have to transition into gym wear to do them. So initially it was convenient, I just did them as and where the notion took me. But to maintain it I do realise I needed to sort of commit a particular timeslot or I needed to build it into my…I needed to set time aside for it." (RE group, over 50 years old, male, non-completer)

Other participants reported creating a routine which helped them to do their exercise, while one participant did not have one and that suited her.

> "I found that if I had some spare time, I would just do a few of the exercises and then I got myself into the routine in order to really programme me into thinking, right, it's this day, this sort of time, time for the ten minutes of exercises so there is no danger of forgetting." (FLEX group, over 50 years old, female, completer)

> "Part of the reason that I chose to do it before work is I fall into very bad habits but work doesn't stop because you're at your house, there is no packing it away. So I was just concerned that if it was left until the evening when the kids are in school you get pulled into, have you done this, have you got that, whereas in the morning neither of them wake up so it's my time. So that's why I found that habit so, again, it was good and, again, I'm going to keep with that as well." (RE group, between 35-50 years old, female, non-completer)

11) Weather

Only one participant reported that really hot weather made her not want to exercise.

> "And then, also there were a couple of weeks where it was like 90 degrees and 110 degrees, like, I didn't really want to do anything. Like, those days, I'm like no, I don't even want to move around kind of thing." (RE group, younger than 35 years old, female, completer)

12) Work

Some participants reported work as a barrier to performing exercise, mentioning that they were busy with work or that work got busier.

> "I: And then is there anything got into the way of you doing the exercises?
>
> P: Not really. No, not really. Sometimes I would just forget that [inaudible 20:09], work is super crazy right now, so just end of the week I'd realise that I had not done two a day so I had to do them all at once. So work pressures would be at times, because they were like easy to do and didn't require much set up it was pretty easy to work it in. Much easier than going to the gym or something like that, so I reckon I could do it at home." (RE group, between 35-50 years old, female, non-completer)

> "Well, my kids are up early so you're up early with the kids to get them ready for school, then I've normally got meetings on here and I don't move from here until 5:30, six o'clock and then halfway through you don't really think about, oh, I'll get up and do an exercise, because you're always constantly…it depends how busy you are but I'm pretty busy so, yes." (FLEX group, between 35-50 years old, male, non-completer)

Appendix AU: Descriptive Summary Motivations for the exercise

1) Part of a research study:

Overall almost every participant reported being part of a research study and being accountable because of it as their main motivator.

> "I knew that I wanted to do exercises but I just wasn't, and so knowing I was part of a study and that there was…I didn't know whether someone would be looking at those results, like so to not log in would be to not take part, so I felt the responsibility of being part of something. So, I was motivated…well generally because I wanted to do it but I think if I don't have that…someone recording it and then having to do like assessments later down the line that…I guess that was the thing that ensured I did it, almost like a personal trainer." (RE group, between 35-50 years old, female, completer)

> "I: Then what motivated you to do the exercises each week?
>
> P: Just being part of the programme.
>
> I: So being part of the programme, and what else?
>
> P: The same reason I go to the yoga classes, just to try and maintain that flexibility." (FLEX group, over 50 years old, male, completer)

> "I: So what motivated you to do the exercises each week?
>
> P: Panic that M would get me in trouble. I think by having a deadline, that pushes you, it gets you done. And because it was very, a university thing, it was a serious thing, so, I'll tell you what it was, it wasn't about me. Doing it for someone else, that was the drive that made you do it every week. Whereas, all of a sudden, this is week 13, and I'm saying, oh, I really need to get those exercises done again. So all of a sudden my mindset's changed.
>
> I: Okay. Anything else that motivated you?
>
> P: No, not for that. I'd say that's probably the main focus. Yes, I could say it was about me getting fitter, but actually that was just an extra for me. I was more excited about taking part, and doing something for someone, so, yeah." (RE group, younger than 50 years old, male, completer)

2) Progress or lack of it:

Overall, there were more people in the resistance group than in the flexibility group who were motivated to do the exercise because of wanting to see their progress and feeling their progress through the programme.

> "I think it probably did because I started to do more exercises rather than just the minimum. So I mean I could have just stuck to the minimum and said well that's all I have to do and that's it. But I felt I wanted to do more because you see that things are improving when you're going up the bands and you're doing more repetitions." (RE group, over 50 years old, female, completer)

> "Personally, I was just interested to see if I actually would get better, especially at the resistance exercises that I'd not really done before and…don't think I'm particularly strong, so just that bit of motivation to be able to see that you had progressed and that you were still progressing." (RE group, between 35-50 years old, female, non-completer)

> "I think primarily to obviously improve my own flexibility." (FLEX group, over 50 years old, female, completer)

One participant in the flexibility group reported to have gotten bored of the exercises during the programme.

> "I: Okay, I know what you mean. What happened at the end of the programme that you found it really hard to keep up?
>
> P: It was just my boredom, basically, that was the issue, the only issue. That is why I preferred whatever I am doing right now because it is so diverse. It changes, the first day is not the same as the last.
>
> I: Right, perfect. What motivated you in the beginning then? You have mentioned that at the end of it, your motivation was more to complete the programme itself because you joined the study. But what was motivating you before?
>
> P: I think at the very beginning I was quite excited to do something else and just taking it in a light manner and do some things. It was fun enough at the very beginning. Finally, I am moving my body basically. (FLEX group, younger than 28 years old, female, completer)

Appendix AV: Descriptive Summary Other people

Several people were mentioned by the participants. These include family, partners, their children friends, friends, neighbours, people at work, flatmates and the Reflex Study researchers. In the family category, participants mentioned their spouses, children, parents, siblings, nieces and in-laws.

1) **People the participants told about their participation in the study**

Almost all the participants mentioned having told their family and friends about them participating in the study and doing an exercise programme. In general, everyone's reaction was positive and showed interest in the their participation and in the topic.

> "I told friends. Just my…all my friends, people that I talk to about what's going on in my life. I said, I'm doing this thing. And then people were quite interested. My sister." (RE group, between 35-50 years old, female, completer)

> "Well, my husband I told and he was interested in it. Well, he wanted to know about some of the exercises so I told him about them. And then I told a couple of friends. One of my friends actually wanted to do it but she didn't and I can't remember why. And the other friend I told about it was asking about it as well. But, no, they were interested in it but they don't want to do it." (RE group, over 50 years old, female completer)

> "Just to obviously, you know, my daughters and my husband, that I was helping out with a study, yeah… They thought it was quite interesting, you know, how doing certain things and then you take your measurements to see if it was beneficial to people." (FLEX group, between 35-50 years old, female, non-completer)

> "Well my mother's a retired PE teacher so she said – about time – but that's just my mother for you. They were all very positive about that kind of…that's a good idea, you know, let us know how it goes kind of thing, how does it feel. So there was that kind of curiosity about…they were curious about why I'd agreed to do it then they were curious about how it was progressing." (RE group, over 50 years old, male, non-completer)

One participant did not tell anyone about his participation in the study, because he did not think about it.

"I: Did you tell other people about the programme?

P: No.

I: No one?

P: No.

I: Any why is that, why didn't you share with anyone?

P: Just didn't think about it. I mean, with COVID I haven't really been in contact with lots of people to discuss things and so it's not really on the radar." (FLEX group, over 50 years old, male, non-completer)

One participant reported that friends from his son ad her youngest son were interested in the research from a degree point of view.

"...two of M's friends are going to go, or hoping to go, on and do sports science so they were particularly interested, they want to get to Loughborough. So they were interested in it just from life after a degree, from that point of view. And my son as well, my youngest, is going to go in that direction." (RE group, between 35-50 years old, female, non-completer)

2) People that engaged with the participants while exercising

Several participants had their partners and spouses interacting with them while doing the exercises and trying some of the exercises together. Some of them had them helping them fill the results in the web app or giving them feedback on how to do the exercise properly.

"So I did some kind of…not like that much, but some of the exercises I would do with my partner who's kind of…he does some similar things anyway. So, say we would kind of have a competition to do the plank and see who could do the plank for longer; kind of things like that. So, he's been supportive of me doing those kind of things." (RE group, younger than 35 years old, female, completer)

"My partner who said, great, an opportunity for you to do. It was like a discussion point as well because he is more into fitness. Sometimes when he was coming around, I would be like, hey, look at this exercise, look how I can do it or this one how does this one feel and things like that." (FLEX group, younger than 35 years old, female, completer)

> "'Cause quite often my wife would sit with the app, while I was doing it, and she would fill in the details, while I was breathing." (RE group, younger than 35 years old, male, completer)

Another participant reported that his wife reminded him of doing the exercises during the programme.

> "My wife kind of said, have you done your exercise this week? So she was the nag, sorry, she was the reminder. But again, she was curious so sometimes she would watch me do the exercises and try some of them herself out of curiosity. I'll let you try that, sort of thing." (RE group, over 50 years old, male, non-completer)

One participant had her children wanting to join in with her while exercising and reported that they enjoyed playing with the exercise bands.

> P: "Occasionally, if I was doing them, my children wanted to join in.
>
> I: And how did it go with the bands, how…?
>
> P: I quite liked them, they were…my children really enjoyed seeing them as well." (RE group, between 35-50 years old, female, non-completer)

3) People affecting participants' exercise sessions

A few participants reported having their exercise programme affected by their husbands. A couple of them were because their husbands were away during the night or arrived later than usual which made them have to take care of the children on their own, having to push their exercise session. Another participant reported being interrupted once during her exercise session.

> "Initially there were a couple of times when my husband disturbed me but I was in the middle of them and said…and he'd forgotten, he'd basically forgotten and after that, I let him or when my stepdaughters are here, I'd let them know, I'm going to do my exercises, I'll be ten minutes and I can't be disturbed, so that was it." (FLEX group, over 50 years old, female, completer)

In addition, some participants reported being affected by their children. One mentioned that something happened with her children therefore she could not

exercise. The other participant mentioned doing his exercises in a rush to be able to put the baby to bed after that.

> "I: Anything else you felt after doing the exercises?
>
> P: It probably would have helped, if I wasn't then in a rush to get the little one to bed." (RE group, younger than 35 years old, male, completer)

Finally, another participant mentioned forgetting to do her exercises when she was visiting her parents.

4) Other

A couple of participants mentioned the researcher during their interview. They mentioned that they were nice and relaxed and that they helped them to properly perform the exercise tests.

> "Just that I felt a lot less nervous in the kind of, different follow-up measures that we did, because you'd been so nice and relaxed. So I kind of just felt like, oh this is fine. They're not testing me and they're not going to be annoyed with me if I can't do very much." (RE group, younger than 35 years old, female, completer)

One participant mentioned that her husband helped with the camera during the exercise measurement sessions.

Finally, another participant reported that being able to exercise again has made her feel more like herself again because she had two babies in the last couple of years.

> "Yeah, I feel a little better about myself. Yeah, I've had two babies in the last couple of years and so I've been feeling a little bit just like I…I don't know, exercising made me feel a little bit more like my old self, feel a little better about myself, so I do think that it's been helpful to my…I wasn't like depressed or anything before, but I do think I feel a little better about myself right now than I did at the beginning." (RE group, between 35-50 years old, female, non-completer)

Appendix AW: Descriptive Summary Impact of the programme

1) **Mental and Emotional changes or the lack of them:**

a. Flexibility programme

Half of the flexibility group reported not experiencing any mental or emotional changes, including positive or negative. Only two participants reported changes, such as feeling better about themselves and having a big mental shift towards change and getting fitter.

> "A lot better, a lot better because I think when something is brought to your attention like that, obviously we're all getting older, I'm getting older but you're trying to keep as active as you can and as fit as you can and I think when you are unable to sort of do what would have been a straightforward manoeuvre for me ten years ago and you can't and then you see yourself being able to do it, I think it makes you feel a lot better. I felt a lot better about myself and it gives you a lot of incentive, as far as I'm concerned, I'm going to continue with this programme even beyond the obviously our three months because I could see the benefit to me." (FLEX group, over 50 years old, female, completer)

> "I think it's quite a big one actually. Because I'm 56 now and I kind of got myself into the mindset that, oh, you're getting old, physically you're going to be getting worse now, things are not going to improve, they're just going to get worse. And I think doing this programme has been a big part of changing that for me, thinking, well, actually, no, I can get more physically fit. There are things I can do and I can change things. So that's helped a lot, that's quite a big psychological shift actually." (FLEX group, over 50 years old, female, completer)

b. Resistance programme

Almost half of the resistance group reported not experiencing any mental or emotional changes due to the exercise programme. Additionally, a few participants did report positive changes such as feeling more confident, feeling better about themselves or feeling more like themselves, having a better self-perception, and feeling positive towards change.

> "Now I'm sure for a lot of people, yes, the exercises have changed them, maybe mentally, but it didn't do anything for me, 'cause I was

so strong mentally anyway. I'm very positive, very happy, but physically more tired, because I'm not getting the same amount of sleep." (RE group, younger than 35 years old, male, completer)

"I feel a little better about myself. Yeah, I've had two babies in the last couple of years and so I've been feeling a little bit just like I…I don't know, exercising made me feel a little bit more like my old self, feel a little better about myself, so I do think that it's been helpful to my…I wasn't like depressed or anything before, but I do think I feel a little better about myself right now than I did at the beginning." (RE group, between 35-50 years old, female, non-completer)

2) Physical Changes or the lack of them:

a. Flexibility programme

Over half of the flexibility group reported an improvement in their flexibility, while only a couple of participants reported not experiencing any flexibility improvement.

"I've seen the benefit to me. I guess it's my ignorance in a sense that if you see some improvement you want to do something even more and you've got to be careful not to do it too much but I think if you could do them say a couple of times a week, I might see even better improvements in my personal flexibility." (FLEX group, over 50 years old, female, completer)

"I've certainly…think I've noticed some improvement in my upper body flexibility." (FLEX group, over50 years old, male, completer)

Additionally, a few participants reported that the programme helped them feel less pain in their knees, back and shoulder. On the other hand, a couple of participants reported having pain in their back and knee due to the exercise programme.

"I: Any physical changes?

P: I think my knees improved but I don't know how much that could be attributed to the programme itself or other things that I was doing, going out for walks a bit more. No, no, I finished this programme and then I started therapy so they didn't intersect.

I: How did your knees improve?

P: I spend a lot of time sitting at one point it gets a bit painful. Doing even a little bit more exercise, I wouldn't get to that pain as often." (FLEX group, younger than 35 years old, female, completer)

"One of the exercises did give me some soreness in the back. The exercise that I mentioned with lying on the front and lifting your shoulders up and your arms and trying to bend at the pelvis, that one did leave me with back pain." (FLEX group, over 50 years old, male, completer)

Only one person from this group reported having lost weight during the programme.

b. Resistance programme

Half of the resistance exercise group reported improving their strength and performance in the exercises as a result of the programme, while only one participant reported not experiencing any strength improvement and a couple reported not noticing any changes of strength in their daily life.

"I mean, I think that realistically I wasn't doing the exercises frequently enough to notice big changes because, although it seemed like a dramatic thing for me to do the exercises once or twice a week for 12 weeks. I noticed, kind of, a little bit of difference in how I was feeling kind of core wise I felt stronger and my legs felt slightly stronger and I noticed that the main thing was the improvements in my performance on the exercises." (RE group, younger than 35 years old, female, completer)

"I've noticed…I think my legs are stronger. I do cycle a little and I think I've noticed that going up some hills I'm not…it's easier. My legs have definitely improved. My upper body strength has definitely improved, because lifting things, I can that a lot easier. I even see from doing push-ups that I can do it longer, for more repetitions than before. So there's definitely a major difference." (RE group, over 50 years old, female, completer)

"I: How you thought the programme was improving or was changing your fitness, did you notice any changes as a result of the programme?

P: No, I don't think so. I mean, when I was good…I got up higher on the bands on some of them, but I didn't specifically notice anything in my general life, no." (RE group, over 50 years old, female, completer)

Additionally, one participant reported an improvement in flexibility and a couple reported no improvements in flexibility or balance. Finally, A few participants mentioned weight changes, such as weight gain and loss, while only one reported no changes in weight.

> "I: Did you notice any changes as a result of the programme by the end of it?
>
> P: Loads, I had lost just over…I have plenty to lose but I've lost just over a stone in weight through doing them and my mother is convinced my bottom has gone square and flat although my stomach still looks like I'm ten months pregnant. But even my mum commented my back's gone flatter so, yeah, there is a difference." (RE group, between 35-50 years old, female, non-completer)
>
> "I feel stronger, I feel like I've got fatter, but I think that's 'cause we're eating more, 'cause we're in the house more. That's nothing to do with the exercises, 'cause the exercises were making me physically stronger and fitter, but didn't necessarily work on the weight, does that make sense?" (RE group, younger than 35 years old, male, completer)

3) Ripple Effect:

    a. Flexibility programme

Some participants from the flexibility group reported changes in their lives due to being part of the programme, such as doing more walking and thinking about their diet, water intake, and sleep. Also, some participants have reported to be doing other types of exercise, such as yoga, exercise with increasing levels and band exercises.

> "I: In general, any positive or negative changes throughout the study that you can remember?
>
> P: Yes. It was definitely…it enabled me to focus on me a lot more, because I was doing something for me, so…which then spilled over into, okay, right, I can go for a walk. So, there's more kind of add on stuff going on. I could exercise, go for a walk, or I could think about, do I really need to eat that, am I drinking enough water. So, there's all that kind of roll-on benefits." (FLEX group, between 35-50 years old, female, completer)

"I: So did you continue? So you ended two weeks ago. Did you continue doing the exercises after that programme ended?

P: No, I haven't but I have been able to do my yoga classes.

I: And why did you stop?

P: Because I was…one of the reasons I joined the programme, I suppose, was at the time I wasn't a member of a yoga class. I prefer to go to classes rather than exercise on my own, I just find it easier to hold that discipline if I'm committed to go to a class." (Flex group, over 50 years old, male, completer)

Additionally, some participants have mentioned that they want to do other types of exercise and that they are willing to continue the flexibility exercise programme, while one participant reported to have continued the programme.

"I: Did you continue doing the exercises, you just finished yesterday, so will you continue, do you think you will continue?

P: Yes, I will.

I: And why is that, why would you want to continue?

P: Because, as I said, the flexibility, the strength I've felt, like I've got in my back. I'm very conscious of that because, as I said, I've hurt my back in the past. It's not pleasant, and so anything to, sort of, relieve that from happening again, and just ability to, sort of, to move around quite happily and climb into spaces where before I would get quite stiff trying to do that.

I: Any other reason you would want to continue?

P: No, that's primarily it." (FLEX group, over 50 years old, male, non-completer)

b. Resistance programme

Similarly to the flexibility programme, one participant reported that because of being in the programme they have started to think about having a healthy lifestyle. Other participants have mentioned to be doing other types of exercise, like cycling, aquafit, climbing and more resistance exercise.

"I: So you feel there are some physical changes, so you feel a bit fitter?

P: I do, I think so. I feel like I've been feeling a little better too, but I'm not sure if it's all the exercise. But when you get like the healthy mindset of exercising, but I feel like I'm usually eating better falls along with that really, as well as exercising I probably shouldn't eat like Cheetos right afterwards. So I guess I feel a little fitter, a little bit stronger maybe.

I: You've mentioned something about diet, so that you felt that if you're exercising then you should also be eating better.

P: Yeah, I do. I feel like the psychology works that way for me. If I'm just like in a gross place where I just want to eat and be lazy, then that's just how I am, whereas if I'm like actually putting energy into exercising then I'm usually a little bit more conscious of what I'm eating, put a little more effort into eating well. So they do go hand in hand for me, I feel.

I: That's great. So has your diet changed in a way over the 12 weeks?

P: Yeah, I think I've been making an effort to eat a little better, I think given this study opportunity is a chance to just overall improve my health. So since I'm exercising, certainly not perfect still, but I'm trying to eat more regular meals, I'm trying not to eat after seven o'clock, things like that. So trying to decrease my alcohol intake." (RE group, between 35-50 years old, female, non-completer)

Finally, some participants have reported wanting to continue the exercise programme or already have continued it. Only one participant mentioned wanting to do other types of exercise.

"I think I'll continue with one set. I'll probably do one set for a few more months and see what happens. Because I noticed that the number of reps I could do with a specific band or exercise was levelling off quite a lot. Like with press-ups for example, I started off being able to do about ten I think, and now it's 16 or 17; but it's never any more than 17. So, I don't think I'm doing enough exercise to continue improving, but I think I've done enough to improve a bit." (RE group, between 35-50 years old, male, completer)

"I have continued with them, and I hope to still do that, because I think I can still make some improvements or just maintain what I have. I find it difficult…I mean I do cycle; I find it difficult for upper body strength to do exercises that help. But now I've got the bands I think they do help that, without having to go to a gym and do weights and things like that." (RE group, over 50 years old, female, completer)

Appendix AX: Descriptive Summary Suggestions for the programme

1) **Volume of exercise progression and programme suggestions:**

Several participants from both exercise groups suggested increasing the intensity and volume of the exercise programmes, for example doing all six muscle group exercises on one day and repeating that several times during the week. On the other hand, one participant suggested a longer exercise programme with a circuit format including different exercises and more sets of each to be able to keep doing the exercises beyond the 12 weeks, or even mixing both exercise programmes together.

> "so I may have had a preference for it being more intensive because I knew that I was motivated to take part and so had it been more intensive I think I would have done it and it would have had an even bigger benefit, if that makes sense?" (RE group, between 35-50 years old, female, completer)

> "I think there was lots of choice, but I only did it for 12 weeks. So, if I had now done that for 20 weeks, I think now I would be at the stage of saying, I've reached all those, now what? Now, that's really hard, because it then is, you know, more things would have to be produced. But then I suppose that might be to do with doing a mix, so you have to do five press ups and then ten squats and then five press ups and ten squats, that's when it turns into more of a synergy type circuit, it would be more like a circuit. So again, the things would have to be in place for that to be recorded, so you did Circuit One, which was 5, 10, 5, 10 something like that. So the programme is great, but it was beautifully done for 12 weeks, anybody that could tack through that whole thing and finish everything in 12 weeks, shouldn't be on the programme, 'cause they were already too fit." (RE group, younger than 35 years old, male, completer)

Other participants proposed to have more leg exercises, core exercises and chest exercises. In addition, Some participants in the flexibility group suggested having more variety of exercises and more progression in difficulty in the exercises for that programme.

> "In a sense, I think the programme, for the benefit, I think increasing the quantity of the exercises as opposed to what I was currently doing. Obviously the programme is only to do it once a week but I think doing it two or three times given how short it takes, that, sort of, I would say, you know, the benefits of that. And because you were

> doing it more frequently I think it's less likely you'd be that worried if you'd miss a session. Obviously it you're doing it weekly it's more of an impact if you miss a session." (FLEX group, over 50 years old, male, non-completer)

One participant from the resistance exercise programme proposed to have a higher amount of repetitions before moving to the following level.

Finally, a couple of participants proposed to have a more structured schedule with not much freedom, due to being a structured person and like planning things to achieve an objective.

> "For me personally, if I could enable…maybe if you had the option to set up a more structured schedule. But I'm quite a structured person, so I like…if I want to achieve something, I tend to map it out. But because I was given the flexibility to do as I please, I just went all over the place. Whereas, if I was given some recognition kind of system that I could say, right, I'm going to do it every second day, and set up something to say, right, you need to do this every second day." (FLEX group, between 35-50 years old, female, completer)

2) **Webbapp suggestions:**

Several participants suggested having a mobile phone application. Some of them suggested this because it would not need constant sign-in.

> "I think it would have been easier…that was another thing, probably, I tried to keep it open, the tab open on my iPad but then it would fall off or [inaudible 05:04] and then I had to go searching back through the emails to get the link again. So it would probably have been easier if it had been an app that I actually had downloaded on to the iPad, that I didn't have to sign in again and again." (FLEX group, over 50 years old, female, non-completer)

Other participants suggested some changes to the webapp interface, such as an easier and more straightforward way of recording the exercise repetitions, to have the option of selecting the exercise higher, to have an easier way to watch the exercise videos and choosing a specific level, to keep the chosen exercises from one week to the following, to be able to see all exercise history charts on one page and to see all history of a particular exercise with all the levels on one chart with an indicator of the level change.

> "I think maybe just… I found that it was brilliant to have an app because it was a focused place to look, but I found that once I'd got into a routine of what I wanted to do I would have found it easier to do them if I had a way of accessing, like the exercises altogether, because when I was going into the app, like there were quite a lot of stages to go through before you could add your exercises." (RE group, younger than 35 years old, female, completer)

> "I: So what did you think about the exercise diary?
>
> P: So it had its flow chart which was good, it meant I could see where I was progressing. I would have liked, if I could have seen on one page, all of my flow charts, so I could see a line of all my press ups, all this, because I think that would have helped me choose the next week. I might have said, well, I've done press ups for the last three weeks, I'll now do planks.
>
> I: Yes.
>
> P: So, that would have helped, definitely.
>
> I: Okay, anything else that would have helped?
>
> P: I suppose just the layout. The history was fine, but you had to go into, into, into. And I think the other problem is, when you went up a level, there was nothing to show your progression. So the flow chart didn't say, band one, band three, so it didn't change colour, it was just like, that's band one, a completely separate flow chart for band two. So I think that would be really nice, if I could see the progression from my very, very first week, not just how many weeks I've done band three on row, does that make sense?" (RE group, younger than 35 years old, male, completer)

Half of the participants interviewed suggested having a reminder inbuilt in the application, to remind people to do the exercise. In addition, other participants suggested having a reminder to select the exercise during the week, a reminder to fill in the repetitions and to have a reminder that goes off until the person does the exercise even if the week finishes.

> "What it could have done is and I missed quite a few because sometimes you forget, it could do with a reminder, I think, to reminder you. I don't know if they could build in an alarm to remind you." (FLEX group, between 35-50 years old, male, non-completer)

> "If I'd thought about it at the beginning I should have like set up a notification on my phone or something like that to remind me, I should have just done that, but I never bothered to. If there were an app it would be great to have the app, it would be like, hey, it's been eight days since you've done this one or something like that, that

> would be helpful. But again I could have just done it myself on my calendar, I just didn't for whatever reason." (RE group, between 35-50 years old, female, non-completer)

Some participants proposed a scheduling feature for the app with the person's diary and to have a reminder adjacent to it.

A couple of participants from the flexibility group suggested having a timer inbuilt into the app to help them do the stretches or to have videos with the complete exercises for people to be able to do the exercise alongside the video. playing. On the other hand, a participant of the resistance group suggested having a voice recognition feature, in which the person counts aloud the number of repetitions and the app records the highest number.

> "It would have been useful to have a timer built into the app. I just purchased a little separate timer to make sure I was doing the exercises for the right amount of time." (FLEX group, over 50 years old, male, completer)

> "I think I would have liked it to be kind of like the apps that are available now so that when the video goes you go with it." (FLEX group, younger than 35 years old, female, completer)

Another suggestion was to include an anonymous ranking of people of different groups depending on age and fitness level, to motivate participants to improve within their group.

> "So if the app allowed it, if enough people were to take part, then you get put into a category that says, congratulations you're not 32 in the ranking of people your age, people your ability, that sort of thing. I think that would be really good fun, because then you're not just pushing yourself for the sake of it. And that might help them." (RE group, younger than 35 years old, male, completer)

Other suggestions were to add a space to ask people how they feel about their exercises during the programme and to have an encouragement message on the app after increasing the number of repetitions and progressing levels.

3) **Supervision suggestions:**

Some participants suggested having a first exercise session with the researcher to teach exercises and show the webapp and give time to ask questions and check-in sessions during the programme.

In addition, it was suggested to have group exercise sessions with other participants, such as a video call drop-in session.

4) **Video suggestions:**

Participants suggested having in the videos a more detailed explanation of the exercises and how they should feel.

A participant in the flexibility programme proposed to communicate in the videos that it is okay for older and unfit people to not be able to stretch as far as the person in the video.

> "Maybe one suggestion, which is when M demonstrates the exercises – she's obviously very flexible and does them really well – it might be for those of us who are older and not so flexible nice to have a kind of if you can't quite do this bit, as long as you're doing that bit that's fine. Don't worry if you can't do it as I'm doing it. So just a bit of encouragement for those of us who are looking at how she's doing the exercises and thinking I can't get even near that. Just to sort of know that the point is not to get to exactly where she is in her demonstration but to be doing a particular part of the stretch. So that might be helpful. But other than that, no, it was all very easy to follow and very well explained and straightforward." (FLEX group, over 50 years old, female, completer)

Finally, it was suggested that the people in the videos should smile and look like they are having a good time so that people will be motivated.

> "I: Aha. Any other suggestions?
>
> P: Yeah, if they're doing more training videos, should smile.
>
> I: Yeah.
>
> P: They looked miserable, so they need to look like they're really having a great time in order to get people to interact with it. Sorry, that might be a daft comment, but if they're looking like they're

enjoying demoing it, then, oh, that was good, yeah, I want to do that one. Yeah, it might be pretty good." (RE group, younger than 35 years old, male, completer)

Appendix AY: Descriptive Summary Selling the programme

1) **Flexibility programme:**

a. Convenience:

Some participants reported that the flexibility programme was accessible, quick to do, you can do the exercises in your own time and pace, fit them easily in your day-to-day life, and required low commitment.

> "I think I'd be saying, and the exercises are really straightforward and you can fit them in very easily into your week." (FLEX group, over 50 years old, female, completer)

b. Exercises:

It was reported that the programme had straightforward gentle exercises that you could learn.

> "… you're also benefiting from learning different techniques to be able to stretch and to improve your flexibility". (FLEX group, between 35-50 years old, female, completer)

c. Effects and impact:

Some participants commented they would recommend this programme because it is good for your physical and mental health. Also, because people would be able to feel the effect on their muscles, they will notice the change and it increases mobility and flexibility.

> "Well, obviously I did the stretching, so I was thinking if I said increase mobility and strengthening your ligaments as opposed to your muscles, so it will make it easier, if you like, for movement. Obviously, my age group being 55, it's more noticeable on that side than it would probably be for a young person. Probably would have difficulty getting my children, if you like, to do it, probably try and, sort of, make it more of a fun thing than anything." (FLEX group, over 50 years old, male, non-completer)

d. Other:

Some participants would recommend this exercise programme as a first step in doing exercise and becoming physically active, and for people that sit a lot.

> "I think once you start, you know, start it because you never know where it might lead you. I've been a bit lazy but someone else might do it and it'll be a starting point for doing more, finding more things to do, I suppose." (FLEX group, over 50 years old, female, completer)

> "Yeah, I think it would be just some light exercises that would just get your body moving. If you were at the very beginning of doing some sports then it is a great way to get into doing something." (FLEX group, younger than 35 years old, female, completer)

2) Resistance programme:

a. Convenience:

Some participants reported that the programme requires minimal equipment (only resistance bands), easy, simple, it doesn't take much time to do the exercises, it does not require a routine, it is easy to fit in schedule, good for people with no time and that do not have resources to pay a gym membership.

> "I suppose I would go back to the point I made earlier which is that kind of it doesn't require – other than the resistance bands – it doesn't require you to wear special clothes… And it's also that kind of…the equipment is basically four or five large rubber bands so there isn't a treadmill taking up a large space in the corner of your room, there isn't a spin bike. It doesn't impact on your environment particularly much, but you still get interesting exercises out of it that, as I say, you can feel the – I don't want to say the burn – but you can feel the effect they have on you when you're doing this sort of thing. So as I say, it's convenient, it's easy and it's simple." (RE group, over 50 years old, male, non-completer)

"Now for me part of the advantage was there wasn't a routine, you could do it whenever you wanted to, to make sure you fitted it in your life and yeah, it was good." (RE group, over 50 years old, female, completer)

> "I would describe it as a great programme for somebody that thinks they're fit, or wants to get fit, but claims they have no time to do it, and that you can do it at home with nothing. Obviously, you've got to have the resistance bands, but it's a very little thing to get, just to

> start it. Yeah, that's what I would say. People that think they're fit or want to get fit, but say that they don't have the time or the money to join the gym, I would say you've got to try this." (RE group, younger than 35 years old, male, completer)

b. Exercises:

Participants commented as a selling point for the programme is that the exercises target all major muscle groups and there is a wide variety of exercises to choose from.

> "…it's a really great programme and the app or whatever …it's really clear of what exercises you are supposed to be doing. And, you know, there's a bunch of choices on which ones you can choose." (RE group, younger than 35 years old, female, completer)

c. Effects and impact:

Some participants commented they would recommend this programme because it is good for your physical and mental health. Also, because people would be able to feel the effect on their muscles, they will notice the change, people got stronger.

> "I'd probably mention that I have got stronger, because I've done it for 12 weeks, so it does work." (RE group, between 35-50 years old, male, completer).

d. Other:

Participants would recommend the programme to someone because it was good, clear, well organised, it had a useful webapp and it was good to be accountable.

> "I would explain the set up and say that for me personally it was really good to be accountable to a study and it was very well organised.." (RE group, between 35-50 years old, female, completer)

> "I would tell them that, you know, it's a really great programme and the app or whatever, I don't know, whatever you call it, it's really useful and it's really clear of what exercises you are supposed to be doing. And, you know, there's a bunch of choices on which ones you can choose." (RE group, younger than 35 years old, female, completer)

Finally, a couple of participants reported as a reason that is was motivating and encouraging to see the progress in the webapp.

> "And that it's really, like, kind of encouraging because you can see your past exercises and [inaudible - 0:45:45] time. And that it's nice to like kind of have, you know, a time that you're supposed to do it by because it can encourage you like, okay, well I really need to get that done or whatever. As opposed to just kind of like blowing it off and being like, oh, whatever, you know, I'll do it next week or whatever. It kind of sets you up for making it a habit." (RE group, younger than 35 years old, female, completer)

Appendix AZ: PhD Training Courses

1) Postgraduate Research Student Induction Course
2) Excel: Introduction Graphs and Charts
3) Word: Creating a Dissertation or Thesis
4) Establishing a Writing Practice (SCI)
5) Successful Writing
6) Introduction to Good Clinical Practice (GCP) eLearning
7) Research Data Management Sciences Course
8) Research Governance Training
9) Research Integrity- Sciences
10) Intellectual Property & Economic Impact Opportunities for your Research
11) Ethical Issues and Procedures for Non-clinical Research Involving Human Subjects, Zoom Link for pre-recorded session.
12) Advanced Medical Statistics
13) Statistics - Diagnostic Testing and Comparing Methods of Measurement
14) Statistics - Linear Regression
15) Applied Statistics for Postgraduate Students
16) Medical Statistics II for Non Statisticians
17) Teaching with Technology
18) Introduction to Writing your Thesis

19) Preparing for the Viva

20) NHS Venepuncture course

References

ABOODARDA, S. J., HAMID, M. S. A., CHE MUHAMED, A. M., IBRAHIM, F. & THOMPSON, M. 2013. Resultant muscle torque and electromyographic activity during high intensity elastic resistance and free weight exercises. *European Journal of Sport Science,* 13**,** 155-163.

ABOODARDA, S. J., SHARIFF, M. A. H., MUHAMED, A. M. C., IBRAHIM, F. & YUSOF, A. 2011. Electromyographic activity and applied load during high intensity elastic resistance and nautilus machine exercises. *Journal of Human Kinetics,* 30**,** 5-12.

ACHAMRAH, N., COLANGE, G., DELAY, J., RIMBERT, A., FOLOPE, V., PETIT, A., GRIGIONI, S., DECHELOTTE, P. & COEFFIER, M. 2018. Comparison of body composition assessment by DXA and BIA according to the body mass index: A retrospective study on 3655 measures. *PLoS One,* 13**,** e0200465.

ACSM 2016. *ACSM's Guidelines for Exercise Testing and Prescrption*, Wolters Kluwer.

ACSM 2018. *ACSM's Health-Related Physical fitness Assessment Manual*, Philadelphia, Wolters Kluwer.

AINSWORTH, B. E., HASKELL, W. L., HERRMANN, S. D., MECKES, N., BASSETT, D. R., TUDOR-LOCKE, C., GREER, J. L., VEZINA, J., WHITT-GLOVER, M. C. & LEON, A. S. 2011. 2011 compendium of physical activities: A second update of codes and MET values. *Medicine and Science in Sports and Exercise,* 43**,** 1575-1581.

AL OZAIRI, E., ALSAEED, D., AL ROUDHAN, D., JALALI, M., MASHANKAR, A., TALIPING, D., ABDULLA, A., GILL, J. M. R., SATTAR, N., WELSH, P. & GRAY, S. R. 2023. The effect of home – based resistance exercise training in people with type 2 diabetes: A randomized controlled trial. *Diabetes/Metabolism Research and Reviews,* 39**,** 1-10.

ANDERSEN, C. H., MORTENSEN, O. S., POULSEN, O. M., ZEBIS, M. K., ANDERSEN, L. L. & BJORNLUND, I. B. T. 2010. Muscle Activation and Perceived Loading During Rehabilitation Exercises: Comparison of Dumbbells and Elastic Resistance. *Physical Therapy,* 90**,** 538-549.

ANDERSON, A. M. 2005. *The Community Builder's Approach to Theory of Change A PRACTICAL GUIDE TO THEORY DEVELOPMENT* [Online]. The Aspen Institute Roundtable on Community Change. Available: www.theoryofchange.org [Accessed 27/032025 2025].

ARNTZ, F., MARKOV, A., BEHM, D. G., BEHRENS, M., NEGRA, Y., NAKAMURA, M., MORAN, J. & CHAABENE, H. 2023. Chronic Effects of Static Stretching Exercises on Muscle Strength and Power in Healthy Individuals Across the Lifespan: A Systematic Review with Multi-level Meta-analysis. *Sports Medicine,* 53**,** 723-745.

ASHTON, R. E., TEW, G. A., ANING, J. J., GILBERT, S. E., LEWIS, L. & SAXTON, J. M. 2020. Effects of short-term, medium-term and long-term resistance exercise training on cardiometabolic health outcomes in adults: Systematic review with meta-analysis. *British Journal of Sports Medicine,* 54**,** 341-348.

BACCHI, E., NEGRI, C., ZANOLIN, M. E., MILANESE, C., FACCIOLI, N., TROMBETTA, M., ZOPPINI, G., CEVESE, A., BONADONNA, R. C., SCHENA, F., BONORA, E., LANZA, M. & MOGHETTI, P. 2012. Metabolic Effects of Aerobic Training and Resistance Training in Type 2 Diabetic Subjects: A randomized controlled trial (the RAED2 study). *Diabetes Care,* 35**,** 676-682.

BENNIE, J. A., SHAKESPEAR-DRUERY, J. & DE COCKER, K. 2020. Muscle-strengthening Exercise Epidemiology: a New Frontier in Chronic Disease Prevention. *Sports Medicine - Open,* 6.

BIRTWISTLE, S., DEAKIN, E., WHITFORD, R., HINCHLIFFE, S., DANIELS-CREASEY, A. & RULE, S. 2021. The Scottish health survey 2021: A national statistics publication of Scotland.

BLAIR, S. N., LAMONTE, M. J. & NICHAMAN, M. Z. 2004. The evolution of physical activity recommendations: how much is enough? *Am J Clin Nutr,* 79**,** 913S-920S.

BOHANNON, R. W., STEFFL, M., GLENNEY, S. S., GREEN, M., CASHWELL, L., PRAJEROVA, K. & BUNN, J. 2018. The prone bridge test: Performance, validity, and reliability among older and younger adults. *J Bodyw Mov Ther,* 22**,** 385-389.

BRANDÃO, G. S., OLIVEIRA, L. V. F., BRANDÃO, G. S., SILVA, A. S., SAMPAIO, A. A. C., URBANO, J. J., SOARES, A., SANTOS FARIA, N., PASQUALOTTO, L. T., OLIVEIRA, E. F., OLIVEIRA, R. F., PIRES-OLIVEIRA, D. A. A. & CAMELIER, A. A. 2018. Effect of a home-based exercise program on functional mobility and quality of life in elderly people: Protocol of a single-blind, randomized controlled trial. *Trials,* 19**,** 1-10.

BURTON, E., FARRIER, K., LEWIN, G., PETTIGREW, S., HILL, A. M., AIREY, P., BAINBRIDGE, L. & HILL, K. D. 2017. Motivators and barriers for older people participating in resistance training: A systematic review. *Journal of Aging and Physical Activity,* 25**,** 311-324.

CARVALHO, L., JUNIOR, R. M., BARREIRA, J., SCHOENFELD, B. J., ORAZEM, J. & BARROSO, R. 2022. Muscle hypertrophy and strength gains after resistance training with different volume-matched loads: a systematic review and meta-analysis. *Applied Physiology, Nutrition and Metabolism,* 47**,** 357-368.

CASPERSEN, C. J., POWELL, K. E. & CHRISTENSON, G. M. 1985. Physical Activity, Exercise, and Physical Fitness: Definitions and Distinctions for Health-Related Research. *Public Health Reports,* 100**,** 126-31.

CHAABENE, H., PRIESKE, O., HERZ, M., MORAN, J., HÖHNE, J., KLIEGL, R., RAMIREZ-CAMPILLO, R., BEHM, D. G., HORTOBÁGYI, T. & GRANACHER, U. 2021. Home-based exercise programmes improve physical fitness of healthy older adults: A PRISMA-compliant systematic review and meta-analysis with relevance for COVID-19. *Ageing Research Reviews,* 67**,** 101265-101265.

CHEN, Y., NIU, M. E., ZHANG, X., QIAN, H., XIE, A. & WANG, X. 2018. Effects of home-based lower limb resistance training on muscle strength and functional status in stable Chronic obstructive pulmonary disease patients. *Journal of Clinical Nursing,* 27**,** e1022-e1037.

CHURCH, T. S., BLAIR, S. N., COCREHAM, S., JOHANNSEN, N., JOHNSON, W., KRAMER, K., MIKUS, C. R., MYERS, V., NAUTA, M., RODARTE, R. Q., SPARKS, L., THOMPSON, A. & EARNEST, C. P. 2010. Effects of Aerobic and Resistance Training on Hemoglobin A 1c Levels in Patients With Type 2 Diabetes. *JAMA,* 304**,** 2253-2253.

COBB, P., CONFREY, J., DISESSA, A., LEHRER, R. & SCHAUBLE, L. 2003. Design Experiments in Educational Research. *Educational Researcher,* 32**,** 9-13.

COLMAN, A. M. 2009. floor effect. Oxford University Press.

DEPARTMENT OF, H. & SOCIAL, C. 2019. UK Chief Medical Officers' Physical Activity Guidelines 2019.

DI MEO, S., IOSSA, S. & VENDITTI, P. 2017a. Improvement of obesity-linked skeletal muscle insulin resistance by strength and endurance training. *Journal of Endocrinology,* 234**,** R159-R181.

DI MEO, S., IOSSA, S. & VENDITTI, P. 2017b. Skeletal muscle insulin resistance: Role of mitochondria and other ROS sources. *Journal of Endocrinology,* 233**,** R15-R42.

DWORKIN, S. L. 2003. A woman's place is in the ... cardiovascular room?? Gender relations, the body, and the gym. Albany: State University of New York Press.

EKELUND, U., STEENE-JOHANNESSEN, J., BROWN, W. J., FAGERLAND, M. W., OWEN, N., POWELL, K. E., BAUMAN, A. & LEE, I. M. 2016. Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. *The Lancet,* 388**,** 1302-1310.

EUROQOL, G. 2009. *RE: EQ-5D-5L.*

EVANS, J. W. 2019. Periodized Resistance Training for Enhancing Skeletal Muscle Hypertrophy and Strength: A Mini-Review. *Front Physiol,* 10**,** 13.

FIGUEIREDO, V. C., DE SALLES, B. F. & TRAJANO, G. S. 2018. Volume for Muscle Hypertrophy and Health Outcomes: The Most Effective Variable in Resistance Training. *Sports Medicine,* 48**,** 499-505.

FISHER, J., STEELE, J. & SMITH, D. 2013. Evidence-Based Resistance Training Recommendations for Muscular Hypertrophy. *Medicina Sportiva,* 17**,** 217-235.

FISHER, J., STEELE, J., WOLF, M., ANDROULAKIS KORAKAKIS, P., SMITH, D. & GIESSING, J. 2022. The Role of Supervision in Resistance Training; an Exploratory Systematic Review and Meta-Analysis. *International Journal of Strength and Conditioning,* 2.

FRANCHI, M. V., LONGO, S., MALLINSON, J., QUINLAN, J. I., TAYLOR, T., GREENHAFF, P. L. & NARICI, M. V. 2018. Muscle thickness correlates to muscle cross-sectional area in the assessment of strength training-induced hypertrophy. *Scandinavian Journal of Medicine & Science in Sports,* 28**,** 846-853.

FYFE, J. J., DALLA VIA, J., JANSONS, P., SCOTT, D. & DALY, R. M. 2022a. Feasibility and acceptability of a remotely delivered, home-based, pragmatic resistance 'exercise snacking' intervention in community-dwelling older adults: a pilot randomised controlled trial. *BMC Geriatrics,* 22**,** 1-12.

FYFE, J. J., HAMILTON, D. L. & DALY, R. M. 2022b. Minimal-Dose Resistance Training for Improving Muscle Mass, Strength, and Function: A Narrative Review of Current Evidence and Practical Considerations. *Sports Medicine,* 52**,** 463-479.

GENTIL, P., BOTTARO, M., GIESSING, J., STEELE, J., FISHER, J., CAMPOS, M. H., PAOLI, A. & SILVA, M. H. 2018. Effects of equal-volume resistance training with different training frequencies in muscle size and strength in trained men. *PeerJ,* 6**,** e5020-e5020.

GOLDRING, N., WILES, J. D. & COLEMAN, D. 2014. The effects of isometric wall squat exercise on heart rate and blood pressure in a normotensive population. *J Sports Sci,* 32**,** 129-36.

GORZELITZ, J., COSTANZO, E., GANGNON, R., KOLTYN, K., DIETZ, A. T., SPENCER, R. J., RASH, J. & CADMUS-BERTRAM, L. 2023. Feasibility and acceptability of home-based strength training in endometrial cancer survivors. *Journal of Cancer Survivorship,* 17**,** 120-129.

GRGIC, J., LAZINICA, B., MIKULIC, P., KRIEGER, J. W. & SCHOENFELD, B. J. 2017. The effects of short versus long inter-set rest intervals in resistance training on measures of muscle hypertrophy: A systematic review. *European Journal of Sport Science,* 17**,** 983-993.

GRGIC, J., LAZINICA, B., SCHOENFELD, B. J. & PEDISIC, Z. 2020. Test-Retest Reliability of the One-Repetition Maximum (1RM) Strength Assessment: a Systematic Review. *Sports Med Open,* 6**,** 31.

GRGIC, J., SCHOENFELD, B. J., DAVIES, T. B., LAZINICA, B., KRIEGER, J. W. & PEDISIC, Z. 2018a. Effect of Resistance Training Frequency on Gains in Muscular Strength: A Systematic Review and Meta-Analysis. *Sports Medicine,* 48**,** 1207-1220.

GRGIC, J., SCHOENFELD, B. J. & LATELLA, C. 2019. Resistance training frequency and skeletal muscle hypertrophy: A review of available evidence. *Journal of Science and Medicine in Sport,* 22**,** 361-370.

GRGIC, J., SCHOENFELD, B. J., ORAZEM, J. & SABOL, F. 2022. Effects of resistance training performed to repetition failure or non-failure on muscular strength and hypertrophy: A systematic review and meta-analysis. *Journal of Sport and Health Science,* 11**,** 202-211.

GRGIC, J., SCHOENFELD, B. J., SKREPNIK, M., DAVIES, T. B. & MIKULIC, P. 2018b. Effects of Rest Interval Duration in Resistance Training on Measures of Muscular Strength: A Systematic Review. *Sports Medicine,* 48**,** 137-151.

HANCOX, J. E., VAN DER WARDT, V., POLLOCK, K., BOOTH, V., VEDHARA, K. & HARWOOD, R. H. 2019. Factors influencing adherence to home-based strength and balance exercises among older adults with mild cognitive impairment and early dementia: Promoting activity, independence and stability in early dementia (praised). *PLoS ONE,* 14**,** 1-19.

HURLEY, K. S., FLIPPIN, K. J., BLOM, L. C., BOLIN, J. E., HOOVER, D. L. & JUDGE, L. W. 2018. Practices, Perceived Benefits, and Barriers to Resistance Training Among Women Enrolled in College. *International journal of exercise science,* 11**,** 226-238.

HURST, C., DISMORE, L., GRANIC, A., TULLO, E., NOBLE, J. M., HILLMAN, S. J., WITHAM, M. D., SAYER, A. A., DODDS, R. M. & ROBINSON, S. M. 2023. Attitudes and barriers to resistance exercise training for older adults living with multiple long-term conditions, frailty, and a recent deterioration in health: qualitative findings from the Lifestyle in Later Life – Older People's Medicine (LiLL-OPM) st. *BMC Geriatrics,* 23**,** 1-9.

ISMAIL, A. D., ABA ALKHAYL, F. F., WILSON, J., JOHNSTON, L., GILL, J. M. R. & GRAY, S. R. 2019. The effect of short duration resistance training on insulin sensitivity and muscle adaptations in overweight men. *Experimental Physiology***,** 2-7.

IVERSEN, V. M., MORK, P. J., VASSELJEN, O., BERGQUIST, R. & FIMLAND, M. S. 2017. Multiple-joint exercises using elastic resistance bands vs. conventional resistance-training equipment: A cross-over study. *European Journal of Sport Science,* 17**,** 973-982.

KASSIANO, W., NUNES, J. P., COSTA, B., RIBEIRO, A. S., SCHOENFELD, B. J. & CYRINO, E. S. 2022. Does Varying Resistance Exercises Promote Superior Muscle Hypertrophy and Strength Gains? A Systematic Review. *Journal of Strength and Conditioning Research,* 36**,** 1753-1762.

KATZMARZYK, P. T., FRIEDENREICH, C., SHIROMA, E. J. & LEE, I. M. 2022. Physical inactivity and non-communicable disease burden in low-income, middle-income and high-income countries. *British Journal of Sports Medicine,* 56**,** 101-106.

KIKUCHI, N., MOCHIZUKI, Y., KOZUMA, A., INOGUCHI, T., SAITO, M., DEGUCHI, M., HOMMA, H., OGAWA, M., HASHIMOTO, Y., NAKAZATO, K. & OKAMOTO, T. 2022. The Effect of Online Low-intensity Exercise Training on Fitness and Cardiovascular Parameters. *International Journal of Sports Medicine,* 43**,** 418-426.

KIKUCHI, N., OHTA, T., HASHIMOTO, Y., MOCHIZUKI, Y., SAITO, M., KOZUMA, A., DEGUCHI, M., INOGUCHI, T., SHINOGI, M., HOMMA, H., OGAWA, M., NAKAZATO, K. & OKAMOTO, T. 2023. Effect of Online Home-Based Resistance Exercise Training on Physical Fitness, Depression, Stress, and Well-Being in Middle-Aged Persons: A Pilot Study. *International Journal of Environmental Research and Public Health,* 20**,** 1769-1769.

KIS, O., BUCH, A., STERN, N. & MORAN, D. S. 2019. Minimally supervised home-based resistance training and muscle function in older adults: A meta-analysis. *Archives of Gerontology and Geriatrics,* 84**,** 103909-103909.

KODAMA, S. 2009. Cardiorespiratory Fitness as a Quantitative Predictor of All-Cause Mortality and Cardiovascular Events in Healthy Men and Women. *JAMA,* 301**,** 2024-2035.

KRAEMER, W. J. & RATAMESS, N. A. 2005. Hormonal Responses and Adaptations to Resistance Exercise and Training. *Sports Medicine,* 35**,** 339-361.

KRAEMER, W. J., RATAMESS, N. A. & FRENCH, D. N. 2002. Resistance Training for Health and Performance. *Current Sports Medicine Reports,* 1**,** 165-171.

LAMBERT, C., BECK, B. R., WATSON, S. L., HARDING, A. T. & WEEKS, B. K. 2020. Enjoyment and acceptability of different exercise modalities to improve bone health in young adult women. *Health Promotion Journal of Australia***,** 1-12.

LEE, J. H., KIM, D. H. & KIM, C. K. 2017. Resistance Training for Glycemic Control, Muscular Strength, and Lean Body Mass in Old Type 2 Diabetic Patients: A Meta-Analysis. *Diabetes Therapy,* 8**,** 459-473.

LEITE, T., DE SOUZA TEIXEIRA, A., FRANCISCO, S., LEITE, R. D., RHEA, M. R. & SIMÃO, R. 2015. Influence of Strength and Flexibility Training, Combined or Isolated, on Strength and Flexibility Gains. *Journal of Strength and Conditioning Research,* 29**,** 1083-1088.

LEVINGER, I., GOODMAN, C., HARE, D. L., JERUMS, G., TOIA, D. & SELIG, S. 2009. The reliability of the 1RM strength test for untrained middle-aged individuals. *Journal of Science and Medicine in Sport,* 12**,** 310-316.

LOPES, J. S. S., MACHADO, A. F., MICHELETTI, J. K., DE ALMEIDA, A. C., CAVINA, A. P. & PASTRE, C. M. 2019. Effects of training with elastic resistance versus conventional resistance on muscular strength: A systematic review and meta-analysis. *SAGE Open Medicine,* 7**,** 205031211983111-205031211983111.

LOPEZ, P., TAAFFE, D. R., GALVAO, D. A., NEWTON, R. U., NONEMACHER, E. R., WENDT, V. M., BASSANESI, R. N., TURELLA, D. J. P. & RECH, A. 2022. Resistance training effectiveness on body composition and body weight outcomes in individuals with overweight and obesity across the lifespan: A systematic review and meta-analysis. *Obes Rev,* 23**,** e13428.

LORENZ, D. & MORRISON, S. 2015. CURRENT CONCEPTS IN PERIODIZATION OF STRENGTH AND CONDITIONING FOR THE SPORTS PHYSICAL THERAPIST. *The International Journal of Sports Physical Therapy,* 10**,** 734-747.

LUND, L. W., AMMITZBØLL, G., HANSEN, D. G., ANDERSEN, E. A. W. & DALTON, S. O. 2019. Adherence to a long-term progressive resistance training program, combining supervised and home-based exercise for breast cancer patients during adjuvant treatment. *Acta Oncologica,* 58**,** 650-657.

MAHMOOD, A., NAYAK, P., DESHMUKH, A., ENGLISH, C., N, M., SOLOMON, M. J. & B, U. 2023. Measurement, determinants, barriers, and interventions for exercise adherence: A scoping review. *J Bodyw Mov Ther,* 33**,** 95-105.

MAÑAS, A., GÓMEZ-REDONDO, P., VALENZUELA, P. L., MORALES, J. S., LUCÍA, A. & ARA, I. 2021. Unsupervised home-based resistance training for community-dwelling older adults: A systematic review and meta-analysis of randomized controlled trials. *Ageing Research Reviews,* 69**,** 101368-101368.

MARKLAND, D. & TOBIN, V. 2004. A modification to the behavioural regulation in exercise questionnaire to include an assessment of amotivation. *Journal of Sport and Exercise Psychology,* 26**,** 191-196.

MARTINS, W. R., DE OLIVEIRA, R. J., CARVALHO, R. S., DE OLIVEIRA DAMASCENO, V., DA SILVA, V. Z. M. & SILVA, M. S. 2013. Elastic resistance training to increase muscle strength in elderly: A systematic review with meta-analysis. *Archives of Gerontology and Geriatrics,* 57**,** 8-15.

MCARDLE, W. D., KATCH, F. I. & KATCH, V. L. 2015. *Exercise Physiology: nutrition, energy, and human performance,* Baltimore, Wolters Kluwer Health.

MCGINLEY, S. K., ARMSTRONG, M. J., BOULÉ, N. G. & SIGAL, R. J. 2014. Effects of exercise training using resistance bands on glycaemic control and strength in type 2 diabetes mellitus: a meta-analysis of randomised controlled trials. *Acta Diabetologica,* 52**,** 221-230.

MCLEOD, J. C., CURRIER, B. S., LOWISZ, C. V. & PHILLIPS, S. M. 2023. The influence of resistance exercise training prescription variables on skeletal muscle mass, strength, and physical function in healthy adults: An umbrella review. *Journal of Sport and Health Science,* 00**,** 1-14.

MILLER, E. G., SETHI, P., NOWSON, C. A., DUNSTAN, D. W. & DALY, R. M. 2017. Effects of progressive resistance training and weight loss versus weight loss alone on inflammatory and endothelial biomarkers in older adults with type 2 diabetes. *European Journal of Applied Physiology,* 117**,** 1669-1678.

MOESGAARD, L., BECK, M. M., CHRISTIANSEN, L., AAGAARD, P. & LUNDBYE-JENSEN, J. 2022. Effects of Periodization on Strength and Muscle Hypertrophy in Volume-Equated Resistance Training Programs: A Systematic Review and Meta-analysis. *Sports Medicine,* 52**,** 1647-1666.

MOMMA, H., KAWAKAMI, R., HONDA, T. & SAWADA, S. S. 2022. Muscle-strengthening activities are associated with lower risk and mortality in major non-communicable diseases: a systematic review and meta-analysis of cohort studies. *British journal of sports medicine,* 56**,** 755-763.

MOON, K. & BLACKMAN, D. 2014. A Guide to Understanding Social Science Research for Natural Scientists. *Conservation Biology,* 28**,** 1167-1177.

MOON, K., CVITANOVIC, C., BLACKMAN, D. A., SCALES, I. R. & BROWNE, N. K. 2021. Five Questions to Understand Epistemology and Its Influence on Integrative Marine Research. *Frontiers in Marine Science,* 8.

NATIONAL INSTITUTE FOR HEALTH, R. 2016. Procedure for Measuring Hand Grip Stregth Using the Jamar Dynamometer. 1-6.

NEVES, R. P., VECHIN, F. C., TEIXEIRA, E. L., DA SILVA, D. D., UGRINOWITSCH, C., ROSCHEL, H., AIHARA, A. Y. & TRICOLI, V. 2022. Effect of different training frequencies on maximal strength performance and muscle hypertrophy in trained individuals-a within-subject design. *PLoS ONE,* 17**,** 1-14.

NHS. 2021. *RE: Physical activity guidelines for adults aged 19 to 64.*

NHS DIGITAL 2023. Health Survey for England, 2021 part 2.

NÓBREGA, S. R. & LIBARDI, C. A. 2016. Is resistance training to muscular failure necessary? *Frontiers in Physiology,* 7**,** 75-78.

NUNES, J. P., KASSIANO, W., COSTA, B. D. V., MAYHEW, J. L., RIBEIRO, A. S. & CYRINO, E. S. 2021. Equating Resistance-Training Volume Between Programs Focused on Muscle Hypertrophy. *Sports Medicine,* 51**,** 1171-1178.

NUÑEZ, C., GALLAGHER, D., VISSER, M., PI-SUNYER, F. X., WANG, Z. & HEYMSFIELD, S. B. 1997. Bioimpedance analysis: evaluation of leg-to-leg system based on pressure contact foot-pad electrodes. *Medicine & Science in Sports & Exercise,* 29.

PAGE, P. 2012. CURRENT CONCEPTS IN MUSCLE STRETCHING FOR EXERCISE AND REHABILITATION. *Int J Sports Phys Ther,* 7**,** 109-19.

PAYNE, W. R., WALSH, K. J., HARVEY, J. T., LIVY, M. F., MCKENZIE, K. J., DONALDSON, A., ATKINSON, M. G., KEOGH, J. B., MOSS, R. S., DUNSTAN, D. W. & HUBBARD, W. A. 2008. Effect of a Low-Resource-Intensive Lifestyle Modification Program Incorporating Gymnasium-Based and Home-Based Resistance Training on Type 2 Diabetes Risk in Australian Adults. *Diabetes Care,* 31**,** 2244-2250.

PERKIN, O. J., MCGUIGAN, P. M. & STOKES, K. A. 2019. Exercise Snacking to Improve Muscle Function in Healthy Older Adults: A Pilot Study. *Journal of Aging Research,* 2019.

PETERS, N. A., SCHLAFF, R. A., KNOUS, J. L. & BARUTH, M. 2019. Barriers to resistance training among college-aged women. *Journal of American College Health,* 67**,** 4-9.

PHILLIPS, S. M. & WINETT, R. A. 2013. Uncomplicated Resistance Training and Health-Related Outcomes. *Current Sports Medicine Reports,* 9**,** 208-213.

PLOTNIKOFF, R. C., EVES, N., JUNG, M., SIGAL, R. J., PADWAL, R. & KARUNAMUNI, N. 2010. Multicomponent, home-based resistance training for obese adults with type 2 diabetes: A randomized controlled trial. *International Journal of Obesity,* 34**,** 1733-1741.

RADAELLI, R., FLECK, S. J., LEITE, T., LEITE, R. D., PINTO, R. S., FERNANDES, L. & SIMÃO, R. 2015. Dose-Response of 1, 3, and 5 Sets of Resistance Exercise on Strength, Local Muscular Endurance, and Hypertrophy. *Journal of Strength and Conditioning Research,* 29**,** 1349-1358.

RALSTON, G. W., KILGORE, L., WYATT, F. B. & BAKER, J. S. 2017. The Effect of Weekly Set Volume on Strength Gain: A Meta-Analysis. *Sports Medicine,* 47**,** 2585-2601.

RALSTON, G. W., KILGORE, L., WYATT, F. B., BUCHAN, D. & BAKER, J. S. 2018. Weekly Training Frequency Effects on Strength Gain: A Meta-Analysis. *Sports Medicine - Open,* 4.

REFALO, M. C., HELMS, E. R., TREXLER, E. T., HAMILTON, D. L. & FYFE, J. J. 2023. Influence of Resistance Training Proximity-to-Failure on Skeletal Muscle Hypertrophy: A Systematic Review with Meta-analysis. Springer International Publishing.

REINHOLZ, D. L. & ANDREWS, T. C. 2020. Change theory and theory of change: what's the difference anyway? *International Journal of STEM Education,* 7.

ROBERTS, H. C., DENISON, H. J., MARTIN, H. J., PATEL, H. P., SYDDALL, H., COOPER, C. & SAYER, A. A. 2011. A review of the measurement of grip strength in clinical and epidemiological studies: Towards a standardised approach. *Age and Ageing,* 40**,** 423-429.

ROSENBERG, M. 1965. *Society and the Adolescent Self-Image,* Princeton, NJ, Princeton University Press.

RYAN, R. M. & FREDERICK, C. 1997. On Energy, Personality, and Health: Subjective Vitality as a Dynamic Reflection of Well-Being. *Joumal of Personality,* 65**,** 3-3.

SAEIDIFARD, F., MEDINA-INOJOSA, J. R., WEST, C. P., OLSON, T. P., SOMERS, V. K., BONIKOWSKE, A. R., PROKOP, L. J., VINCIGUERRA, M. & LOPEZ-JIMENEZ, F. 2019. The association of resistance training with mortality: A systematic review and meta-analysis. *Eur J Prev Cardiol,* 26**,** 1647-1665.

SARIC, J., LISICA, D., ORLIC, I., GRGIC, J., KRIEGER, J. W., VUK, S. & SCHOENFELD, B. J. 2018. Resistance Training Frequencies of 3 and 6 Times Per Week Produce Similar Muscular Adaptations in Resistance-Trained Men. *Journal of Strength and Conditioning Research***,** 1-1.

SCHIAFFINO, S. & MAMMUCARI, C. 2011. Regulation of skeletal muscle growth by the IGF1-Akt/PKB pathway: Insights from genetic models. *Skeletal Muscle,* 1**,** 4-4.

SCHOENFELD, B. J., CONTRERAS, B., KRIEGER, J., GRGIC, J., DELCASTILLO, K., BELLIARD, R. & ALTO, A. 2018. Resistance Training Volume Enhances Muscle Hypertrophy. *Medicine & Science in Sports & Exercise***,** 1-1.

SCHOENFELD, B. J., GRGIC, J., OGBORN, D. & KRIEGER, J. W. 2017a. Strength and hypertrophy adaptations between low- vs. High-load resistance training: A systematic review and meta-analysis. NSCA National Strength and Conditioning Association.

SCHOENFELD, B. J., GRGIC, J., VAN EVERY, D. W. & PLOTKIN, D. L. 2021. Loading Recommendations for Muscle Strength, Hypertrophy, and Local Endurance: A Re-Examination of the Repetition Continuum. *Sports,* 9**,** 1-26.

SCHOENFELD, B. J., OGBORN, D. & KRIEGER, J. W. 2016. Effects of Resistance Training Frequency on Measures of Muscle Hypertrophy: A Systematic Review and Meta-Analysis. *Sports Medicine,* 46**,** 1689-1697.

SCHOENFELD, B. J., OGBORN, D. & KRIEGER, J. W. 2017b. Dose-response relationship between weekly resistance training volume and increases in muscle mass: A systematic review and meta-analysis. *Journal of Sports Sciences,* 35**,** 1073-1082.

SCHOENFELD, B. J., OGBORN, D. I. & KRIEGER, J. W. 2015a. Effect of Repetition Duration During Resistance Training on Muscle Hypertrophy: A Systematic Review and Meta-Analysis. *Sports Medicine,* 45**,** 577-585.

SCHOENFELD, B. J., PETERSON, M. D., OGBORN, D., CONTRERAS, B. & SONMEZ, G. T. 2015b. Effects of Low- vs. High-Load Resistance Training on Muscle Strength and Hypertrophy in Well-Trained Men. *Journal of Strength and Conditioning Research,* 29**,** 2954-2963.

SIGAL, R. J., ALBERGA, A. S., GOLDFIELD, G. S., PRUD'HOMME, D., HADJIYANNAKIS, S., GOUGEON, R., PHILLIPS, P., TULLOCH, H., MALCOLM, J., DOUCETTE, S., WELLS, G. A., MA, J. & KENNY, G. P. 2014. Effects of aerobic training, resistance training, or both on percentage body fat and cardiometabolic risk markers in obese adolescents: The healthy eating aerobic and resistance training in youth randomized clinical trial. *JAMA Pediatrics,* 168**,** 1006-1014.

SIGAL, R. J., KENNY, G. P., BOULÉ, N. G., WELLS, G. A., PRUD'HOMME, D., FORTIER, M., REID, R. D., TULLOCH, H., COYLE, D., PHILLIPS, P., JENNINGS, A. & JAFFEY, J. 2007. Effects of aerobic training, resistance training, or both on glycemic control in type 2 diabetes: A randomized trial. *Annals of Internal Medicine,* 147**,** 357-369.

SOUSA-SANTOS, A. R. & AMARAL, T. F. 2017. Differences in handgrip strength protocols to identify sarcopenia and frailty - A systematic review. *BMC Geriatrics,* 17.

STEWART-BROWN, S. & JANMOHAMED, K. 2008. Warwick-Edinburgh Mental Well-being Scale User Guide.

STRAIN, T., FITZSIMONS, C., KELLY, P. & MUTRIE, N. 2016. The forgotten guidelines: Cross-sectional analysis of participation in muscle strengthening and balance & co-ordination activities by adults and older adults in Scotland. *BMC Public Health,* 16**,** 1-12.

STRASSER, B., ARVANDI, M. & SIEBERT, U. 2012. Resistance training, visceral obesity and inflammatory response: A review of the evidence. *Obesity Reviews,* 13**,** 578-591.

TENNANT, R., HILLER, L., FISHWICK, R., PLATT, S., JOSEPH, S., WEICH, S., PARKINSON, J., SECKER, J. & STEWART-BROWN, S. 2007. The Warwick-Dinburgh mental well-being scale (WEMWBS): Development and UK validation. *Health and Quality of Life Outcomes,* 5**,** 1-13.

THOMAS, M. H. & BURNS, S. P. 2016. Increasing Lean Mass and Strength: A Comparison of High Frequency Strength Training to Lower Frequency Strength Training. *International journal of exercise science,* 9**,** 159-167.

TORGERSON, D. J. & ROBERTS, C. 1999. Understanding controlled trials: Randomisation methods: concealment. *BMJ,* 319**,** 375-376.

TOSCHI, A., LEE, E., XU, L., GARCIA, A., GADIR, N. & FOSTER, D. A. 2009. Regulation of mTORC1 and mTORC2 Complex Assembly by Phosphatidic Acid: Competition with Rapamycin. *Molecular and Cellular Biology,* 29**,** 1411-1420.

TROIANO, R. P., STAMATAKIS, E. & BULL, F. C. 2020. How can global physical activity surveillance adapt to evolving physical activity guidelines? Needs, challenges and future directions. *Br J Sports Med,* 54**,** 1468-1473.

TROST, S. G., OWEN, N., BAUMAN, A. E., SALLIS, J. F. & BROWN, W. 2002. Correlates of adults' participation in physical activity: review and update. *Med. Sci. Sports Exerc,* 34**,** 1996-2001.

TSEKOURA, M., BILLIS, E., TSEPIS, E., DIMITRIADIS, Z., MATZAROGLOU, C., TYLLIANAKIS, M., PANAGIOTOPOULOS, E. & GLIATIS, J. 2018. The effects of group and home-based exercise programs in elderly with sarcopenia: A randomized controlled trial. *Journal of Clinical Medicine,* 7.

TULLOCH, H., SWEET, S. N., FORTIER, M., CAPSTICK, G., KENNY, G. P. & SIGAL, R. J. 2013. Exercise facilitators and barriers from adoption to maintenance in the diabetes aerobic and resistance exercise trial. *Canadian Journal of Diabetes,* 37**,** 367-374.

VAISHYA, R., MISRA, A., VAISH, A., URSINO, N. & D'AMBROSI, R. 2024. Hand grip strength as a proposed new vital sign of health: a narrative review of evidences. *J Health Popul Nutr,* 43**,** 7.

VASUDEVAN, A. & FORD, E. 2022. Motivational Factors and Barriers Towards Initiating and Maintaining Strength Training in Women: a Systematic Review and Meta-synthesis. *Prevention Science,* 23**,** 674-695.

VIKBERG, S., BJÖRK, S., NORDSTRÖM, A., NORDSTRÖM, P. & HULT, A. 2022. Feasibility of an Online Delivered, Home-Based Resistance Training Program for Older Adults – A Mixed Methods Approach. *Frontiers in Psychology,* 13**,** 1-11.

VITALE, J. A., BONATO, M., BORGHI, S., MESSINA, C., ALBANO, D., CORBETTA, S., SCONFIENZA, L. M. & BANFI, G. 2020. Home-Based Resistance Training for Older Subjects during the COVID-19 Outbreak in Italy: Preliminary

Results of a Six-Months RCT. *International Journal of Environmental Research and Public Health*, 17, 9533-9533.

WAGNER, B., KRÜGER, S., HILBERG, T., AY, C., HASENOEHRL, T., HUBER, D. F. X. & CREVENNA, R. 2020. The effect of resistance exercise on strength and safety outcome for people with haemophilia: A systematic review. *Haemophilia,* 26, 200-215.

WESTCOTT, W. 2009. ACSM STRENGTH TRAINING GUIDELINES. *ACSM's Health & Fitness Journal,* 13, 14-22.

WEWEGE, M. A., DESAI, I., HONEY, C., COORIE, B., JONES, M. D., CLIFFORD, B. K., LEAKE, H. B. & HAGSTROM, A. D. 2022. The Effect of Resistance Training in Healthy Adults on Body Fat Percentage, Fat Mass and Visceral Fat: A Systematic Review and Meta-Analysis. *Sports Medicine,* 52, 287-300.

WHO. 2010. *RE: Global recommendations on physical activity for health.*

WHO 2022a. Global status report on physical activity 2022. Geneva.

WHO. 2022b. *Physical activity* [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/physical-activity [Accessed].

ZHANG, F., WANG, Z., SU, H., ZHAO, H., LU, W., ZHOU, W. & ZHANG, H. 2022. Effect of a home-based resistance exercise program in elderly participants with osteoporosis: a randomized controlled trial. *Osteoporosis International*, 1937-1947.