Web-based physiotherapy for people with chronic health conditions: South Asians with type 2 diabetes

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Abstract

South Asians are disproportionally affected by type 2 diabetes (T2DM) and its complications. Structured exercise is recommended for people with T2DM, however, evidence regarding the effectiveness of exercise in T2DM management has emerged from studies mainly involving white Europeans. In addition, South Asians are less likely to engage in exercise due to barriers such as lack of gender-specific exercise facilities and family commitment. The aims of this thesis were to investigate the effectiveness of exercise interventions in the management of T2DM in South Asians and to explore the acceptability and the likely effect of a web-based exercise intervention as a solution to facilitate the engagement of South Asians with T2DM in exercise interventions. This was done through three studies.

The first study was a systematic review of clinical trials examining the effectiveness of exercise interventions in the management of T2DM in South Asians. This review included 18 studies which involved 1,063 participants and examined the effect of aerobic, resistance, balance and combined exercise programmes. All these types of exercise programmes were associated with improvements in at least one of the following: glycaemic control, blood pressure, waist circumference, blood lipids, muscle strength, functional mobility, quality of life and neuropathy progression. However, further studies of robust methodology are required to strengthen the findings and to identify the most appropriate exercise dose.

The second study was a three-stage user-centred design process which aimed to customise a web-based physiotherapy platform to be accessible and culturally relevant for South Asians. The first stage involved two gender-specific exploratory focus groups to explore South Asians' views and identify their needs. Three themes were identified that enabled an understanding of South Asians' perceptions regarding exercise, using technology as a delivery method and also highlighted the modifications needed to make the platform acceptable and culturally relevant for South Asians. The second stage involved refining and customising the platform based on participant views gathered during stage one. Several modifications were made to the platform which included translating the available exercise videos into Urdu as well as filming new exercise video clips with actors from different ethnic backgrounds wearing modest clothes. The final stage involved two gender-specific confirmatory focus groups to obtain feedback on the modifications made to the platform in the previous stage. One theme was identified at this stage highlighting participants views on the modified platform. The final output of this study was the co-production of an accessible and culturally relevant web-based exercise platform for people from South Asian communities that was used in the final study to deliver a web-based exercise intervention.

The final study was a pilot, randomised controlled study embedded with interviews to investigate the feasibility, the acceptability and the likely effect of a 12-week personalised exercise programme delivered using a web-based platform, compared to usual care, in terms of glycaemic control, muscle strength, functional ability, blood lipid profile, blood pressure and quality of life in adult South Asians with T2DM. Twenty-four out of 33 participants (73%) completed the post intervention assessment. Five participants were interviewed at the end of the intervention. No adverse events were reported from this study. Seventy-six percent of participants used the platform and accessed the intervention. The adherence to the intervention was satisfactory (ranged from 57% during the first four weeks to 31% in the last four weeks). Participants who were interviewed perceived the intervention as being helpful, practical, and a trusted source of knowledge. Female participants in particular felt that the intervention helped them to overcome the cultural barriers to exercise that are related to the lack of gender-specific exercise facilities. Participants liked the platform and described it as easy to use. Participants suggested a few modifications to further improve the ease of use. In terms of effectiveness, compared to the control group, participants in the intervention group showed trends towards improvements with moderate to large effect sizes in the following outcomes: total cholesterol levels, triglyceride levels, handgrip strength, the Timed up and Go, and the physical health sub-domain of the WHO Quality of Life-BREF.

In conclusion, the studies within this thesis indicate that exercise is beneficial for South Asians with T2DM. The web-based exercise intervention was found feasible and acceptable to South Asians with T2DM and has the potential for effectiveness. Further powered studies are required to strengthen, expand and confirm the current findings.

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Table of Contents

List of Tables

List of Figures

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Author's Declaration

I hereby declare that explicit reference is made to the contribution of other, that this thesis is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institutions.

Signature:

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Publication arising from this work

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List of Abbreviations

T1DM	Type 1 diabetes
T2DM	Type 2 diabetes
HbA1c	Glycated haemoglobin A1c
IDF	the International Diabetes Federation
HHNS	Hyperosmolar hyperglycaemic non-ketotic syndrome
BMI	Body mass index
WC	Waist circumference
SBP	Systolic blood pressure of
DBP	Diastolic blood pressure
LDL	How-density lipoprotein
HDL	High-density lipoprotein
FBG	Fasting blood glucose
RCT	Randomised controlled trial
CCT	Controlled clinical trials
CI	Chief Investigator
TUG	The Timed Up and Go test
10MWT	Ten Meter Walking Test
MDC	Minimal detectable change
NICE	National Institute for Health and Care Excellence
WHO	World Health Organization
WHO-QOL BREF	The World Health Organization Quality of Life Scale Brief
Ofcom	The office of communication
NHS	National health services

Chapter 1 – Introduction

This chapter will introduce the topic of the PhD, highlight the aims of the PhD, describe the stages undertaken to complete this PhD and finally the chapter will present the layout of the thesis.

1.1 Background

Type 2 diabetes (T2DM) is a common chronic health condition associated with a wide range of complications including heart disease, stroke, limb amputation, muscle weakness, functional decline, disability and poor quality of life (Fowler, 2008; Cade, 2008; Shah and Kanaya, 2014). South Asians – people who describe themselves as originating from India, Pakistan, Sri Lanka, Bangladesh or Nepal – are disproportionally affected by T2DM and its complications compared to other ethnic groups (Barnett et al., 2006; Hanif et al., 2014). Exercise, in addition to diet and medications, is a core strategy in T2DM management. Exercise interventions are considered to improve several risk factors associated with T2DM complications such as glycaemic control, blood lipid profile, blood pressure, muscle strength, functional mobility and quality of life (Gordon et al., 2009; Liubaoerjijin et al., 2016; Cai et al., 2017). Currently, several international scientific organisations encourage prescribing exercise for people with T2DM which should be undertaken on a regular basis (Inzucchi et al., 2012; International Diabetes Federation Guideline Development Group, 2014).

1.2 Overview of the PhD project

This PhD will begin with a literature review covering the main topics underpinning this project. This review highlighted two main areas that required further work. First, although evidence indicates variation in exercise responses among ethnic groups, exercise prescription guidelines for people with T2DM and systematic reviews confirming the effectiveness of exercise in T2DM management emerged from studies involving mainly white European participants (Gordon et al., 2009; Liubaoerjijin et al., 2016; Cai et al., 2017). As such the generalisability of the current evidence to South Asian is limited.

Second, people from South Asian communities living in western countries do not participate in enough exercise due to several barriers such as the lack of gender-specific exercise facilities, family commitment and transportation problem (Naeem, 2003; Lawton et al., 2006; Galdas et al., 2012; Babakus and Thompson, 2012; Bhatnagar et al., 2015; Sohal et al., 2015). Using technology, particularly web-based exercise intervention, is an option that might help South Asians with T2DM to overcome the associated barriers. However, to date no study has explored the acceptability and the effectiveness of web-based exercise interventions in South Asians with T2DM. Above and beyond this, South Asians might not have access to such interventions due to the scarcity of linguistically and culturally competent web-based exercise platforms.

1.2.1 Aims of this PhD project

This thesis had three specific aims:

(1) to review the current evidence regarding the effectiveness of exercise interventions in the management of T2DM in South Asians;

(2) to customise and refine an existing web-based physiotherapy platform (i.e. www.webbased physio.com) to be accessible and culturally relevant for South Asians;

(3) to explore the feasibility, the acceptability and the likely effectiveness of a web-based exercise intervention as a solution to help South Asians with T2DM to overcome exercise barriers.

1.2.2 Outline of this PhD project

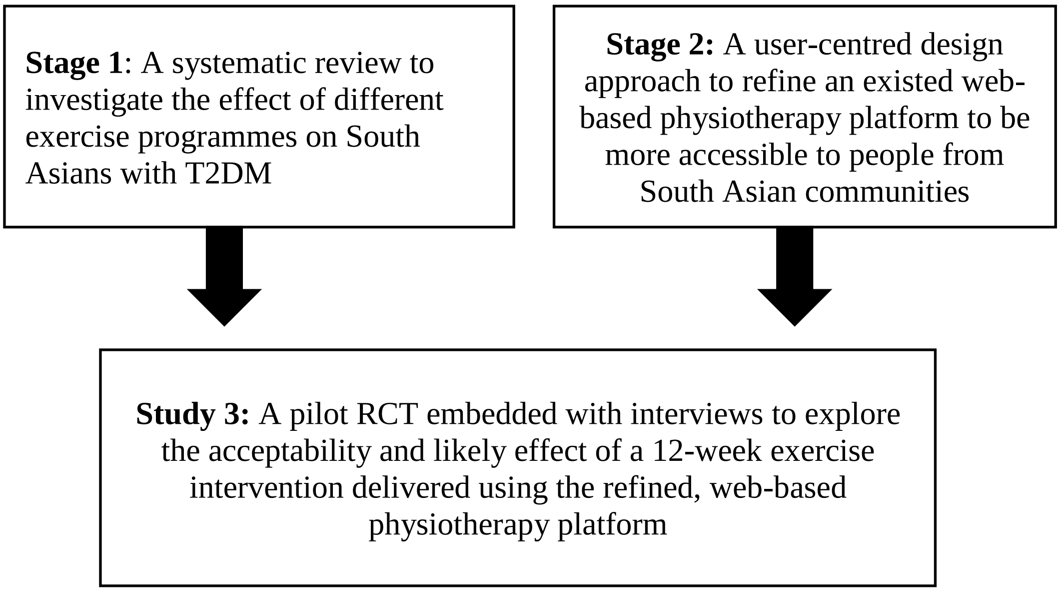
The aims of this PhD project were achieved through three consecutive stages (Figure 1.1). Stage one was a systematic review which was undertaken to explore the current literature regarding the effectiveness of exercise interventions in the management of T2DM in South Asians.

Stage two was the field work undertaken to inform and guide the customisation of a web-based physiotherapy platform to be accessible and culturally relevant for people from South

Asian communities. This stage involved two exploratory focus groups, two confirmatory focus groups, and the results of which were used to feed into the customisation of the platform. This stage resulted in an accessible and culturally relevant web-based exercise platform that could be used to deliver exercise interventions for people from South Asians communities the effect of which was examined in the third stage.

Stage three was the work undertaken to explore the feasibility, the acceptability and the likely effect of a 12-week personalised web-based exercise intervention. This involved carrying out a pilot, randomised controlled trial embedded with five face to face interviews to gather participants' views on the intervention.

Figure 1.1 PhD project stages



1.3 Declaration of the student's contribution

The table below (Table 1.1) illustrates the contribution Hani Albalawi made to each study within this thesis.

Table 1.1 Student's contribution toward each study

Study	Student contribution
Study 1: Systematic review	• Developed the study design, research questions and study protocol including the search strategy for the literature search • Screened titles, abstracts and full papers • • Extracted the data • Conducted the quality assessment of the literature • • Prepared the manuscript for publication
Study 2: User-centred design study	• Developed the study design, research questions and study protocol. • Conducted male focus groups • Transcribed the focus groups • Analysed data
Study 3: A pilot RCT embedded with interviews	• Developed the study design, research questions and study protocol. • Trained the blind assessor • Screened participants for inclusion criteria • Randomised participants • Designed personalised exercise programmes • Analysed data

1.4 Thesis layout

This thesis comprises of 9 chapters, which are set out as follows:

This chapter, Chapter 1, is a brief introductory chapter that introduces the topic of the PhD, highlights the aims of the PhD project, outlines the stages of the PhD project, and presents the layout of the thesis.

Chapter 2 contains the literature review covering the main topics underpinning this thesis, namely the prevalence of T2DM, T2DM in South Asians in particular, T2DM complications, exercise interventions in the management of T2DM, limitations in the current evidence regarding the effectiveness of exercise intervention, barriers to South Asian participation in exercise intervention, the potential of technology to facilitate South Asian engagement in exercise programmes.

Chapter 3 presents the first study in this PhD project, which is a published systematic review conducted to explore the current evidence regarding the effectiveness of exercise intervention in the management of T2DM in South Asians (Albalawi et al., 2017).

Chapter 4 presents a user-centred design study carried out to customise and refine an existing web-based physiotherapy platform in order for it to be more accessible and culturally relevant for people from South Asian communities.

Chapter 5 presents the aims and methods of a pilot RCT embedded with interviews, conducted to examine the acceptability and the likely effect of a 12-week web-based exercise intervention for South Asians with T2DM.

Chapter 6 presents the quantitative results and Chapter 7 presents the qualitative findings of the pilot RCT.

Chapter 8 presents the discussion about the findings of the pilot RCT and lastly Chapter 9 presents the final discussion and conclusion.

Chapter 2 – Background

This chapter describes the current literature that covers the main topics underpinning this thesis, namely diabetes, the prevalence of diabetes, type 2 diabetes (T2DM) in South Asians in particular, T2DM complications, exercise interventions in the management of T2DM, limitations in the current evidence regarding the effectiveness of exercise intervention, barriers to South Asian participation in exercise intervention, and the potential of technology to facilitate South Asian engagement in exercise programmes. This chapter will also highlight the gaps in the literature, the aims of this PhD project and the studies conducted to meet these aims will be highlighted.

2.1 Diabetes mellitus

The term 'diabetes mellitus' or 'diabetes' refers to a group of metabolic disorders characterised by chronic elevated levels of blood glucose (hyperglycaemia) (American Diabetes Association, 2009). The classic symptoms of diabetes are polyuria, polydipsia and unexplained weight loss (American Diabetes Association, 2015). Diabetes is usually diagnosed when these symptoms are associated with an abnormal blood glucose level that meet one of the following criteria: 1) a random plasma glucose level ≥ 200 mg/dl (11.1 mmol/l); 2) fasting plasma glucose ≥ 126 mg/dl (7.0 mmol/ l); 2-hour plasma glucose ≥ 200 mg/dl (11.1 mmol/l) during an oral glucose tolerance test; or 4) glycated haemoglobin A1c (HbA1c) ≥ 6.5% (World Health Organisation, 2019).

Blood glucose is a biological source of energy for most body cells, particularly neurons (James and McFadden, 2004). Although blood glucose is important, both hyperglycaemia and low concentrations of blood glucose (hypoglycaemia) can lead to serious health problems, and in extreme cases death (James and McFadden, 2004). In healthy people, blood glucose level is regulated at specific ranges (approximately 4.0 to 5.4 mmol/L) by a complex network involving various hormones and neurotransmitters released from different parts of the body including the brain, pancreas, liver and intestine as well as muscle tissues (Röder et al., 2016; Bannister and Berlanga, 2016).

Insulin is a principal hormone in the complex network that works to lower blood glucose levels by stimulating the uptake, utilisation and storage of glucose (Röder et al., 2016).

Insulin is released by beta pancreatic cells in response to increased levels of blood glucose (Röder et al., 2016). Insulin signals insulin-sensitive tissues to absorb glucose, either to use it as immediate energy or to store it as a backup fuel, in the form of glycogen, in hepatocytes in the liver and skeletal muscle (Röder et al., 2016). In people with diabetes, however, the normal regulation of blood glucose is disturbed due to absolute or relative deficiencies in insulin production, the inability of insulin-sensitive tissues to respond to the action of insulin, or both (Waryasz and McDermott, 2010). Therefore, unless treated, blood glucose levels will remain high.

Based on the underlying mechanism/ aetiology causing the hyperglycaemia, diabetes can be classified into four categories – namely, type 1 diabetes (T1DM), type 2 diabetes (T2DM), gestational diabetes, and specific types of diabetes due to other causes such as drug- or chemical-induced diabetes and genetic defects of the beta cell (American Diabetes Association, 2015). Gestational diabetes which occurs in women during pregnancy and specific types of diabetes account only for small proportion of all cases of diabetes (i.e. 1-3%) (International Diabetes Federation, 2017). Whereas, Type 1 diabetes and T2DM are considered the main two categories.

T1DM represents approximately 7-11% of all cases of diabetes worldwide (International Diabetes Federation, 2017). The hyperglycaemia associated with T1DM is the result of an absolute deficiency of insulin secretion due to a destructive lesion of the pancreatic islet beta cells that produce insulin (Ozougwu et al., 2013; Baynest, 2015). As such, people with T1DM rely on insulin treatment to survive (Copenhaver and Hoffman, 2017). In the majority of cases with T1DM, the destructive lesion of pancreatic beta cells results from an auto-immune attack, triggered by both environmental and genetic factors which are poorly defined (Copenhaver and Hoffman, 2017). In a few cases of T1DM there is no signs for autoimmune destructive attack or other known causes, and therefore these cases are classified as having idiopathic T1DM (American Diabetes Association, 2004). Typically, T1DM presents in children and young adults and is less common than T2DM.

T2DM, the focus of this thesis, is the most common type of diabetes. This type of diabetes represents approximately 87-91% of all cases of diabetes worldwide (International Diabetes Federation, 2017). In people with T2DM, hyperglycaemia develops when the insulin-sensitive tissues fail to respond to insulin action properly (insulin resistance), and the body does not produce sufficient insulin to overcome the resistance (beta-cell decline) (Ozougwu et al., 2013). T2DM is progressive, occurring over the course of several years and is usually preceded by a stage known as "pre-diabetes" (Tabák et al., 2012). In the pre-diabetes stage, blood glucose levels are elevated to a point just below the diagnosis level for diabetes (e.g. fasting plasma glucose of 5.6–6.9 mmol/L (100–125 mg/dL) or an HbA1c of 39–48 mmol/mol (5.7% to 6.5%) (Tabák et al., 2012; Dunning, 2014; Baynest, 2015). Several modifiable and non-modifiable factors contribute to the onset of T2DM. Modifiable risk factors include physical inactivity, poor diet, and obesity. Non-modifiable risk factors include older age, family history of diabetes, ethnicity, and history of gestational diabetes (American Diabetes Association, 2009). This type of diabetes was previously referred to as "non-insulin-dependent diabetes mellitus" or, as it typically affects adults, as "adult-onset diabetes".

2.2 Prevalence of type 2 diabetes

According to the International Diabetes Federation, the global prevalence of diabetes has increased rapidly throughout the last two decades (International Diabetes Federation, 2017). In 2001 there were approximately 171 million people in the world with diabetes. By 2017, this number had increased to more than 451 million adults (20-99 years old) living with diabetes, 326.5 million of them at working age (20–64 years old) (International Diabetes Federation, 2017). This number represents around 8% of the global adult population and is expected to reach 625 million by 2040 (International Diabetes Federation, 2017). This increasing prevalence of diabetes reflects population growth, increased life expectancy and aging, increased obesity rates, and sedentary lifestyles, which are considered the main risk factors for the development of diabetes (International Diabetes Federation, 2017).

The high prevalence rate of T2DM is evident in both men and women from all age groups (International Diabetes Federation, 2017). Worldwide, it is estimated that 8.3% of women aged between 20 and 79 years are living with diabetes, while the prevalence of diabetes for men is estimated to be slightly higher at 9.1% (International Diabetes Federation, 2017). T2DM tends to develop in people over the age of 40 years and the peak age of diagnosed T2DM is 65–79 years in both males and females (International Diabetes Federation, 2017). However, although T2DM is considered an age-related disease, recent studies show that the prevalence rates of T2DM are also increasing among adolescents and young adults (<40 years), especially those who are obese or from certain ethnic groups (Lascar et al., 2018; Candler et al., 2018).

T2DM is not an ethnic-specific condition and people with T2DM are from all ethnic backgrounds. However, evidence from multi-ethnic countries such as the United States of America (USA) and the United Kingdom (UK) show that there are specific ethnic groups who are at greater risk of developing T2DM compared with others (Holman et al., 2011; Meeks et al., 2016). For example, in the USA, there is low prevalence (5.5%) among Alaskan natives compared to very high prevalence (33%) among Native Americans (Spanakis and Golden, 2013). Ethnic minority groups living in Western countries are particularly at risk of developing T2DM compared with native white Europeans (Oldroyd et al., 2005; Ujcic-Voortman et al., 2009; Holman et al., 2011).

People of South Asian backgrounds particularly constitute one of the largest ethnic groups (one-fifth of the total world population) who live in different countries around the world and are disproportionally affected by T2DM (Barnett et al., 2006; Khan et al., 2011; Hanif et al., 2014; Kanaya et al., 2014). A recent meta-analysis comparing the prevalence of T2DM in ethnic minority groups and their counterparts among white Europeans found that South Asians have the highest likelihoods of T2DM, followed by people from the Middle East and North Africa, Sub-Sahara Africa, Western Pacific, and South and Central America (Meeks et al., 2016).

2.3 Type 2 diabetes in South Asians

2.3.1 Overview

The term "South Asian" refers to a group of people who describe themselves as having ancestors from South Asia or the Indian subcontinent (Gujral et al., 2013; Shrivastava and Misra, 2015; Unnikrishnan et al., 2018). South Asia or the Indian subcontinent represents the southern region of the Asian continent, which includes the following countries: India, Pakistan, Bangladesh, Nepal, Bhutan, Sri Lanka, and the Maldives. Although South Asia represents only 11% of the land area, it hosts more than one-fifth of the adults with diabetes worldwide (Unnikrishnan et al., 2018). In the global list of countries with the highest number of diabetes cases, India ranked second with more than 65.1 million cases, while Bangladesh and Pakistan were in 10th and 13th position, respectively (International Diabetes Federation, 2015).

The high prevalence rate of T2DM among South Asians persists and inflates when they live outside South Asia (Gujral et al., 2013; Meeks et al., 2016; Weisman et al., 2018). The number of immigrant South Asians is increasing rapidly (Rai and Reeves, 2009). Currently, there are approximately 30 million South Asians living in different parts of the world, especially in developed countries such as the UK, the USA and Canada (Rai and Reeves, 2009). Evidence from these countries shows that the prevalence of T2DM in South Asian communities is higher than other ethnic group (Kanaya et al., 2014; Weisman et al., 2018)A cross-sectional study in the USA, which compared the prevalence of T2DM in South Asians with four other ethnic groups, found that South Asians had the highest prevalence rates of diabetes compared with white Europeans, African Americans, Latinos and Chinese Americans, even after adjusting for potential confounders such as education, smoking, exercise and family income (23%, 6%, 18%, 17%, 13%, respectively) (Kanaya et al., 2014). In Oslo, a cross-sectional survey showed that, at similar age, prevalence of diabetes is significantly higher among people of South Asian background (up to 26%), compared with 6.4% in the native white European population (Jenum et al., 2012).

2.3.2 Type 2 diabetes in South Asians living in the UK

South Asians represent the largest ethnic minority group living in the UK, representing approximately 4.9% of the total population (approximately 3 million individuals) (Office for National Statistics, 2011). South Asians living in the UK mainly originate from India, Pakistan and Bangladesh, however, they are not a homogeneous group. South Asians living in the UK speak different languages and have different religious beliefs. The main spoken languages are Urdu, Panjabi, Sylheti, Bengali and Hindi; and the main religious beliefs are Islam, Sikhism, Hinduism and Christianity (Leung and Stanner, 2011; Office for National Statistics, 2013).

Although the actual number of South Asians with T2DM in the UK is not clearly recorded, it is estimated that 11.2% of people with T2DM in the UK are South Asians (Hanif et al., 2014). South Asians living in the UK are up to five times more likely to develop T2DM, compared with people of white European backgrounds (NHS Health and Social care

Information Centre, 2004; Holman et al., 2011; Ntuk et al., 2014). The onset of the disease also occurs up to a decade earlier in this population compared with white European people, despite having a lower body mass index (BMI) (Mukhopadhyay et al., 2006). As a result, the National Institute for Health and Care Excellence (NICE) guideline recommends encouraging South Asians to have a risk assessment at age 25 years, rather than age 40 as recommended in the general population (NICE, 2012).

2.4 Causes of the increased prevalence of T2DM among South Asians

A great deal of research has explored why South Asians are at increased risk of developing T2DM compared to white Europeans (Mohan, 2004; Barnett et al., 2006; Chowdhury and Hitman, 2007; Kanaya et al., 2010; Bhopal, 2013; Gujral et al., 2013; Misra et al., 2014; Kanaya et al., 2014; Sattar and Gill, 2015; Shah et al., 2016; Unnikrishnan et al., 2018). Yet, despite the large number of these studies there is no agreed explanation for this phenomenon (Bhopal, 2013). The aetiology is complicated and involves complex interactions of both environmental and biological factors (Bhopal, 2013). The most cited environmental and biological factors predisposing South Asians to T2DM are similar to those factors identified in other ethnic groups (Mohan, 2004; Unnikrishnan et al., 2018). These factors include physical inactivity, poor diet, obesity, insulin resistance, beta cell dysfunction, and genetic factors (Barnett et al., 2006; Bhopal, 2013; Sattar and Gill, 2015; Nanditha et al., 2016). However, the profile and the magnitude of these factors may differ in South Asians (Barnett et al., 2006; Bhopal, 2013; Misra et al., 2014; Sattar and Gill, 2015; Nanditha et al., 2016).

2.4.1 Physical inactivity

Physical inactivity is one of the contributing factors to the onset of T2DM globally (Aune et al., 2015). While people from all ethnic groups are facing difficulties in maintaining recommended physical activity levels (Hayes et al., 2002), comparative studies have reported that South Asians are less active than other ethnic groups (Shaukat et al., 1995; Lean et al., 2001; Hayes et al., 2002; Fischbacher et al., 2004; Biddle et al., 2019). For instance, Williams et al., (2011) compared self-reported physical activities levels using data from the Health Survey for England (1999–2004) on 5421 South Asians and 8974 white Europeans, and found that South Asians were approximately 60% less active than white Europeans. This difference in physical activities levels was also evident even after adjusting for age, sex, education and adiposity. However, physical activity in this study was measured using a self-reported measure. More recently, Biddle et al., (2019) examined the differences in objectively measured physical activity between adult South Asians (n=289) and white Europeans (n=963) living in the UK. All participants worn the Actigraph GT3X+ for seven days. The results of this study showed that compared to white Europeans, South Asians did significantly fewer steps (6404 vs 7405,) less moderate-vagarious activities (24 vs 33 min/day,).

2.4.2 Diet

In addition to physical inactivity, poor diet such as low fibre intake, low fruit intake, low green leafy vegetable intake, high saturated fatty acids intake, and high carbohydrate intake have been associated with insulin resistance and T2DM (Hu et al., 2001). All these factors were reported in studies examining diet habits in people from South Asian communities either living in the Indian subcontinent or in Western countries (Gopalan, 2001; Goyal and Yusuf, 2006; Misra et al., 2009; Mani and Kurpad, 2016). However, while these factors play a role, dietary factors alone cannot explain the high prevalence rates of T2DM in South Asians compared with other ethnic groups, especially since there is evidence that diet habits among South Asians are better on several counts, such as lower saturated fatty acids intake and total sugar, than those of white Europeans (Leung and Stanner, 2011; Bhopal, 2013).

2.4.3 Obesity and body composition

Obesity or excessive body fat is an independent risk factor for T2DM as it leads to insulin resistance (see section 2.4.4.below) (Al-Goblan et al., 2014; World Health Organisation, 2016). BMI, defined as weight in kilograms divided by the square of height in metres, is a widely used measure to estimate body fat and categorises people as being obese if their BMI is ≥30 kg/m^2. Typical South Asians have a lower BMI compared with white people (Mohan, 2004; Lear et al., 2009). However, a low BMI does not necessarily mean a low percentage of body fat in South Asians (Razak et al., 2007; Lear et al., 2009; Unnikrishnan et al., 2018). Abnormalities in blood glucose levels that occur in white Europeans with a BMI of >30 kg/m^2 can be seen in South Asians with a BMI of 21kg/m^2 (Razak et al., 2007).

Comparative studies have found that, at similar age and BMI, South Asians tend to have a higher percentage of total body fat, abdominal fat, visceral fat, and less muscle, compared to other ethnic groups even at birth, known as "thin-fat Indian phenotype" (Razak et al., 2007; Lear et al., 2009; Unnikrishnan et al., 2018). This phenotype is associated with more insulin resistance (see section below), and a greater propensity to develop T2DM (Lear et al., 2009; Gujral et al., 2013). In order to address this paradox of low BMI and risk of developing diabetes in South Asians, it was suggested lowering the thresholds of BMI and using other anthropometric measures related to central obesity such as waist circumference (Bodicoat et al., 2014; Patel et al., 2017).

2.4.4 Increased insulin resistance

Insulin resistance or an inability of body tissues (mainly muscles, liver and adipose tissues) to respond to insulin action is a hallmark in the pathogenesis of T2DM in all ethnic groups (Ozougwu et al., 2013). However, even at similar age, BMI and comparable diet habits, South Asians were found to have a higher degree of insulin resistance compared to other ethnic groups (Dickinson et al., 2002). Even at birth South Asians have are more insulin resistant compared to white Europeans (Lawlor et al., 2014). The cause of this increased insulin resistance among South Asians could be attributable to several factors including central obesity, as discussed above (section 2.4.3), intrauterine malnutrition and epigenetic factors (Gujral et al., 2013). Having less lean muscle compared to white Europeans has also been postulated as another factor explaining the lower insulin sensitivity in South Asians, as skeletal muscles are considered a main site for glucose disposal (Sattar and Gill, 2015). It was indicated that approximately 80% of blood glucose uptake in humans happens in skeletal muscle (DeFronzo and Tripathy, 2009).

2.4.5 Beta-cell dysfunction

Inadequate pancreatic beta-cell function (reduced insulin secretion) is central to the pathogenesis of T2DM (Ozougwu et al., 2013). Although this area has been less studied, it was suggested that South Asians experience an early decline in insulin production compared to other ethnic groups (Ikehara et al., 2015; Sattar and Gill, 2015). The reasons for this decline are still not well understood (Ikehara et al., 2015; Unnikrishnan et al., 2018). However, it has been postulated that this early decline in beta-cell function is a result of an exhaustion of beta-cells as a consequence of long-term insulin resistance from childhood (Ikehara et al., 2015). Intrauterine malnutrition, genetics, epigenetics, or endocrine disruptors such as pollution have also been postulated to play a role in beta-cell dysfunction in South Asians (Unnikrishnan et al., 2018).

2.4.6 Genetic factors

The higher prevalence of T2DM among South Asians compared to white Europeans, despite similarities in age, diet and obesity, indicates genetic and epigenetic factors underpinning the pathogenesis (Gujral et al., 2013). In addition, an association between family history and T2DM has been shown in South Asians (Viswanathan et al., 1985). Approximately 60 diabetes genes have been discovered through genome-wide association in white Europeans (Gujral et al., 2013). The majority of these genes have also been confirmed in South Asians (Ng et al., 2008; Ma and Chan, 2013). However, studies to date have not found any genetic differences between ethnic groups (Gujral et al., 2013). Rather, they have indicated that the location and frequency of alleles are different (Gujral et al., 2013).

2.5 Diabetes-related complications

Regardless of ethnicity, T2DM is associated with a number of serious acute and chronic health complications. Chronic complications contribute to the majority of morbidity and mortality associated with T2DM (de Rekeneire et al., 2003; Roglic et al., 2005; Avogaro et al., 2007). Therefore, this thesis focuses on chronic complications. However, a brief description of acute complications is considered.

2.5.1 Acute complications

Acute complications associated with T2DM are life-threatening and require immediate management. There are three main acute complications associated with T2DM namely, hypoglycaemia, diabetic ketoacidosis and hyperosmolar hyperglycaemic non-ketotic syndrome (HHNS).

Hypoglycaemia occurs when there is low level of blood glucose (Dunning, 2014). The severity of hypoglycaemia ranges from mild where it can be self-treated, to severe where help is required (Dunning, 2014). The initial symptoms associated with hypoglycaemia are sweating, feeling dizzy, fatigue and blurred vision (Dunning, 2014). A blood glucose level below 3.0 mmol/l is considered clinically significant hypoglycaemia (International

Hypoglycaemia Study Group, 2017). Hypoglycaemia is less common among people with T2DM, compared with those living with type 1 diabetes (Zammitt and Frier, 2005). However, it does frequently affect people with T2DM who are treated by insulin or hypoglycaemic agents (Gehlaut et al., 2015).

Diabetic ketoacidosis and HHNS, on the other hand, are both hyperglycaemic emergencies (Umpierrez et al., 2002). Diabetic ketoacidosis occurs when there is a high blood glucose level, but the body cannot absorb glucose due to a lack of insulin (Umpierrez et al., 2002). Consequently, the body starts to metabolise fat and produces ketones bodies (ketogenesis) (Umpierrez et al., 2002). Typical symptoms and signs of diabetic ketoacidosis evolve within 24 hours and include vomiting, dehydration, increased respiratory rate, acetone smell on breath, and abdominal pain (Kearney and Dang, 2007). Since the lack of insulin is the main cause, diabetic ketoacidosis tends to mainly affect people with type 1 diabetes or those with T2DM who produce little insulin (Umpierrez et al., 2002).

HHNS occurs mainly in people with T2DM. This condition develops over a period of a week as a result of having high blood glucose levels (>33 mmol/l (600 mg/dl) for long time (Kearney and Dang, 2007). It is characterised by relative reduction in insulin concentration to maintain a normal glucose level but adequate levels to prevent ketogenesis (Umpierrez et al., 2002). HHNS symptoms include high blood glucose levels, dehydration, confusion thirst, and nausea (Kearney and Dang, 2007).

2.5.2 Chronic complications associated with type 2 diabetes

Above and beyond the acute complications, T2DM is strongly associated with both micro- and macrovascular diseases (Fowler, 2008; Cade, 2008; Shah and Kanaya, 2014). These diseases can lead to acquired blindness, renal failure, non-traumatic lower-limb amputations, physical disability, neurological deficits, myocardial infarctions, stroke, and poor quality of life (Fowler, 2008; Cade, 2008; Shah and Kanaya, 2014). Not only do micro- and macrovascular diseases affect people with longstanding diabetes, they can also be present at diagnosis or even in those yet to be diagnosed. For example, a recent study found that 35% of people with T2DM had diabetes-related complications at the time of diagnosis (Gedebjerg et al., 2018).

2.5.2.1 Microvascular diseases

Microvascular diseases are vascular diseases resulting from alterations in small (micro) vessels (e.g. arterioles, capillaries and venules) (Girach et al., 2006; Vithian and Hurel, 2010). The main cause of microvascular diseases is chronic hyperglycaemia (Vithian and Hurel, 2010). As such, microvascular diseases tends to mainly affect insulin-dependent tissues such as kidney (nephropathy), retina (retinopathy) and vascular endothelium where tissues are exposed to glucose levels that are relatively comparable to blood glucose levels (Vithian and Hurel, 2010).

Diabetic retinopathy is a common progressive condition responsible for more than 2.6% of acquired blindness worldwide (Bourne et al., 2013). Diabetic retinopathy occurs when there is alteration in retinal vascular permeability and/or structure (Vithian and Hurel, 2010). The severity of diabetic retinopathy ranges broadly from mild vision problems (non-proliferative) to more severe form where abnormal capillaries begin to develop within the retina, leading to vision loss and retinal detachment (proliferative retinopathy) (Harding, 2003; Duh et al., 2017). Approximately 16.3–47% of people with T2DM have some evidence of retinopathy (Lee et al. 2015).

Diabetic nephropathy or diabetic kidney disease is another common and serious microvascular complication that can lead to kidney failure, requiring dialysis and kidney transplantation (Fowler, 2008). Diabetic nephropathy results from glomerular damage derived by hyperglycaemia and hypertension (Vithian and Hurel, 2010). The glomerulus is a tuft of small blood vessels in the kidneys and is involved in blood filtration. Nephropathy progresses through recognisable stages. The first stage is typically microalbuminuria, which progresses to overt albuminuria and then to renal failure (Fowler, 2008). Approximately 25% of people with T2DM develop some degree of diabetic nephropathy (Adler et al., 2003).

Diabetic neuropathy or damage to nerves is another common microvascular complication in people with T2DM, affecting approximately half of people with diabetes (Singh et al., 2014). It involves somatic sensory nerves, motor nerves, and autonomic nerves (Tesfaye and Boulton, 2009). Depending on the nerve affected, neuropathy can lead to different consequences including decreased sensation, impaired coordination, muscle weakness, balance problems, painful limbs, resting exercise intolerance, and orthostatic hypotension

(Cade, 2008). Decreased sensation in the lower limbs may increase the risk of lower-limb amputation (Cade, 2008). This is mainly because people with impaired sensation tend not to recognise injuries, which in turn leads to delay in treatment and infected wounds. Not surprisingly, people with T2DM are at more than 25 times greater risk of amputation than those without the condition (International Diabetes Federation, 2017).

2.5.2.2 Macrovascular diseases

Macrovascular diseases are those vascular diseases resulting from structural or functional changes in medium and large-sized blood vessels including coronary artery diseases, cerebrovascular disease, and peripheral artery disease (Cade, 2008). The cause of death in those with T2DM is dominated by these complications (Rahman et al., 2007; Thomas, 2016). T2DM increases the risk of macrovascular diseases by advancing the risk of developing atherosclerosis (Fowler, 2008). Atherosclerosis is a condition in which the inside of an artery hardens and narrows due to the build-up of fatty substances, leading to reduced or blocked blood flow (Hales, 2011). T2DM is an independent risk factor for macrovascular complications (Cade, 2008). Although the mechanisms through which T2DM contributes to the formation of the atherosclerotic plaque are not well understood, it is widely believed that hyperglycaemia, along with other traditional risk factors such as hypertension and dyslipidaemia, which are common among people with T2DM, can act both independently and cumulatively over time to significantly increase the risk (Fowler, 2008; Martín-Timón et al., 2014).

Coronary heart disease is of particular concern in people with T2DM as it is the most common cause of death among people with T2DM (Rahman et al., 2007; Cade, 2008; Thomas, 2016). People with T2DM are at least two times more likely to experience a myocardial infarction compared with individuals without diabetes (Anand et al., 2000; Juutilainen et al., 2004). People with T2DM also tend to have poorer outcomes after myocardial infarction than people without diabetes, including developing congestive heart failure (Thomas, 2016). Statistically, people with T2DM have a higher risk of mortality after myocardial infarction compared with a person without diabetes (Kapur and De Palma, 2007; Thomas, 2016).

Other than coronary heart disease, T2DM increases the risk of cerebrovascular disease, which results in stroke and neurological deficits (Shah et al., 2015). The risk of experiencing a stroke is up to four times greater in people with T2DM (Deshpande et al., 2008). Similar to coronary artery disease, individuals with T2DM who survive a stroke are more likely to have poorer outcomes, and higher recurrence and mortality rates than those without diabetes (Elneihoum et al., 1998; Parsons et al., 2002; Megherbi et al., 2003). For instance, Megherbi et al. (2003) found that people affected by stroke tend to have greater limb weakness and disability (measured by the Barthel Index) when they have diabetes.

Peripheral artery disease, another macrovascular disease, is strongly associated with T2DM (Shah et al., 2015). It affects about one-third of people with T2DM (Thiruvoipati et al., 2015). Peripheral artery disease results from blockage or narrowing of lower-limb arteries due to atheroma (Thiruvoipati et al., 2015). The main symptom associated with peripheral artery disease is intermittent claudication, which is a disabling condition characterised by pain or cramping in the calves, thighs or buttocks, which increases with activity and decreases with rest (Dolan et al., 2002). Peripheral artery disease reduces peripheral blood flow in small vessels leading to ischaemia and is associated with poor wound healing and therefore it is considered a main risk factor for gangrene and lower-extremity amputation (Cade, 2008).

2.5.2.3 Physical disability

T2DM is a strong predictor of functional disability. Gregg et al. (2000) estimated the incidence of physical disability, defined by the inability to perform activities associated with daily living, was double for people with T2DM as compared to people with other chronic diseases. This increased risk of disability can be explained by the wide range of complications associated with T2DM (Tabesh et al., 2018). In addition, T2DM was found to accelerate the risk of sarcopenia (e.g. progressive and generalised loss of skeletal muscle mass), which in turn increases the risk of functional limitations (Volpato et al., 2012; Umegaki, 2015). For example, Park et al., (2007) measured muscle strength in 1840 participants at baseline and after 3 years and found that people with T2DM had significant deterioration in muscle strength with time as compared to people without diabetes.

2.5.2.4 Poor quality of life

Considering quality of life as a complication reflects the wider concept of health. The World Health Organization defines health as a "state of complete physical, mental, and social wellbeing and not merely the absence of disease or infirmity" (WHO 2006). It is also well recognised that T2DM negatively affects quality of life (Clouet et al., 2001; Trikkalinou et al., 2017). Clouet et al. (2001) found that people with T2DM have poorer quality of life compared with healthy people. The problem is more evident among those living with diabetes-related complications (Trikkalinou et al., 2017).

2.5.3 Diabetes-related complications in South Asians

The term "South Asian" itself is a well-established, non-modifiable risk factor for vascular complications, even in the absence of diabetes (Gupta et al., 2006; Nair and Prabhakaran, 2012). Several studies have compared the risk and prevalence of diabetes-related complications between South Asians and other ethnic groups, mainly white Europeans (Chowdhury and Lasker, 2002; Bellary et al., 2010; Nair and Prabhakaran, 2012)

Overall, it appears that, compared to white Europeans, South Asians are at greater risk of developing diabetes-related complications, particularly retinopathy, nephropathy, coronary heart disease and stroke (Chowdhury and Lasker, 2002; Gupta and Misra, 2016b; Gupta and Misra, 2016a). With regards to coronary heart disease, Mather et al. (1998) found that South Asians with diabetes are 3.8 times more likely to have a myocardial infarction compared with white Europeans. Regarding stroke, the risk is up to three-fold higher in South Asians compared with white Europeans (Tan et al., 2002) (Shah and Kanaya, 2014). Only peripheral artery disease and neuropathy were found to be less common among South Asians compared with white Europeans (Gupta and Misra, 2016b; Gupta and Misra, 2016a). The reason behind this is unknown. However, some authors have postulated that the lower rate of smoking in South Asians compared with white Europeans might be the reason (Shah and Kanaya, 2014; Gupta and Misra, 2016b; Gupta and Misra, 2016a).

Diabetes-related complications also affect South Asians at a younger age and more severely than white Europeans (Shah and Mohan, 2015). Several factors may explain this (Garduño-Diaz and Khokhar, 2012). Firstly the early onset of T2DM and delayed diagnosis (Garduño-Diaz and Khokhar, 2012). Second, traditional cardiovascular risk factors have been found to be more pronounced in South Asians than in white Europeans (Garduño-Diaz and Khokhar, 2012). Third, diabetes management remain poor in people of a South Asian background as it was reported that South Asians had worse glycaemic control compared with white Europeans (Mukhopadhyay et al., 2006; James et al., 2012; Negandhi et al., 2013).

Despite this trend, recent studies have failed to replicate the higher prevalence of diabetes-related complications in South Asians as compared with white Europeans seen in earlier work (Gupta and Misra, 2016a; Johns and Sattar, 2017). A study conducted in the UK involving 1486 South Asians and 492 white Europeans with T2DM found that cardiovascular events and deaths were not significantly greater among South Asians compared with white Europeans (Bellary et al., 2010). This difference in the prevalence of diabetes-related complications between earlier published work and recent studies might be due to the fact that South Asians have recently benefited from earlier detection and treatment of diabetes, better screening and treatment for cardiovascular risk factors, and earlier exposure to anti-glycaemic and blood lipid lowering drugs (Johns and Sattar, 2017). For example, The National Institute for Health and Clinical Excellence recommends that general practitioners should consider diabetes risk assessment for South Asians at age 25 years, rather than age 40 as recommended in the general population (NICE, 2012). In addition, several prevention programmes targeting ethnic minority groups have been introduced in the last decade with the stated aim of targeting high risk groups and reducing health disparities such as the healthier you programme (NHS, 2019). As such it could be argued that earlier published work that reported high diabetes-related complications in south Asians may have included first generation South Asian migrants who may have had longer periods of undiagnosed diabetes (Johns and Sattar, 2017).

2.6 Risk factors for diabetes-related complications

Identifying risk factors associated with T2DM and its negative consequences provides the basis for designing health interventions that have the capacity to minimise the risk of developing such complications (Leon and Maddox, 2015; American Diabetes Association, 2016). Numerous studies have explored risk factors in people with T2DM and found that many factors are strongly linked to T2DM and its complications (Nazimek-Siewniak et al., 2002; Adler et al., 2003; Colhoun et al., 2004; Girach et al., 2006; Orr et al., 2006; Park et al., 2007; Fowler, 2008; del Cañizo Gómez et al., 2011; Mannucci et al., 2013; Bianchi et al., 2013; Lee et al., 2015). These factors can be divided into modifiable and non-modifiable factors (Table 2. 1).

Table 2. 1 Common risk factors for diabetes-related chronic complications in people with type 2 diabetes[1]

Risk factor		**Microvascular disease**			**Macrovascular**			**Disability**
Modifiable		Retinopathy	Neuropathy	Nephropathy	Coronary artery disease	Cerebrovascular disease	Peripheral vascular disease	
	Poor glycaemic control	√	√	√	√	√	√	√
	Hypertension	√	√	√	√	√	√	
	Abnormal blood lipids profile	√	√	√	√	√	√	
	BMI and/or waist circumference	√	√	√	√	√	√	√
	Lack of exercise				√	√		√
	High fat diet							
	Tobacco use	√	√	√	√	√	√	
	Muscle weakness				√			√
	Poor physical performance							√
	Insulin resistance				√	√	√	
Non-modifiable	Age	√	√					
	Ethnicity and family history	√	√	√	√	√	√	√
	Early onset of T2DM	√			√	√		
	Time since diagnosis	√	√	√	√	√	√	√
	Gender				√	√		√
	Comorbidities	√						

[1] The table was adapted from Cade (2008) and was expanded based on information from Gupta et al., 2006; Cade, 2008; Paulweber et al., 2010; Bellary et al., 2010b; Nair and Prabhakaran, 2012; Umegaki, 2015; Wong et al., 2016; Patel et al., 2017; Tabesh et al., 2018)[1]

2.6.1 Non-modifiable risk factors

Non-modifiable risk factors are defined as those factors that increase the risk of complications but cannot be resolved or changed (USFC, 2019). Older age, longer duration of diabetes, gender, early onset, and ethnicity are the most common non-modifiable factors associated with T2DM and its complications (Girach et al., 2006). Since these factors cannot be controlled, it is of great importance to target modifiable risk factors (American Diabetes Association, 2016).

2.6.2 Modifiable risk factors for diabetes-related complications

Modifiable risk factors are those factors that increase the risk but are amendable to treatment (USFC, 2019). The most common modifiable risk factors associated with T2DM and its complications are hyperglycaemia, hypertension, abnormal blood lipid profile, obesity, muscle weakness, and poor functional performance (Bruce et al., 2005; Girach et al., 2006; Cade, 2008).

2.6.2.1 Hyperglycaemia

Hyperglycaemia or poor glycaemic control is a main risk factor for both micro- and macrovascular complications (Shah et al., 2015). Glycated haemoglobin (HbA1c) is the gold standard in measuring glycaemic control as it measures average blood glucose levels during the previous two to three months (Sherwani et al., 2016). People with T2DM are advised to keep their HbA1c below 6.5-7% (NICE, 2015). Many studies have shown that people with poor glycaemic control, as measured by HbA1c, are at greater risk of developing diabetes-related complications (Stratton et al., 2001; del Cañizo Gómez et al., 2011; Nicholas et al., 2013). South Asians, who have higher prevalence of complications, were also found to be more likely to have poorer glycaemic control than white Europeans (Mukhopadhyay et al., 2006).

2.6.2.2 Blood lipid profile

Dyslipidaemia, abnormal lipid profile, is a major cardiovascular disease risk factor, which is the main cause for morbidity and mortality in people with T2DM (Wong et al., 2016). Dyslipidaemia coexists in almost 50% of people with T2DM mainly due to insulin resistance, which increases the mobilisation of free fatty acids from adipose tissues (Saydah et al., 2004; Leon and Maddox, 2015). The blood lipid profile in people with T2DM is characterised by high triglyceride levels, low high-density lipoprotein (HDL) levels and high or normal low-density lipoprotein (LDL) levels, (Krauss, 2004; Rask-Madsen and King, 2013). This pattern of lipid profile is strongly associated with atheroma and cardiovascular disease and therefore is referred to as "atherogenic dyslipidaemia" (Nazimek-Siewniak et al., 2002; Miccoli et al., 2008; Leon and Maddox, 2015). Studies comparing blood lipid profiles in South Asians and white Europeans have shown that the former have higher triglyceride and lower HDL cholesterol (Anand et al., 2000; Bilen et al., 2016).

For people with T2DM the following levels are recommended: total cholesterol < 4.0 mmol/l, LDL < 2.0 mmol/l, triglyceride < 1.7 mmol/l, and HDL > 1.0 for men or 1.2 mmol/l for women (Diabetes UK, 2019). Current evidence shows that lowering the blood lipid profile in people with T2DM decreases the risk of cardiovascular complications (Colhoun et al., 2004; Sugiyama and Saisho, 2018). For example, in a randomised controlled trial, Colhoun et al. (2004) demonstrated that the risk of stroke and coronary artery disease decreased significantly in those with T2DM who received blood lipid lowering medication as compared to the placebo group.

2.6.2.3 Hypertension

Hypertension is another risk factor for micro- and macrovascular complications in people with T2DM. The latest definition of hypertension is an average systolic blood pressure of (SBP) ≥130 mmHg, and an average diastolic blood pressure of (DBP) ≥80 mmHg (Thomas et al., 2017). An estimated two-thirds of people with T2DM have hypertension (Pavlou et al., 2018). Obesity, visceral obesity, aging, and endothelial dysfunction are the most common pathogenetic factors contributing to the high prevalence of hypertension among people with T2DM (Pavlou et al., 2018). However, unlike glycaemic control and blood lipid profile, blood pressure tends to be similar or lower among South Asians compared with white Europeans (Agyemang and Bhopal, 2002). A blood pressure goal of <140/90 is recommended for people with T2DM (Solini and Grossman, 2016). The evidence also suggests that improvements in systolic/diastolic blood pressure may result in a 10% reduction in cardiovascular risk in people with and without diabetes (Turnbull et al., 2005; Blood Pressure Lowering Treatment Trialists' Collaboration et al., 2013).

2.6.2.4 Obesity

Excessive body fat is also an important risk factor associated with cardiovascular disease. Obesity is also associated with disability in people with T2DM as it leads to immobility (Tabesh et al., 2018). The difference in body fat distributed between South Asians and white European is discussed above (section 2.4.3). BMI is an obesity measure that is widely used to indicate cardiovascular risk (Misra, 2015). The recommended cut off scores in South Asian populations to define obesity are as the follow: normal 18–22.9 kg/m^2, overweight 23–24.9 kg/m^2, obese > 25) (Misra, 2015).

Waist circumference (WC) has also been found to be a useful anthropometric indicator of cardiovascular risk in people from South Asian backgrounds (Patel et al., 2017). This is mainly because South Asians tend to have central obesity (Patel et al., 2017). It was found that a WC greater than 90cm in South Asian men and 88cm in South Asian women is associated with greater risk of cardiovascular disease (Misra and Shrivastava, 2013).

2.6.2.5 Muscle weakness and physical function decline

Poor performance on objective functional mobility tests and muscle weakness are also associated with disability in people with T2DM (Sakurai et al., 2012; Leenders et al., 2013; Bianchi et al., 2013). The majority of studies targeting muscle weakness and physical function in people with T2DM tend to focus on people with diabetic neuropathy or the elderly. However, muscle weakness and poor physical performance in functional mobility tests are reported even in those without diabetic neuropathy and in middle age (Yavuzer et al., 2006). For this reason, targeting these factors is of great importance.

2.7 Physiotherapy in T2DM management

The main aim of T2DM management is to prevent or delay the onset of diabetes-related complications (Colberg et al., 2010; Leon and Maddox, 2015). Effective treatment therefore requires targeting the risk factors associated T2DM and its complications (Leon and Maddox, 2015). Exercise has the potential to improve a number of the risk factors associated with T2DM complications (Colberg et al., 2010; De Feo and Schwarz, 2013). Therefore, exercise interventions are now recommended by several international organisations such as the International Diabetes Federation, The European Association for the Study of Diabetes, the American Diabetes Association, American College of Sports Medicine and the Belgian physiotherapy (Inzucchi et al., 2012; Hansen et al., 2013; International Diabetes Federation Guideline Development Group, 2014).

According to the Charted Society of Physiotherapy, physiotherapists are one of the healthcare professionals who can advise on, and design, personalised exercise programmes that aim to target the risk factors associated with T2DM and its complications (Charted Society of Physiotherapy, 2019). Physiotherapists often work with other health care professionals on a multidisciplinary team to manage T2DM and it's complications (Charted Society of Physiotherapy, 2019; NHS Networks, 2019) Physiotherapists are also involved in self-management education programmes and weight reduction programmes offered for people with T2DM (Buckinghamshire Healthcare NHS Trust, 2019). In addition, people with T2DM often have other comorbidities such as osteoarthritis, heart disease, balance problems and neuropathy. In these cases, it is important that the exercise programmes designed for people with T2DM meets their personal needs and functional ability. Physiotherapists role is to provide specialist assessment, personal advice, and prescription and monitoring of personalised exercise programmes.(Cade, 2008; Charted Society of Physiotherapy, 2019; NHS Networks, 2019). Physiotherapists also encounter people with T2DM in homecare and the private sector (Hansen et al., 2013). With this in mind, the following section will discuss the effect of exercise programmes on the risk factors associated with T2DM complications.

2.7.1 Clarification of terms related to exercise

The terms *exercise* and *physical activity* tend to be used interchangeably in the literature but their meanings, while closely related, are not the same. *Physical activity* is defined as "any body movement produced by skeletal muscles that results in energy expenditure above resting level'' (Kruk, 2009, p.1). These body movements include shopping, gardening and all leisure activities. Exercise is define as a "predetermined structured programme of physical activity described in terms of type, intensity, duration and weekly frequency (Haddad et al. 2003, p.1). Evidence suggests that exercise interventions are more effective than physical activity advice alone in improving diabetes related complications risk factors (Umpierre et al., 2011). The following section will discuss the use of exercise interventions in T2DM management.

2.7.2 The effect of exercise interventions

Overall, the evidence regarding the impact of exercise interventions on the risk factors associated with T2DM complications are positive. A number of systematic reviews and meta-analyses showed that, compared to no exercise, exercise interventions of eight weeks or more resulted in a significant improvement in glycaemic control (Gordon et al., 2009; Liubaoerjijin et al., 2016; Cai et al., 2017). These studies reported that exercise leads to a decrease in HbA1c by up to 0.89% (Umpierre et al., 2011). This change is clinically important as it could minimise the risk of both micro and macro complications associated with T2DM (Sherwani et al., 2016). The exercise-induced reduction in HbA1c is also associated with a reduction in the need for hyperglycaemia-related medications (Cuff et al., 2003).

It is believed that exercise promotes glycaemic control in people with T2DM mainly through improving whole-body insulin sensitivity (Way et al., 2016). A systematic review and meta-analysis of 14 randomised controlled trials (RCTs) examining the effect of exercise interventions on insulin sensitivity in people with T2DM found significant improvements in favour of exercise compared with a control group which was generally usual care (Way et al., 2016). However, it should be noted that improvement in insulin sensitivity usually deteriorated within three to ten days of the last exercise session (van Dijk and van Loon, 2015). Therefore, the long-term effect of exercise on glycaemic control in people with T2DM is mainly attributable to the cumulative effect of individual exercise sessions rather than long-term adaptation to exercise (van Dijk and van Loon, 2015).

Blood lipid profiles in people with T2DM were also found to improve after exercise interventions (Hayashino et al., 2012; Pan et al., 2018). Evidence from systematic reviews and meta-analyses showed that exercise interventions significantly decreased total cholesterol and LDL triglyceride levels and raised HDL cholesterol (Hayashino et al., 2012; Pan et al., 2018). For example, Hayashino et al. (2012) undertook a systematic review and meta-analysis of 42 RCTs and found that exercise interventions significantly reduced low-density lipoprotein levels by 0.16 mmol/L and significantly improved HDL levels by 0.08 mmol/L for people with T2DM, although no significant change in triglyceride levels was shown. More recently, Pan et al., (2018) conducted a systematic review and regression analysis of 37 RCTs and found that, compared to no exercise, exercise interventions resulted in significant reductions in total cholesterol by 1.12 mmol/L, triacylglycerol by 1.1 mmol/L, and LDL by 0.7 mmol/L. However, it was argued that the exercise-induced improvement in blood lipid profiles is less likely to meet the targeted levels recommended for people who are at greater risk of cardiovascular events (Kemps et al., 2019). As such, the European Association of Preventive Cardiology emphasised that exercise should support lipid-lowering medication for achieving target blood lipid values, but should not replace medication (Kemps et al., 2019).

Exercise interventions also have a beneficial effect on blood pressure in people with T2DM (Figueira et al., 2014; Zou et al., 2016). Figueira et al. (2014) conducted a systematic review and meta-analysis to examine the effect of exercise interventions on blood pressure in people with T2DM. The authors included 30 RCTs and found that compared to no exercise, exercise interventions significantly decreased both systolic and diastolic blood pressure by 4.22 mmHg and 2.07 mmHg, respectively. In a more recent systematic review, Zou et al. (2016) reported a greater improvement in SBP (7.98 mmHg) and a similar reduction in DBP by 2.70 mmHg when exploring the impact of exercise interventions specifically on obese people with T2DM.

Measures related to obesity were also found to improve with exercise interventions in people with T2DM (Sabag et al. 2017). Sabag et al. (2017) conducted a systematic review and meta-analysis to examine the impact of exercise interventions on visceral fat levels in overweight/obese people with T2DM. The authors included 24 RCTs and found that exercise interventions of four weeks or more significantly improved visceral fat levels when measured using magnetic resonance imaging, computed tomography, proton magnetic resonance spectroscopy or muscle biopsy in people with T2DM. Other obesity measures, such as waist circumference and BMI, were also found to improve after exercise interventions (Chudyk and Petrella, 2011; Qiu et al., 2014). However, exercise guidelines and systematic reviews highlighted that exercise interventions are less likely to be successful if they are not combined with dietary interventions (Thomas et al., 2006; Colberg et al., 2010; Qiu et al., 2014).

Muscle strength in people with T2DM has also been shown to improve with exercise (Irvine and Taylor, 2009; Hovanec et al., 2012; Lee et al., 2017). In terms of muscle strength, there is convincing evidence from systematic review and meta-analyses that resistance exercise interventions significantly improve muscle strength in people with T2DM (Irvine and Taylor, 2009; Hovanec et al., 2012; Lee et al., 2017). For example, Irvine and Taylor, (2009) conducted a systematic review of 9 RCTs and showed that resistance exercise significantly improved muscle strength in elderly with T2DM.

However, very little work has been done to explore the impact of exercise on functional mobility in people with T2DM, despite the need for research in this field. Previous work targeting functional mobility in people with diabetes focused on diabetic neuropathy and included participants with both Type-1 diabetes and T2DM (Richardson et al., 2001; Richardson et al., 2004; Mueller et al., 2013). In addition, the majority of outcome measures relating to functional mobility and balance have not been validated for use with people with T2DM (Dixon et al., 2017). Despite this, results that have emerged from the few studies including only people with T2DM are promising (Castaneda and Layne, 2002; Allet et al., 2010; Park and Lee, 2015). For example, an RCT conducted by Allet et al. (2010) compared the effects of 12 weeks of exercise in people with T2DM alongside a control group who received no treatment. The authors used several measures related to functional mobility, including performance-oriented mobility assessments, static balance and dynamic balance. The overall results showed that all of these measures significantly improved in individuals in the exercise group compared with the control group.

The benefits of exercise interventions go beyond the physiological effects reported above to that of quality of life. Investigating the effects of exercise interventions on quality of life reflects the wider concept of health. Two systematic reviews examined the impact of exercise on quality of life. Van der Heijden et al. (2013) were unable to draw a clear conclusion due to limitations such as the heterogeneity of participants and the different outcome measures used to estimate the effect of exercise on quality of life. Therefore, they emphasised that more research in this area is required. More recently, Cai et al. (2017) conducted a systematic review of 30 clinical trials and found that exercise interventions significantly improved quality of life in people with T2DM.

Despite the improvements mentioned above, not all of the mentioned outcomes were shown to improve among all the studies (Böhm et al., 2016). Variations in response to exercise are observed, especially in outcomes such as blood lipid variables, BMI and blood pressure. This variation in response could be attributed to several factors, including variation in the selection of exercise types, duration of the exercise sessions, frequency and/or intensity levels. In addition, it is believed that non-compliance and participant characteristics play an important role (Böhm et al., 2016). The following section will highlight these aspects.

2.7.3 Exercise dose parameters in Type-2 diabetes management

2.7.3.1 Length of exercise interventions

For people with T2DM, it appears that exercise interventions should be lifelong and undertaken on a regular basis (Oliveira et al., 2012). Although improvements in risk factors such as glycaemic control, blood pressure, muscle strength and functional mobility in people with T2DM have been reported after participating in exercise interventions over a short duration (e.g., eight weeks), the effect of exercise on these variables in people with T2DM is lost very rapidly on cessation (Hordern et al., 2012; Park and Lee, 2015; Kemps et al., 2019). In addition, systematic reviews and meta-analyses involving studies with different intervention lengths noted a strong positive relationship between the length of the exercise intervention and outcome measures in people with T2DM (Zou et al., 2016; Grace et al., 2017). For example, Grace et al. (2017) found that exercise interventions of 13 weeks significantly improved glycaemic control, as measured by HbA1c, by 0.69% after exercise intervention as compared to a control group. The authors performed sub-analysis and noted more improvement in HbA1c by 0.009% -0.043% after every additional week of exercise. Zou et al. (2016) conducted a systematic review and meta-analysis in which studies were stratified by intervention lengths (3, 4, 6, and 12 months) and noticed that blood pressure and total cholesterol only improved significantly after six months, while HDL-C only improved after 12 months.

2.7.3.2 Types, intensity and duration of exercise interventions

The success of exercise interventions in people with T2DM depends greatly on the selection of the appropriate type of exercise with appropriate dosage variables (Schwingshackl et al., 2014; Pan et al., 2018). Exercise prescription guidelines for people with T2DM recommends aerobic, resistance and combined aerobic and resistance exercise interventions (Colberg et al., 2010; Hordern et al., 2012; Mendes et al., 2015; Kemps et al., 2019). Aerobic interventions refer to exercise programmes that involve planned activities aimed at raising heart rate and oxygen consumption such as walking, treadmill use, running, stepping, rowing and cycling (Balducci et al., 2014). Evidence from systematic reviews and meta-analyses revealed that aerobic exercise interventions have the potential to improve a wide range of risk factors associated with T2DM and its complications, including glycaemic control, blood pressure, blood lipids profile, BMI and quality of life (Haddad et al., 2003; Kelley and Kelley, 2007; Chudyk and Petrella, 2011; Qiu et al., 2014; Liubaoerjijin et al., 2016; Rees et al., 2017; Cai et al., 2017; Qiu et al., 2017; Grace et al., 2017).

In order to achieve improvements, it is widely recommended that people with T2DM undertake at least 150 minutes of aerobic exercise at moderate intensity, spread over three to five sessions a week with no more than two consecutive days of rest (Mendes et al., 2015). Aerobic exercise sessions can be performed for 30–60 minutes per session or in bouts of ten minutes throughout the day (Mendes et al., 2015). Manipulation of aerobic exercise variables, such as intensity, duration, volume or frequency, may influence the impact of such interventions (Umpierre et al., 2013; Liubaoerjijin et al., 2016). Aerobic exercise interventions fewer than three times a week and/or at low intensity were found to be less likely to cause a positive impact on glycaemic control or other risk factors in people with T2DM (Hordern et al., 2012). In contrast, studies with higher exercise intensity and/or longer weekly durations (> 150 minutes a week) tended to report better results in terms of glycaemic control, blood lipids, blood pressure and body weight (Umpierre et al., 2013; Liubaoerjijin et al., 2016). As such, several guidelines encourage people with T2DM to perform aerobic exercise at high intensity and longer duration, but exercise progression should be slow (Marwick, Matthew D Hordern, et al., 2009; Hordern et al., 2012; Colagiuri et al., 2013; Dugan, 2016; Kemps et al., 2019).

Resistance exercise is another form of exercise that is recommended for people with T2DM (Colberg et al., 2010; Mendes et al., 2015). This type of interventions refers to exercise programmes aimed at increasing muscle strength and requiring skeletal muscles to resist body weight (or an external weight) in order to force them to contract (McGinley et al., 2015). Lifting free weights, push-ups, sit-ups and using resistance bands are good examples of such exercises. Authors recommending resistance exercise argue that people with T2DM are usually obese and elderly and, as such, it is easier for them to participate in resistance exercise than aerobic exercises (Willey and Singh, 2003; Gordon et al., 2009). In addition, people with T2DM are often prone to muscle weakness and are at a higher risk of decreased functional ability and disability. Therefore, resistance-based exercise may be of particular importance (Willey and Singh, 2003; Gordon et al., 2009).

Several systematic reviews examined the impact of resistance exercise interventions in people with T2DM and showed positive results in terms of improving glycaemic control, blood lipids profile, blood pressure, muscle strength and functional mobility (Irvine and Taylor, 2009; Gordon et al., 2009; Hills et al., 2010; Lee et al., 2017; Liu et al., 2019). However, in order to achieve improvements, it is generally recommended that resistance exercise should involve one to four sets of five to ten multi-joint exercises targeting the main muscle groups, at a moderate to vigorous intensity of 50–80% of the one-repetition maximum test, and ideally three times a week (Colberg et al., 2010; Mendes et al., 2015). Evidence from a recent meta-analysis of 24 RCTs shows that even low to moderate-intensity resistance exercise was found to improve glycaemic control in people with T2DM (Liu et al., 2019). However, this meta-analysis also showed that high-intensity exercise interventions were associated with greater improvements in glycaemic control compared with low to moderate intensity interventions (Lee et al., 2017; Liu et al., 2019).

The impact of aerobic and resistance exercise interventions appears to be similar in terms of improving glycaemic control, blood pressure and blood lipids (Yang et al., 2013; Nery et al., 2017; Pan et al., 2018). Several systematic reviews and meta-analyses compared the impact of aerobic and resistance exercise interventions in people with T2DM and found neither statistically significant nor clinically important differences in terms of glycaemic control, blood lipid levels and blood pressure (Nery et al., 2017). Despite this, resistance exercise interventions were found to have a greater effect on muscle strength and functional capacity compared with aerobic exercise; while aerobic exercise was found to be superior to resistance exercise in terms of improving body weight and quality of life (Irvine and Taylor, 2009; Yang et al., 2013; Nery et al., 2017; Pan et al., 2018).

However, people with T2DM may benefit more by undertaking a combination of aerobic and resistance exercise (Reid et al., 2010; Chudyk and Petrella, 2011; Umpierre et al., 2013; Schwingshackl et al., 2014; Pan et al., 2018). Systematic reviews and meta-analyses comparing the impact of different exercise interventions for people with T2DM showed that a combination of resistance and aerobic exercise would be more beneficial than either aerobic or resistance exercise alone (Snowling and Hopkins, 2006; Schwingshackl et al., 2014). As such, several exercise prescription guidelines recommend combined exercise interventions for people with T2DM (Colberg et al., 2010; Mendes et al., 2015).

Combined interventions can either involve resistance and aerobic exercise in the same session three times a week, or in separate sessions five times a week (e.g., three days aerobic and two days resistance) (Oliveira et al., 2012; Umpierre et al., 2013). Establishing the most effective dose of combined training in terms of improving glycaemic control and preventing complications is difficult due to the lack of high-quality studies comparing different dosage variables (Oliveira et al. 2012). Oliveira et al. (2012) conducted a systematic review in order to analyse the characteristics of combined interventions and the extent to which they improve glycaemic control in people with T2DM. A total of 28 studies with different study designs were included in this review. However, due to variations between the studies in terms of duration, intensity, frequency and type of exercise, the authors were unable to recommend a specific type of exercise. Combined interventions involving moderate aerobic exercise of at least 33 minutes combined with one to four sets of five to ten multi-joint exercises targeting the main muscle groups at a moderate intensity at least three times a week, showed positive results in terms of glycaemic control (Oliveira et al., 2012; Umpierre et al., 2013). In addition, splitting aerobic and resistance exercise sessions between different days might have additional benefits for glycaemic control (Oliveira et al., 2012).

Few studies have examined the effects of a combination of aerobic and/or resistance exercise with other types of exercise (e.g., balance or functional training) (Ozdirenç et al., 2004; Allen et al., 2010; Morrison et al., 2014). Studies that have incorporated a variety of exercises, such as balance, gait training, aerobic and strengthening, tend to focus on the effects of exercise on functional performance in people with T2DM. For example, an RCT conducted by Allet et al. (2010) compared the effects of 12 weeks of balance and gait training as well as function-oriented strengthening in people with T2DM alongside a control group receiving no treatment. The overall results showed that performance-oriented mobility assessment, static and dynamic balance significantly improved in the exercise group compared to the control group.

2.7.4 Participant characteristics and exercise

The impact of exercise in people with T2DM seems to be also dependent on the characteristics of the participants (Stephens and Sparks, 2015; Böhm et al., 2016). Systematic reviews and meta-analyses noted that studies involving elderly people, obese people, people with longer disease duration, and people with poor outcomes at baseline tended to report better results, particularly in terms of glycaemic control (Hordern et al., 2012; Hayashino et al., 2012). Unfortunately, it was also noted that approximately 15–20% of people with T2DM may not show improvement in their metabolic profile even with exercise interventions (Stephens and Sparks, 2015). Further, a few people may show deterioration in diabetic and cardiovascular risk factors even with exercise interventions (Bouchard et al., 2012; Stephens and Sparks, 2015). For example, based on data from six exercise intervention studies involving 1,687 adults, Bouchard et al. (2012) found that 8–13% of participants showed a deterioration in at least one of the following factors: blood pressure, fasting insulin levels, HDL, and triglyceride levels. The causes of the deterioration or the lack of improvement with exercise interventions are poorly understood. However, it is believed that in addition to non-compliance, genetic and epigenetic factors are thought to play a role (Bouchard et al., 2012; Stephens and Sparks, 2015).

2.7.5 Limitations in the generalisability of the current evidence

Despite the high number of systematic reviews and exercise guidelines that confirm the benefits of exercise interventions, the generalisability of the current evidence to South Asians is limited. Indeed, evidence presented in guidelines and systematic reviews either merged trials involving white European participants or did not report the participants' ethnicity. In short, ethnic minorities, especially south Asians, are less represented in clinical trials (Khunti et al., 2017).

Meanwhile, studies investigating the impact of exercise on people of different backgrounds indicated variations in exercise responses among ethnic groups due to physiological, psychological and environmental factors (Glans et al., 2009; Sukala et al., 2012; Celis-Morales et al., 2013; Iliodromiti et al., 2016). For instance, Glans et al. (2009) compared the impact of combined exercise programmes on sedentary overweight Arabians and white European (Swedish) women with T2DM. After six months, the results demonstrated that only the white European women showed significant improvement in glycaemic control as measured by HbA1c. In another study, South Asians were found to have lower cardiovascular fitness and lower capacity for fat oxidation during exercise than white Europeans (Ghouri et al., 2013). Furthermore, South Asians were found to be at greater risk of hyperglycaemia even at higher level of physical activity as compared to white Europeans (Waidyatilaka et al., 2013). As such, many authors have advocated for ethnic specific exercise guidelines (Waidyatilaka et al., 2013; Shrivastava and Misra, 2015).

Ethnic specific exercise guidelines may benefit both people from ethnic minority groups and health care professionals. Such guidelines can help ethnic minority groups to improve their own health as well as to ensure that the exercise programmes and the advice that they receive are based on the best available evidence. Similarly, ethnic specific exercise guidelines can help health care professionals to ensure that both the advice they provide and the exercise programmes that they prescribe are based on the best available evidence. However, it is currently difficult to develop ethnic specific exercise guidelines as studies targeting ethnic minority groups or including people from different ethnic backgrounds are scarce.

At the point when the work on this thesis began, there was no systematic review that had examined the impact of exercise interventions on South Asians with T2DM. In fact, only one systematic review specifically explored the effects of different management strategies that targeted this specific group (Bhurji et al., 2016). Here, it was found that there were limited improvements, which failed to reach a level of statistical significance, in terms of glycaemic control; while interventions comprising of exercise or yoga were found to be the most successful. However, of the 23 studies included within this review, only four involved an exercise-only intervention and one did not involve a control group. Therefore, investigating the effect of different exercise interventions on South Asian adults with T2DM is of great importance but has not been widely investigated.

2.7.6 The need for an innovation approach to engage South Asians in exercise

Although exercise is widely recommended, South Asians were found to be generally less likely to engage in exercise, and other lifestyle interventions, than their white European counterparts (Sohal et al., 2015). Sedentary behaviour is also common among South Asians

(Khunti et al., 2007). In order to facilitate South Asian engagement in exercise, many qualitative studies have investigated South Asians' views on the barriers and facilitators of exercise. While a few of these studies specifically included South Asians with T2DM, the majority recruited South Asians with other chronic diseases or those who are at the greatest risk of developing T2DM (Johnson, 2000; Farooqi et al., 2000; Lawton et al., 2006; Horne and Tierney, 2012; Galdas et al., 2012; Ruth et al., 2012; Vahabi et al., 2012; Horne et al., 2013; Singhal and Siddhu, 2014; Koshoedo et al., 2015; Cross-Bardell et al., 2015; Lisa et al., 2015; Sohal et al., 2015; Rajaraman et al., 2015).

Overall, the studies found that engaging South Asians in exercise interventions requires special consideration. In fact, although South Asians are willing to take part in different types of exercise and generally recognise their benefits (Farooqi et al., 2000; Lawton et al., 2006; Jepson et al., 2012), there are a number of barriers that make it difficult for many South Asians to incorporate exercise in their daily routine (Naeem, 2003; Lawton et al., 2006; Galdas et al., 2012; Babakus and Thompson, 2012; Bhatnagar et al., 2015; Sohal et al., 2015). These factors can be classified into two groups, socio-cultural barriers and general barriers.

Socio-cultural barriers refer to those barriers that are strongly related to South Asian religious beliefs, social norms and languages. In fact, many socio-cultural barriers were found to prevent South Asians from initiating or maintaining exercise. Several studies reported that a lack of gender-specific exercise classes and same-sex instructors are common barriers since segregating males and females into different groups is imbedded in South Asian culture and can be observed even in Muslim prayers (Naeem, 2003; Lawton et al., 2006; Galdas et al., 2012; Babakus and Thompson, 2012; Bhatnagar et al., 2015; Sohal et al., 2015). In addition, the social norms and expectations that women should stay at home after marriage to look after the house and the children are barriers that were highlighted (Babakus and Thompson, 2012). South Asian women also reported feeling unsafe when exercising outside the home (Naeem, 2003; Lawton et al., 2006; Galdas et al., 2012; Babakus and Thompson, 2012; Bhatnagar et al., 2015; Sohal et al., 2015). Furthermore, a preference for maintaining an Islamic and South Asian dress code in public that involves a cultural rejection of 'sporty' identities or attire is another major barrier, while some South Asians also face language barriers (Lawton et al., 2006; Patel et al., 2012).

Studies have also highlighted several general barriers to exercise that make it difficult for many South Asians to incorporate exercise in their daily routine. These barriers are similar to those of other ethnic groups and include transportation problems, bad weather, living in rural areas, fear of injuries, family commitments, having a sedentary job and a lack of time due to work and study commitments (Naeem, 2003; Lawton et al., 2006; Galdas et al., 2012; Babakus and Thompson, 2012; Bhatnagar et al., 2015; Sohal et al., 2015). Overall, understanding these factors and considering them when designing exercise interventions for South Asians is crucial to facilitating the engagement of South Asians in such activities. This ensures maximum reach and effectiveness of exercise for this population.

2.7.7 The potential of digital interventions for limiting exercise barriers in South Asians

Using technology, in particular the Internet, to deliver exercise interventions is an option that might help South Asians to overcome the aforementioned barriers, certainly given that South Asians tend to use the Internet more than people of white European descent (Ofcom, 2013). Internet-based interventions are flexible and may allow South Asians to perform exercise whenever and wherever they wish and do not require the wearing of specific sports clothes. Internet-delivered interventions have been widely used for the prevention and management of various chronic conditions, such as heart failure, osteoarthritis, chronic obstructive pulmonary disease, cancer, stroke and multiple sclerosis (Harada et al., 2010; Chumbler et al., 2012; Mikołajewska and Mikołajewski, 2014; Amatya et al., 2015). These interventions have been found to be as effective as traditional exercise programmes (Hwang et al., 2017; Akinci et al., 2018). People with chronic diseases who take part in internet-based interventions also tend to report a high level of satisfaction (Tsai et al., 2016).

Meanwhile, a considerable number of studies have explored the use of the Internet to deliver health interventions for people with T2DM (e.g. Jennings et al., 2014; Nes et al., 2012; Kim & Kang, 2006). Although these studies mainly focused on health education, they showed promising results in terms of increasing physical activity levels and general satisfaction. Only two studies to date have examined the effect of using technology to deliver an exercise programme for people with T2DM. Taylor (2008), conducted a controlled clinical trial to compare the effects of a home-based exercise programme delivered both via email and by means of a printed exercise sheet. Both methods of delivery were found to be effective and led to significant improvements in muscle strength and aerobic capacity. However, there were a number of methodological limitations that might have biased the results, including a lack of randomisation and blinded assessor. A second study carried out by Akinci et al. (2018) conducted a single blind RCT to investigate the impact of a web-based exercise intervention on 65 people with T2DM. Participants were randomised into three different groups; a control group, receiving a physical activity counselling brochure, a supervised exercise group undertaking a group-based combined exercise programme three times per week for eight weeks, and a web-based exercise group following the same exercise routine delivered via the Internet. At the end of the intervention, both the web-based exercise group and the group-based exercise group showed significant improvements as compared to the control group in glycaemic control, blood lipids, waist circumference and quality of life.

Despite the positive results in both of the above studies, neither Taylor (2008) or Akinci et al. (2018) included people of South Asian background. Indeed, to date, there is a lack of studies that examine the effect of internet-based exercise interventions on South Asians with T2DM. As such, it is important to investigate the effectiveness of internet-based exercise interventions for South Asians with T2DM, who have a higher prevalence rates, associated complications and tend to experience more exercise barriers than other ethnic groups.

In addition, individuals from ethnic minority groups still lack equal access to internet-based interventions, a phenomenon referred to as the 'digital health divide' (Kreuter and McClure, 2004; Morey Mls and Morey, 2007; Christopher, 2011; Isaacs et al., 2016; Lyles et al., 2017). This is evident from the scarcity of studies that target ethnic minority groups or culturally and linguistically diverse groups. This digital divide is not due to lack of physical access to the internet. Rather, it is mainly due to the lack of culturally and linguistically sensitive platforms (Kreuter and McClure, 2004; Morey Mls and Morey, 2007; Christopher, 2011; Isaacs et al., 2016; O'Connor et al., 2016; Lyles et al., 2017; Latulippe et al., 2017).

Although culture plays a role in how people accept, react to and use the internet (Lee et al., 2007), Internet-based exercise platforms and interventions in western countries are usually developed with input mainly from white European participants (Lyles et al., 2017). Little has been done to explore the views of ethnic minorities living in these societies, despite the need for innovative approaches to promote exercise among such ethnic groups (Benitez et al., 2015; Tatara et al., 2016). Consequently, Internet-based exercise interventions may be presented to ethnic minority groups in forms that are not necessarily acceptable (Kreuter and McClure, 2004; Morey Mls and Morey, 2007; Lyles et al., 2017)

Therefore, to bridge the digital divide, it has become increasingly important to develop culturally sensitive platforms that have the capacity to be used with people from different ethnic backgrounds (Lyles et al., 2017). To date, no study has explored the design and operation of an Internet-based exercise platform for South Asians or investigated the perception of South Asians on using internet for exercise and health.

2.8 Gap in the literature - summary

South Asians make up the largest ethnic group living in the UK and are disproportionally affected by T2DM when compared with people of white European background. Exercise interventions have the capacity to improve a wide range of risk factors associated with T2DM and its complications. Therefore, people with T2DM from South Asian communities should be encouraged to undertake exercise on a regular basis. However, further work is required to address the following literature gaps:

- Although evidence shows variation in exercise response among ethnic groups, there was limited evidence regarding the effectiveness of exercise interventions for the management of T2DM in South Asians.

- Using technology to deliver exercise interventions might help South Asians to overcome several barriers to exercise. However, no study has explored South Asians' perception of or accommodate their needs in a culturally sensitive technology-based exercise platform.

- The effect of technology-based exercise interventions in the management of T2DM in South Asians were unknown due to the lack of studies.

2.9 Research aims

- To review available evidence from clinical trials regarding the effects of exercise on T2DM management-related outcomes in adults with T2DM from South Asians backgrounds

- To customise and refine an existing web-based exercise platform to be accessible and culturally relevant for people from South Asians communities.

- To explore the feasibility, the acceptability and the likely effect of a web-based exercise intervention in South Asians with T2DM.

2.10 Studies undertaken

To achieve the aims, three studies were undertaken:

- Study 1: a systematic review of controlled clinical trials examining the effect of exercise interventions on diabetes-related outcomes in South Asian adults with T2DM [Chapter 3]

- Study 2: A user-centred design study in order to guide the refinement and the customisation process of making an existing web-based exercise platform accessible and culturally relevant for people from South Asian communities living in UK [Chapter 4]

- Study 3: A pilot randomised trial embedded with interviews to investigate the feasibility, the acceptability and likely effect of a 12-week personalised exercise programme delivered using a web-based exercise platform, compared to usual care, on glycaemic control, muscle strength, functional ability, blood lipid profile, blood pressure and quality of life in adult South Asians with T2DM

Research questions/objectives for each study are discussed in Chapters [3,4 and 5]

Chapter 3 – Structured exercise for South Asians with T2DM: a systematic review

This chapter presents the first study in this PhD which was a systematic review investigating the effect of exercise interventions in South Asians with type 2 diabetes (T2DM). The systematic review was submitted to The Physician and Sports Medicine Journal in June 2017 and accepted for publication in October 2017 (Albalawi et al., 2017). However, further details were added to this chapter after the PhD viva examination to improve the overall quality of this systematic review. The final section of this chapter presents an update to the published systematic review.

3.1 Introduction

As discussed in chapter 2, exercise is considered a core element in T2DM management and has been found to improve a number of factors strongly linked to T2DM complications, such as glycaemic control, high blood pressure, and abnormal blood lipid profile, muscle weakness, neuropathy, functional decline, and poor quality of life (Yang et al., 2013; Balducci et al., 2014; Schwingshackl et al., 2014). However, the available evidence regarding the effects of exercise emerged from studies mainly including people of white European backgrounds (Mason et al., 2003). Studies investigating the impact of exercise in people of different backgrounds have indicated variations in exercise response among ethnic groups due to physiological, psychological, genetic, social and cultural factors (Sukala et al., 2012; Celis-Morales et al., 2013). Therefore, the generalisability of the available evidence is limited.

To date, no systematic review has specifically explored the impact of exercise on South Asians with T2DM. Recently, Bhurji et al. (2016) reviewed the effects of different management strategies targeting South Asians with T2DM and found limited improvements that failed to reach level of statistically significant in glycaemic control, while interventions comprising of exercise or yoga were most successful. However, of the 23 studies included in this review only 4 consisted of an exercise-only intervention, of which one study did not have a control group. Therefore, the aim of this study was specifically to review controlled trials investigating the effect of exercise interventions in South Asian adults with T2DM.

3.2 Research questions

- Is exercise effective to improve diabetes-related health outcomes in people with type 2 diabetes from South Asians communities?

- What is the optimal dose of exercise for South Asians with T2DM?

3.3 Methods

3.3.1 Data sources and search strategy

An electronic search was conducted in April 2017 of the following databases: Medline, Embase, Cochrane Library, CINAHL, and Physiotherapy Evidence Database (PEDro). Keywords were divided into three categories, namely condition of interest (i.e. T2DM), ethnicity (i.e. South Asian), and intervention (i.e. exercise). Relevant keywords and medical sub-headings related to each category were combined with the Boolean “OR” and “AND” operators. Search strategies were tailored to each database (Table 3.1). Reference lists of included articles and systematic reviews in the field were also searched manually for relevant studies.

To be included in this review, articles were required to be of either randomised controlled trials (RCTs) or non-randomised controlled clinical trials (CCTs), written in English, included solely South Asian adults with T2DM or, where there was a mixed sample of diabetes or ethnicity, distinct results for South Asians with T2DM were presented, evaluated an exercise program and reported at least one T2DM health-related outcome. For the purpose of this review, exercise was defined as a structured predetermined physical activity program lasting four weeks or more. Articles were excluded if programmes compromised of dance, yoga or only provided advice or a recommendation to increase physical activity. Reviews, cross-sectional, case–control, case series studies and conference abstracts were excluded.

Table 3.1 Search Strategy

Database	Search Strategies
MEDLINE **Embase** **Ovid**	1. exp Exercise/ or exp Exercise Therapy/ or exercise.mp. or Circuit-Based Exercise/ or exp Exercise Movement Techniques/ (313503) 2. ("aerobic exercise" or "aerobic training" or (aerobic adj 2 program*) or walking or treadmill or "circuit training" or "circuit exercise" or swimming or ergometer or bike or running).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synony 3. ("balance training" or "functional training").mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] 4. ("thera*band" or "resistance*band" or "weight lifting" or "gym machine" or "physio*ball" or "swiss*ball" or "balance*ball" or "Elastic*band" or "resistance training" or "strengthening training" or "strengthening exercise" or "resistance exercise").mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] 5. "physical activity".mp. 6. 1 or 2 or 3 or 4 or 5 7. exp Diabetes Mellitus, Type 2/ or "non*insulin*dependent".mp. 8. "Type II diabetes".mp. 9. 7 or 8 10. exp Asian Continental Ancestry Group/ or exp Ethnic Groups/ or south asian.mp. 11. (India* or Pakistan* or Bangladesh* or "Sri Lank*" or Nepa* or (south adj2 asia*)).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] 12. 10 or 11 13. 6 and 9 and 12
Cinhal	1. (MH "Exercise+") OR "exercise" OR (MH "Resistance Training") OR (MH "Therapeutic Exercise+") OR (MH "Group Exercise") OR (MH "Sport Specific Training") 2. (MH "Aerobic Exercises+") OR ""aerobic exercise" OR "aerobic training" OR (aerobic N3 program*) OR walking OR treadmill OR "circuit training" OR "circuit exercise" OR swimming OR ergo*meter OR bike OR running" 3. (MH "Balance Training, Physical") OR (MH "Functional Training") OR ""balance training" OR "functional training""

Database	Search Strategies
	4. (MH "Resistance Training") OR (MH "Muscle Strengthening") OR (MH "Body-Weight-Supported Treadmill Training") OR ""thera*band" OR "resistance*band" OR "weight lifting" OR "gym machine" OR "physio*ball" OR "swiss*ball" OR "balance*ball" OR "Elastic*band" OR "resistance training" OR "strengthening training" OR "strengthening exercise" OR "resistance exercise"" 5. (MH "Physical Activity") 6. S1 OR S2 OR S3 OR S4 OR S5 7. (MH "Diabetes Mellitus, Type 2") OR "type 2 diabetes" 8. "non*insulin*dependent" 9. "Type II diabetes" 10. S7 OR S8 OR S9 11. (MH "Asians") OR "south asian" 12. india* OR Pakistan* OR Nepal* OR Bangladesh OR "sri lanka*"
Cochrane: 186	1. MeSH descriptor: [Motor Activity] 1 tree(s) exploded 2. MeSH descriptor: [Exercise] explode all trees 3. (aerobic near/2 exercise) or (aerobic near/2 training) or (aerobic near/2 program?) or walking or treadmill or (circuit near/2 training) or (circuit near/2exercise) or swimming or ergometer or bike or running 4. (balance near/2 training) or (functional near/2 training) 5. thera?band or resistance?band or (weight near/2 lifting) or (gym near/2 machine) or physio?ball or swiss?ball or balance?ball or Elastic?band or (resistance near/2 training) or (strengthening near/2 training) or (strengthening near/2 exercise) 6. #1 or #2 or #3 or #4 or #5 7. (south near/2 asia?) 8. india? 9. pakistan? 10. (sri lanka?) 11. bangladesh 12. nepal? 13. #7 or #8 or #9 or #10 or #11 or #12 14. MeSH descriptor: [Diabetes Mellitus, Type 2] explode all trees 15. non?insulin?dependent 16. #16- #14 or #15 17. #6 and #13 and 16
Pedro	Exercise AND Diabetes

3.3.2 Study selection

All references retrieved from the electronic and manual searches were exported and added to a web-based systematic review tool (www.covidence.org) (Babineau, 2014). To determine whether the papers met the inclusion/exclusion criteria, two independent researchers [LP and HA] initially scanned the titles and abstracts. Articles then were read in full. Inconsistencies in study selection were resolved by discussion between the two researchers.

3.3.3 Quality appraisal and data extraction

Three reviewers [HA, EC, LP] were involved in assessing the methodological quality of the included studies using the PEDro scale (Maher et al., 2003). The PEDro scale is a valid and reliable tool which scores papers based on 10 criteria (Maher et al., 2003). Each article was reviewed and scored by two assessors independently. Discrepancies were resolved by discussion including the third reviewer if required. Trials which scored 6 or higher in the PEDro scale were considered to be of good quality, while those which scored less than 6 were considered to be of poor quality (Paci et al., 2010). Data were extracted from each study by one reviewer (HA). When two or more articles were from the same study but reported either different outcome measures or results from different assessment times, they were combined and considered as a single study. When each article from the same study had different Pedro scores, the higher score was chosen as an overall score for the study. Authors of such studies were contacted for clarification. Due to variations in interventions length and exercise dosage variables among studies, a meta- analysis was not considered appropriate.

3.4 Results

3.4.1 Description of the included studies

The search identified 2,292 potentially related publications, of which 2,274 articles were screened after duplicates were removed. The full text of 49 articles was screened for eligibility, from which 23 articles were included for review. These 23 articles reported findings from 18 original trials (Figure 3. 1; Table 3.2).

Of the 18 trials included, 16 were RCTs and two were CCTs (Nayak et al., 2005; Seshadri et al., 2012). The majority of these trials (n=15) were of poor methodological quality, scoring less than 6/10 on the PEDro scale (Table 3. 3). Only one trial, published in two articles, stated that the assessor was blinded (Dixit et al., 2014a; Dixit et al., 2014b), and the 'concealed allocation' criterion was satisfied in only one trial (Natesan et al., 2015). Six trials, published over eight articles, did not provide between-group analysis (Subramanian and Venkatesan, 2012; Majeed et al., 2013; Subramanian et al., 2014; Supermanian et al., 2014; Subramanian. et al., 2014; Subramanian and Julius, 2014; Hariharasudhan and Varunkumar, 2015; Subramanian et al., 2016). Only three trials, published in four articles, conducted sample size calculations (Hameed et al., 2012; Dixit et al., 2014a; Dixit et al., 2014b; Shakil Ur Rehman et al., 2017).

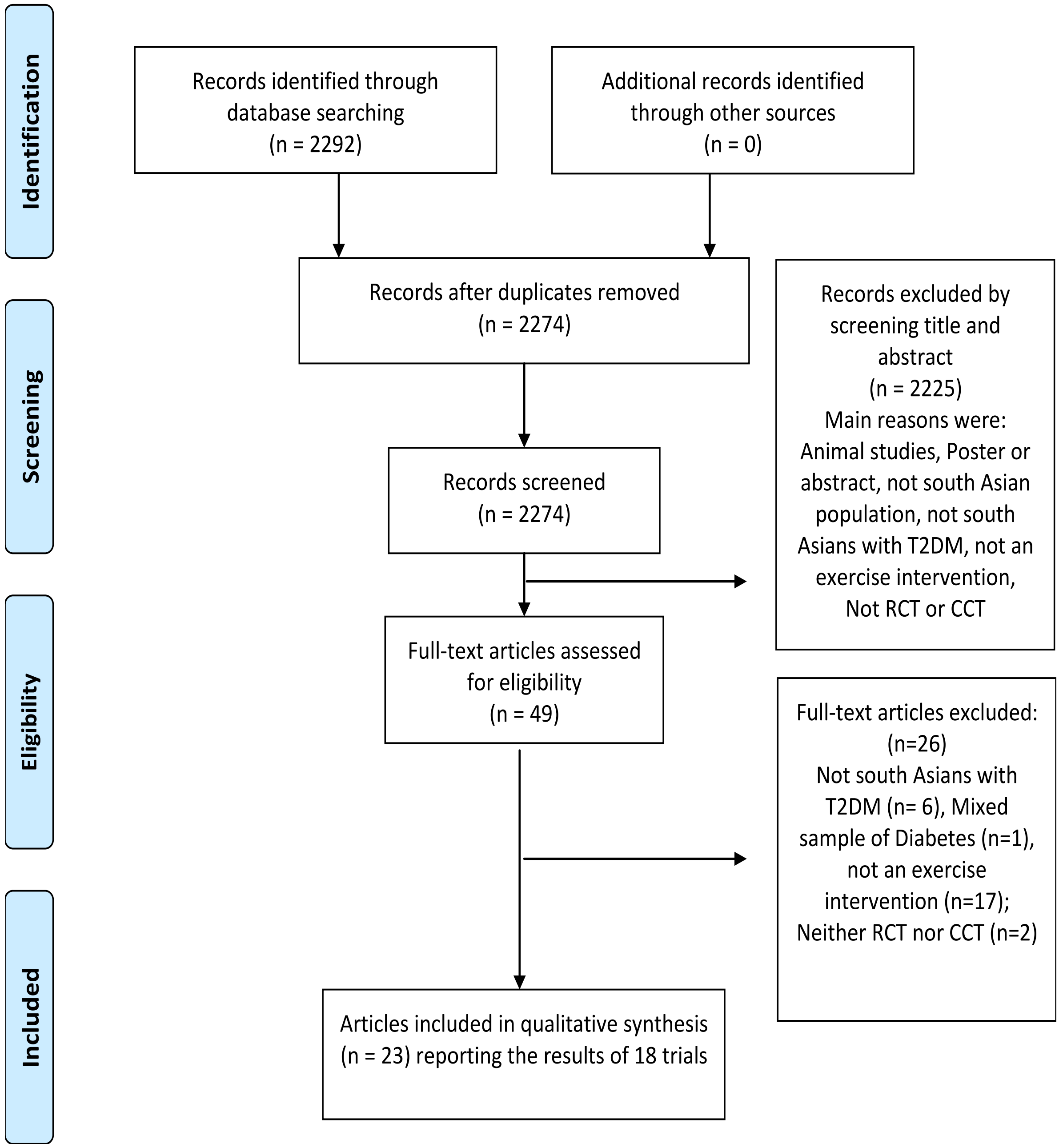


Figure 3. 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses, flowchart of screening and inclusion process of included trials

Table 3.2 Evidence table

Authors, Design, Country	**Participants**	**Exercise intervention**	**Comparison /control**	**Time points (wk)**	**Findings**	**Adverse events**
(Rekha et al., 2014) RCT, India	53 Indians, 35-55 y/o with T2DM For [duration NR]. Comorbidity: No	4 wk partially-supervised Home based AE: walking for 45 mins, x5/wk, Intensity: PRE at 12-14	Usual care	0,4	FBS$^{\uparrow\uparrow}$ Diabetes-specific-QoL questionnaire$^{\uparrow\uparrow}$	NR
(Sridhar et al., 2010) RCT, India	105 Indian,57-65 y/o with T2DM for mean 7 yrs, comorbidity: no	52 wk supervised AE: cycling or treadmill for 60 mins, x5/wk, intensity: NR	Usual care	0,52	HbA1c$^{\uparrow\uparrow}$, SBP $^{\uparrow¥}$, DBP$^{\uparrow¥}$, HRV$^{\uparrow\uparrow}$	NR
(Guglani et al., 2014) RCT, India	102 Indians, 40-70 y/o with T2DM for >1 y. Comorbidity: no	16 wk supervised AE: walking with pedometer for 30-40 mins, x5/wk, Intensity: PRE at 12-14	1-Usual care 2-16 w pedometer	0,16	ADDQol$^{\uparrow\uparrow}$ GWBS$^{\uparrow\uparrow}$	NR
(Shenoy et al., 2010) RCT, India	40 Indians, 40-70 y/o with T2DM for 1-10 years, Comorbidity: No	8 wk supervised AE: walking using heart-rate monitor and pedometer for 35-40 min, x5/wk Intensity: 50-70% of maximum heart rate.	Usual care	0,8	HBA1c$^{\uparrow\uparrow}$, FBG$^{\uparrow\uparrow}$, DBP$^{\uparrow\uparrow}$,SBP$^{\uparrow\uparrow}$, BMI$^{\uparrow}$, GWBS $^{\uparrow\uparrow}$	NR
(Dixit et al., 2014a; Dixit et al., 2014b) € RCT, India	87 Indians, 40-54 y/o, with T2DM for mean: 5.4-6.8 yrs, comorbidity: peripheral neuropathy	8 wk supervised AE: treadmill for30-45 min, x3-6/wk intensity: 40- 60% of heart rate reserve and PRE at (12-14) + diet & Education	Usual care +Education & diet	0,8	Neuropathy Qol$^{\uparrow\uparrow}$,FBS$^{\leftrightarrow}$,PPBS$^{\leftrightarrow}$, BMI$^{\leftrightarrow}$, hip circumference$^{\leftrightarrow}$, hip waist ratio $^{\leftrightarrow}$, MDNS$^{\uparrow\uparrow}$ nerve conduction for peroneal and sural nerve : Latency$^{\leftrightarrow}$, Duration$^{\leftrightarrow}$, Amplitude$^{\leftrightarrow}$, Conduction velocity$^{\uparrow\uparrow}$	NR

Authors, Design, Country	Participants	Exercise intervention	Comparison /control	Time points (wk)	Findings	Adverse events
(Seshadri et al., 2012) CCT, India	18 Indians, > 60 y/o, with T2DM for,[duration: NR], Comorbidity: obesity & physical limitations	24 wk unsupervised home based AE: walking for 5mins per hour for most waking hours, x7/wk Intensity: Low	Usual care	0,24	HbA1c$^{\uparrow\uparrow}$ Weight$^{\uparrow}$ 6-M-W$^{\uparrow}$ QOL-EQ-5D$^{\uparrow}$	NR
(Nayak et al., 2005) CCT, India	20 Indians, 45-60 y/o, with T2DM for NR, Comorbidity: no	6 wk supervised AE: treadmill for 60 mins, x5/wk, Intensity: PRE at 13-14	Usual care	0,6	FBS$^{\uparrow\uparrow}$ PPBS$^{\uparrow\uparrow}$	NR
(Shakil-Ur-Rehman et al., 2017b) RCT, Pakistan	102 Pakistani, mean 54 y/o with T2DM for [duration: NR] Comorbidity: no	25 wk supervised AE: treadmill, progressed from 10 to 50 mins, x3/wk Intensity: NR	Usual care	0,25	HDl$^{\uparrow\uparrow}$ LDL$^{\uparrow\uparrow}$	NR
(Arora et al., 2009; Shenoy et al., 2009) € RCT, india	30 Indians, 40-70 y/o, with T2DM for > 6 months, Comorbidity: no	1) 16 wk Supervised RE: weight-lifting TMMG, 3 sets, 10 reps, x2/wk. Intensity: 60- 100% of 1RM 2) 16 wk Supervised AE: walking for 30mins, x3/wk [intensity: NR]	Usual care	0,8,16	**RE:** HbA1c$^{\uparrow\uparrow\uparrow,}$ FBS$^{\uparrow\uparrow}$, SBP$^{\uparrow\uparrow\uparrow}$, M strength $^{\uparrow\uparrow}$, DBP$^{\uparrow\uparrow\uparrow}$, BBSS$^{\uparrow\uparrow}$, *at w 8:* GWBS$^{\uparrow\uparrow\uparrow,}$ Total-c$^{\uparrow\uparrow\uparrow}$, HDL$^{\leftrightarrow}$,TG$^{\leftrightarrow}$, BMI$^{\leftrightarrow}$ **AE:** HbA1c$^{\uparrow\uparrow}$, FBS$^{\uparrow\uparrow}$, BBSS $^{\uparrow\uparrow,}$ BP $^{\uparrow\uparrow}$, Muscle strength$^{\uparrow\uparrow}$ *At w 8:* GWBS $^{\uparrow\uparrow}$ Total-c$^{\uparrow\uparrow}$,HDL$^{\leftrightarrow}$,TG$^{\leftrightarrow}$, BMI$^{\leftrightarrow}$	NR

Authors, Design, Country	Participants	Exercise intervention	Comparison /control	Time points (wk)	Findings	Adverse events
(Bashyal et al., 2016) RCT, India	28 Indians45-65 y/o with T2DM for NR, Comorbidity: NR	4 wk Supervised RE using swiss-ball TMMG, volume: NR, x3/wk, Intensity: NR.	RE- Thera-band	0, 4	**I**: FBS$^{\uparrow}$, SF-36$^{\uparrow}$ **C:** FBS$^{\uparrow}$, SF-36$^{\uparrow}$	NR
(Hariharasudhan and Varunkumar, 2015) RCT, India	80 Indians, 30-60 y/o with T2DM for [Duration: NR], comorbidity: no	12 wk Supervised RE using swiss-ball TMMG, 3 sets/ 5 reps, x3/wk, Intensity: holding for 0-10 seconds	Usual care	0,12	**¥** **I:** HbA1c$^{\uparrow}$, FBS$^{\uparrow}$, PPBS$^{\uparrow}$,WC$^{\uparrow}$ **C:** all outcomes $^{\leftrightarrow}$	Two hypoglycaemic events
.(Subramanian and Venkatesan, 2012) RCT, India	60 Indians, 30-60 y/o with T2DM for [duration: NR] Comorbidity: no	12 wk Supervised RE using swiss-ball TMMG, 3 sets/5 reps, x3/wk Intensity: per guidelines of ACSM	Usual care	0,12	**¥** **I:** Hba1C$^{\uparrow}$, BMI$^{\uparrow}$ **C:** all outcomes$^{\leftrightarrow}$	major: no Minor: NR
(Hameed et al., 2012) RCT, India	48 Indians, 35-55 y/o, with T2DM for >6 months Comorbidity: no	8 wk Supervised, 8 wk, RE using weight machine TMMG, 3 sets/10reps/ Rest 2 mins, x2-3/wk based on participants' preference, Intensity: 65- 70% of 1-RM	Sham exercise	0,8	Hba1c$^{\uparrow\uparrow}$ HDL-C$^{\uparrow\uparrow}$ TC$^{\leftrightarrow}$, TG$^{\leftrightarrow}$, LHL-c$^{\leftrightarrow}$, SBP$^{\leftrightarrow}$, DBP$^{\leftrightarrow}$ Weight $^{\leftrightarrow}$, WC$^{\uparrow\uparrow}$, Muscle strength$^{\uparrow\uparrow}$	"few instances of muscle soreness"

Authors, Design, Country	Participants	Exercise intervention	Comparison /control	Time points (wk)	Findings	Adverse events
(Supermanian et al., 2014; Subramanian. et al., 2014; Subramanian and Julius, 2014; Subramanian et al., 2016) € RCT, India	100 Indians, 30-60 y/o, with T2DM, [duration: NR], Comorbidity: hypertension	12 wk Supervised RE using swiss-ball TMMG, volume: NR, x3/wk intensity: per ACSM & ADA guidelines	Usual care	0,12	¥ **I:** IHbAc1$^{\uparrow}$, SBP$^{\uparrow}$, DBP$^{\uparrow}$, 14 items-QOL$^{\uparrow}$; BMI$^{\uparrow}$, WC$^{\uparrow}$ C: IHbAc1, SBP $^{\downarrow}$, DBP$^{\downarrow}$, 14 items of QOL$^{\leftrightarrow}$, BMI↔, WC$^{\leftrightarrow}$	Few hypoglycaemic events
(Natesan et al., 2015) RCT, USA	28 (1 Pakistani, 1 Bangladeshi, 26 Indians), 18-85 y/o with T2DM for approximately 7.5 yrs Comorbidity: no	8 wk Supervised CE: Bollywood & weight lifting for 60 mins, x2/wk, intensity: NR	Usual care	0,8	HBA1c$^{\uparrow\uparrow}$ Weight$^{\leftrightarrow}$ BMI$^{\leftrightarrow}$	NR
Paul & Mary(Paul and Mary, 2014) RCT, India	30 Indians, 16 M, 14 F, 45-64 y/o, with T2DM for > 5 yrs. Comorbidity: no	10 wk supervised, CE: (different AE & RE: swiss-ball) for 60 mins, x3/wk Intensity: NR	Supervised, 10 w, AE: (different AE, 1 hour, 3/w, [intensity: NR]	0,10	**CE:** FBS$^{\uparrow\uparrow}$ SF-36$^{\uparrow\uparrow}$ **AE:** FBS$^{\uparrow}$, SF-36$^{\uparrow}$	NR
(Subramanian et al., 2014) RCT,India	100 Indians, 30-60 y/o, with T2DM, [duration: NR]. Comorbidity: obesity	24 wk supervised CE: (AE: x3/wk + RE:2/w) [duration: NR], intensity: per guidelines of ACSM and ADA	Usual care	0,24	¥ **I:**HbA1c$^{\uparrow}$ WC$^{\uparrow}$ **C:** all outcomes $^{\downarrow}$	NR

Authors, Design, Country	Participants	Exercise intervention	Comparison /control	Time points (wk)	Findings	Adverse events
(Majeed et al., 2013) RCT, India	32 Indians, 55-75 y/o with T2DM for [duration: NR]. Comorbidity: peripheral neuropathy	6 wk Supervised balance Exercise for 30min, x3/wk, [intensity: NR]	Usual care + education	0,6	**¥** **I:** Timed-up & go↑, 6-M-W↔ **C:** ↔	NR[2]

Abbreviations: €: one trial published in more than one article; **M**: male; **F**: female; **w**: week; **NR**: not reported; **E**: exercise; **AE**: aerobic exercise; **RE**: resistance exercise; **CE**: combined exercise; ↑: significant improvement compared to baseline, ↑↑: significant improvement compared to a control; ↓: deteriorated significantly compared to baseline; **↔:** no significant change**; ¥**: no between-group analysis provided; **I**: intervention group**; C**: control group; yrs: years; **FBS**: fasting blood sugar; **PPBS:** postprandial blood sugar; **HbA1c**: glycated haemoglobin; **DBP**: diastolic blood pressure, **SBP:** systolic blood pressure **BMI:** body max index **QoL**: quality of life; **ADDQol:** The Audit of Diabetes-Dependent Quality of Life **6-M-W**: 6 Minutes-walk **HDL**: High-density lipoprotein; **LDL**: low-density lipoprotein; **T-cholesterol**: Total cholesterol; **GWBS**: General health-wellbeing scale; **BBS**: Berg Balance scoring Scale; **MDNS**: Michigan Diabetic Neuropathy Score, **yrs:** years; **y/o:** years ol; **ACSM:** American College of Sports Medicine; **TMMG:** targeting Main muscle groups; **1-RM:** one-repetition maximum; **HRV:** hear rate variability; RPE: Rating Perceived Exertion.

Table 3.3 PEDro scores of included articles

Author	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**Total (max 10)**
(Natesan et al., 2015)	1	1	1	1	0	0	0	0	1	1	1	6
(Paul and Mary, 2014)	1	1	0	1	0	0	0	0	0	1	1	4
(Subramanian et al., 2014)	1	1	0	0	0	0	0	0	0	0	1	2
(Bashyal et al., 2016)	0	1	0	1	0	0	0	0	0	1	1	4
(Hariharasudhan and Varunkumar, 2015)	1	1	0	0	0	0	0	1	1	0	1	4
(Subramanian and Venkatesan, 2012)	1	1	0	0	0	0	0	1	0	0	1	3
(Hameed et al., 2012)	1	1	0	1	0	0	0	1	1	1	1	6
(Arora et al., 2009; Shenoy et al., 2009)	1	1	0	1	0	0	0	1	0	1	1	5
(Supermanian et al., 2014) ¥	1	1	0	0	0	0	0	1	1	0	1	4
Rekha et al.(Rekha et al., 2014)	1	1	0	1	0	0	0	1	1	0	1	5
(Sridhar et al., 2010)	1	1	0	1	0	0	0	0	0	1	1	4
(Guglani et al., 2014)	1	1	0	1	0	0	0	1	0	1	1	5
(Shenoy et al., 2010)	1	1	0	1	0	0	0	1	1	1	1	6
(Dixit et al., 2014a; Dixit et al., 2014b)	1	1	0	0	0	0	1	1	1	1	1	6
(Seshadri et al., 2012)	1	0	0	0	0	0	0	0	0	1	1	2
(Nayak et al., 2005)	1	0	0	0	0	0	0	1	1	1	1	4
(Shakil-Ur-Rehman et al., 2017b)	1	1	0	1	0	0	0	0	0	1	1	4
.(Majeed et al., 2013)	1	1	0	1	0	0	0	0	0	0	1	3

C1=Eligibility Criteria (do not count for overall score); C2: Random Allocation; C3: Concealed Allocation; C4: Baseline Comparability; C5: Participant Blinding; C6: Blinding Therapist; C7: Assessor Blinding; C8: < 15% Dropout; C9: Intention to Treat; C10: Between-Group Difference, C10: Point Estimate and Variability.
¥ A study published in four articles and the higher score is presented (Supermanian et al., 2014; Subramanian. et al., 2014; Subramanian and Julius, 2014; Subramanian et al., 2016)

3.4.2 Participant characteristics

The 18 trials included 1063 participants, of whom 959 (90%) were Indian. The time since diagnosis of T2DM was at least six months in seven trials (Shenoy et al., 2009; Arora et al., 2009; Sridhar et al., 2010; Shenoy et al., 2010; Hameed et al., 2012; Guglani et al., 2014; Natesan et al., 2015). The remaining studies did not report T2DM duration. All studies excluded people with contraindications to exercise such as uncontrolled hypertension. Five studies included only participants with complications linked to T2DM, such as neuropathy (Majeed et al., 2013; Dixit et al., 2014a), hypertension (Subramanian et al., 2016), obesity (Seshadri et al., 2012; Subramanian et al., 2014) and restriction in physical performance due to obesity and age-related conditions (Seshadri et al., 2012).

3.4.3 Characteristics of exercise programmes

Of the included 18 trials, 15 compared exercise to control situations. Two trials compared the efficacy of two different exercise programmes (Guglani et al., 2014; Paul and Mary, 2014) and one trial with three intervention arms examined the efficacy of two exercise programmes compared to usual care (Arora et al., 2009). The programmes involved aerobic exercise (n=10) (Nayak et al., 2005; Arora et al., 2009; Sridhar et al., 2010; Seshadri et al., 2012; Paul and Mary, 2014; Guglani et al., 2014; Rekha et al., 2014; Dixit et al., 2014b; Shakil-Ur-Rehman et al., 2017b), resistance exercise (n=7) (Arora et al., 2009; Hameed et al., 2012; Subramanian and Venkatesan, 2012; Subramanian. et al., 2014; Hariharasudhan and Varunkumar, 2015; Subramanian et al., 2016; Bashyal et al., 2016), combined aerobic and resistance (n=3) (Paul and Mary, 2014; Subramanian et al., 2014; Natesan et al., 2015), and balance exercise training (n=1) (Majeed et al., 2013).

3.4.3.1 Aerobic exercise

Aerobic exercise programmes were prescribed in ten trials (Nayak et al., 2005; Arora et al., 2009; Sridhar et al., 2010; Seshadri et al., 2012; Paul and Mary, 2014; Guglani et al., 2014; Rekha et al., 2014; Dixit et al., 2014a; Dixit et al., 2014b; Shakil-Ur-Rehman et al., 2017b), of which eight programmes were fully supervised, while two studies prescribed either partially supervised (Rekha et al., 2014) or unsupervised programmes (Seshadri et al., 2012). The length of aerobic programmes varied ranging from 4 to 52 weeks (Sridhar et al., 2010; Rekha et al., 2014). The modes of aerobic exercise were walking with pedometers (n=1) (Guglani et al., 2014), walking with heart-rate monitors (n=1) (Shenoy et al., 2010), walking on a treadmill (n=3) (Nayak et al., 2005; Dixit et al., 2014a; Shakil-Ur-Rehman et al., 2017b), walking alone (n=3) (Arora et al., 2009; Seshadri et al., 2012; Rekha et al., 2014), stationary cycling (n=1) (Sridhar et al., 2010), or a combination of different modes of aerobic exercise (n=1) (Paul and Mary, 2014).

Nine trials reported session duration ranging from 30 to 60 minutes and a frequency of three to five days per week (Nayak et al., 2005; Arora et al., 2009; Sridhar et al., 2010; Paul and Mary, 2014; Guglani et al., 2014; Rekha et al., 2014; Dixit et al., 2014a; Dixit et al., 2014b; Shakil-Ur-Rehman et al., 2017b). Similarly, the intensity was defined as moderate in five trials; according to heart-rate reserve (Shenoy et al., 2010; Dixit et al., 2014b) or the Borg Rating of Perceived Exertion Scale (Nayak et al., 2005; Rekha et al., 2014; Guglani et al., 2014), while intensity was not reported in four trials (Arora et al., 2009; Sridhar et al., 2010; Paul and Mary, 2014; Shakil-Ur-Rehman et al., 2017b). Only one study included people with mobility limitations, which reported daily, light intensity exercise of five minutes of walking every hour for most waking hours (Seshadri et al., 2012).

3.4.3.2 Resistance exercise

Seven supervised, progressive resistance programmes were prescribed in six trials (Arora et al., 2009; Shenoy et al., 2009; Hameed et al., 2012; Subramanian and Venkatesan, 2012; Subramanian. et al., 2014; Hariharasudhan and Varunkumar, 2015; Subramanian et al., 2016; Bashyal et al., 2016). The length of these programmes ranged from 4 to 16 weeks. The volume of resistance exercise was reported in terms of number of repetitions and sets performed. In four trials the volume was consistent with 3 sets of 10 repetitions (Arora et al., 2009; Hameed et al., 2012; Subramanian and Venkatesan, 2012; Hariharasudhan and Varunkumar, 2015). Only one study specified a rest interval between sets of two minutes (Hameed et al., 2012). The remaining two studies reported neither volume nor time (Bashyal et al., 2016; Subramanian et al., 2016),.

All studies reported targeting the major muscle groups of the body and incorporated exercises such as hamstring curls, sit-ups and wall-squats. These exercises were most frequently performed using a Swiss-ball (n=4) (Subramanian and Venkatesan, 2012; Subramanian and Julius, 2014; Hariharasudhan and Varunkumar, 2015; Bashyal et al., 2016), weight machines (n=2) (Arora et al., 2009; Hameed et al., 2012), and resistance bands (n=1) (Bashyal et al., 2016). The majority of programmes were performed three times per week (n=5). One program was performed twice per week (Arora et al., 2009). Another program was undertaken 2-3 times per week based on participants' preference (Hameed et al., 2012).

3.4.3.3 Combined exercise

Supervised combined exercise programmes were described in three trials (Paul and Mary, 2014; Subramanian et al., 2014; Natesan et al., 2015). The length of these programmes were 8 (Natesan et al., 2015), 10 (Paul and Mary, 2014), and 24 weeks (Subramanian et al., 2014). Only two studies reported duration, and in both sessions lasted 60 minutes (Paul and Mary, 2014; Natesan et al., 2015). Two studies included aerobic and resistance exercise in the same session 2-3 times per week respectively (Paul and Mary, 2014; Natesan et al., 2015), while the remaining study prescribed aerobic and resistance training in different sessions (three days aerobic and two days resistance per week) (Subramanian et al., 2014).

Two of the three combined programmes involved traditional aerobic and resistance exercise (Paul and Mary, 2014; Subramanian et al., 2014), whereas one program employed culturally adapted aerobic exercise (Bollywood dance) plus traditional resistance exercise (Natesan et al., 2015). The intensity of the aerobic and resistance components of the combined exercise was not reported in any of the studies.

3.4.3.4 Balance exercise training

Only one trial prescribed supervised balance exercise (Majeed et al., 2013). The program consisted of multi-sensory exercises including walking forwards, backwards, and sideways with eyes both open and closed, on different ground surfaces for various distances at different speeds. This program was undertaken for 30 minutes, three times per week for six weeks.

3.4.4 Effects of different exercise programmes

All exercise interventions included in this review, regardless of the type of exercise, found positive effects on at least one outcome (Table 3.2; Table 3.4). Six trials provided information related to adverse events, three of which stated there were no exercise-related injuries or serious complications (Nayak et al., 2005; Arora et al., 2009; Subramanian and Venkatesan, 2012). Two trials described “a few” episodes of mild hypoglycemia and one trial reported muscle soreness as a result of resistance exercise, however none resulted in non-compliance with exercise or required hospital admission (Hameed et al., 2012; Subramanian. et al., 2014; Hariharasudhan and Varunkumar, 2015). None of the included trials provided follow-up assessment beyond the end of the intervention period.

3.4.4.1 Effects on glycaemic control

Thirteen trials examined the impact of exercise interventions on glycaemic control in South Asians with T2DM (Shenoy et al., 2009; Sridhar et al., 2010; Shenoy et al., 2010; Subramanian and Venkatesan, 2012; Hameed et al., 2012; Seshadri et al., 2012; Subramanian et al., 2014; Paul and Mary, 2014; Dixit et al., 2014b; Natesan et al., 2015; Hariharasudhan and Varunkumar, 2015; Bashyal et al., 2016; Subramanian et al., 2016). Glycated hemoglobin (HbA1c), was the main glycaemic control measure in 10 trials (Shenoy et al., 2009; Sridhar et al., 2010; Shenoy et al., 2010; Subramanian and Venkatesan, 2012; Hameed et al., 2012; Seshadri et al., 2012; Subramanian et al., 2014; Natesan et al., 2015; Hariharasudhan and Varunkumar, 2015; Subramanian et al., 2016). Six trials, involving seven exercise programmes demonstrated that eight weeks or more of aerobic (n=4) (Shenoy et al., 2009; Sridhar et al., 2010; Shenoy et al., 2010; Seshadri et al., 2012), resistance (n=2) (Shenoy et al., 2009; Hameed et al., 2012), or combined (n=1) (Natesan et al., 2015) exercise programmes were associated with a significant improvement in HbA1c compared to a control group (Arora et al., 2009; Shenoy et al., 2010; Sridhar et al., 2010; Hameed et al., 2012; Seshadri et al., 2012; Natesan et al., 2015). The remaining trials (n=4) did not provide between-group analysis, yet these trials reported a significant reduction in HbA1c following resistance exercise compared to baseline values, while the control groups showed an increase or no change in HbA1c (Subramanian and Venkatesan, 2012; Subramanian et al., 2014; Hariharasudhan and Varunkumar, 2015; Subramanian et al., 2016).

Other glycaemic control measures such as fasting blood glucose (FBG) levels and postprandial glucose levels (PPBS) were assessed in eight studies (Nayak et al., 2005; Arora et al., 2009; Shenoy et al., 2010; Paul and Mary, 2014; Rekha et al., 2014; Dixit et al., 2014a; Hariharasudhan and Varunkumar, 2015; Bashyal et al., 2016). Six studies found a significant improvement in these measures following aerobic (n=4) (Nayak et al., 2005; Arora et al., 2009; Shenoy et al., 2010; Rekha et al., 2014), resistance (n=1) (Arora et al., 2009) or combined exercise (n=1) (Paul and Mary, 2014) as compared to usual care or another exercise intervention (Paul and Mary, 2014). Only two studies did not find significant differences in FBG between groups (Dixit et al., 2014a; Bashyal et al., 2016). Bashyal et al., (2016) compared two resistance exercise programmes and reported significant improvements in both groups compared to baseline. However, this study did not include an inactive control group for comparison. Dixit. et al., (2014a) examined the impact of eight weeks of aerobic exercise compared to usual care. The exercise group showed improvements although the results were not statistically significant.

3.4.4.2 Effects on blood pressure

Five trials investigated the impact of exercise interventions on blood pressure (Shenoy et al., 2009; Shenoy et al., 2010; Sridhar et al., 2010; Hameed et al., 2012; Subramanian et al., 2016). Four trials, involving five exercise programmes, demonstrated that aerobic (n=3) and resistance (n=2) exercise significantly improved both systolic and diastolic blood pressure compared to baseline or a control group (Shenoy et al., 2009; Shenoy et al., 2010; Sridhar et al., 2010; Subramanian et al., 2016). Only one study, consisting of 8 weeks of resistance exercise, did not find a statistically significant improvement in blood pressure (Hameed et al., 2012). This study was of a shorter duration compared to other resistance programmes (i.e. ≥ 12 weeks) (Shenoy et al., 2009; Subramanian et al., 2016).

3.4.4.3 Effects on blood lipids

Three studies examined the impact of exercise on blood lipid profiles (Arora et al., 2009; Hameed et al., 2012; Shakil-Ur-Rehman et al., 2017b). All these studies found positive results following either aerobic or resistance exercise (Arora et al., 2009; Hameed et al., 2012; Shakil-Ur-Rehman et al., 2017b). Hameed et al., (2012) found that eight weeks of resistance exercise led to a significant increase in high-density lipoprotein cholesterol compared to usual care (Hameed et al., 2012). Arora et al., (2009) found that 16 weeks of either aerobic or resistance exercise programmes significantly reduced total cholesterol compared to usual care. Neither noted a change in triglycerides or low-density lipoprotein levels. Despite this, Shakil Ur Rehman et al., (2017) conducted a trial of longer duration (25 weeks) finding significant improvement in both high and low-density lipoprotein cholesterol compared with usual care (Shakil-Ur-Rehman et al., 2017b). This study did not explore effects on triglycerides.

3.4.4.4 Effects on anthropometrics

Ten trials reported BMI, weight, waist circumference (WC) or waist-hip ratio (Arora et al., 2009; Shenoy et al., 2010; Hameed et al., 2012; Subramanian and Venkatesan, 2012; Seshadri et al., 2012; Subramanian et al., 2014; Dixit et al., 2014b; Natesan et al., 2015; Hariharasudhan and Varunkumar, 2015; Subramanian et al., 2016). WC improved significantly following resistance exercise as compared to a control in one trial (Hameed et al., 2012). The remaining trials did not report improvements (Arora et al., 2009; Shenoy et al., 2010; Hameed et al., 2012; Seshadri et al., 2012; Dixit et al., 2014b; Natesan et al., 2015) or the results were limited due to the lack of between group analysis (Subramanian and Venkatesan, 2012; Subramanian et al., 2014; Subramanian. et al., 2014; Hariharasudhan and Varunkumar, 2015).

3.4.4.5 Effects on muscle strength

Two studies examined the effect of exercise on muscle strength using either one repetition maximum strength tests (Hameed et al., 2012), or isotonic/isometric dynamometer software (Arora et al., 2009). These trials demonstrated that either aerobic or resistance exercise improved muscle strength in South Asians with T2DM (Arora et al., 2009; Hameed et al., 2012). Hameed et al., (2012) found 12 weeks of progressive resistance exercise led to statistically significant improvements in lower and upper body musculature strength compared to a control group (Hameed et al., 2012), and Arora et al., (2009) found 16 weeks of either aerobic or progressive resistance exercise improved strength of the muscles of the lower part of the body compared to usual care.

3.4.4.6 Effects on balance/functional mobility

Three trials reported positive results on balance and functional ability following aerobic (n=1) (Shenoy et al., 2009; Seshadri et al., 2012), resistance (n=1) (Shenoy et al., 2009) or balance exercise (n=1) (Majeed et al., 2013). Two trials specifically included people with physical limitations (Seshadri et al., 2012; Majeed et al., 2013). Majeed et al., (2013), which included South Asians with T2DM and peripheral neuropathy, reported significant improvements in functional mobility, measured by the ‘timed up and go’ test, following a 6 week balance exercise program. Seshadri et al., (2012), which included elderly, obese South Asians with T2DM who were unable to walk for long distances, reported significant improvements in the six-minute walk test after 24 weeks of light-intensity aerobic exercise. However, this improvement was not significant compared to usual care. The lack of between group improvements may have been due to the low sample size (n=9 per group). The third trial, Arora et al., (2009), demonstrated that 16 weeks of either aerobic exercise or resistance exercise induced significant improvements in balance compared to a control group, measured using the Berg Balance Scale (Shenoy et al., 2009).

3.4.4.7 Effects on quality of life and well-being

Nine trials assessed the effects of exercise on quality of life and/or well-being (Arora et al., 2009; Shenoy et al., 2010; Paul and Mary, 2014; Subramanian. et al., 2014; Rekha et al., 2014; Guglani et al., 2014; Dixit et al., 2014b; Bashyal et al., 2016). Six trials found aerobic (n=4), resistance (n=1) or combined exercise (n=1) significantly improved quality of life compared to control (Arora et al., 2009; Shenoy et al., 2010; Paul and Mary, 2014; Subramanian. et al., 2014; Rekha et al., 2014; Guglani et al., 2014; Dixit et al., 2014b; Bashyal et al., 2016). Three trials did not report between group differences, yet reported significant improvements compared to baseline (Seshadri et al., 2012; Subramanian and Julius, 2014; Bashyal et al., 2016), . The lack of between group differences, in two trials, may have resulted from the inclusion of an active control group (Bashyal et al., 2016) or under powered sample size (Seshadri et al., 2012). The third trial did not perform between-group analyses (Subramanian and Julius, 2014). However, there was heterogeneity in terms of outcome measures used. These outcomes included the 36-item Short-form Survey, fourteen items measuring quality of life (14-QOL), Audit of Diabetes Dependent Quality of Life (ADDQoL19), Diabetes specific quality of life questionnaire, Neuropathy quality of life questionnaire, well-being questionnaire, 22-items self-administered well-being questionnaire of Bradley and Lewis.

3.4.4.8 Effects on physiological measures related to neuropathy

Two trials reported measures related to neuropathy and showed positive results following aerobic exercise (Sridhar et al., 2010; Dixit et al., 2014a). Sridhar et al., (2010) examined the impact of 52 weeks of aerobic exercise on cardiac autonomic function measured by heart-rate variability (HRV) with a deep breath (Sridhar et al., 2010). This study reported a significant improvement in HRV for the exercise group compared to usual care. Dixit et al., (2014a) compared the effectiveness of eight weeks of moderate-intensity aerobic exercise with usual care. The intervention group demonstrated a statistically significant improvement in the Michigan Diabetic Neuropathy Score and nerve conduction velocity. However, the study did not show improvements in other nerve conduction parameters for peroneal and sural nerves.

Table 3.4 Effects of different exercise programmes

	Aerobic	Resistance	combined	Balance
Hba1c	√ √√√	√√	√	NI
blood pressure	√√√	√√	NI	NI
blood lipids	√√	√√	NI	NI
anthropometrics	x	√	NI	NI
muscle strength	√	√√	NI	NI
balance/functional mobility	√	√		√
quality of life and well-being	√√√√	√	√	NI
√**:** a study reporting statistically significant improvement; **X**: Effect of exercise investigated but no significant improvement was reported; **NI**: The effect of exercise has not been investigated				

3.4.5 Optimal exercise strategy

Three trials, published over four articles, compared the effects of different exercise interventions (Arora et al., 2009; Shenoy et al., 2009; Paul and Mary, 2014; Bashyal et al., 2016). Arora et al., (2009) indicated that both aerobic and resistance exercises are effective in improving glycaemic control, blood pressure, and increasing muscle strength yet, resistance exercise was found to be more beneficial. The results of this trial were limited by small sample size (n=10 in each group). Paul & Mary (2014) found combined exercise was superior to aerobic exercise alone in terms of improving quality of life and decreasing fasting blood glucose levels (Paul and Mary, 2014). Bashyal et al., (2016) compared the effects of two resistance exercise programmes; one using a Swiss ball and another using resistance bands. There were no between-group differences in quality of life or fasting blood glucose. None of these trials compared the effect of other exercise variables (intensity, frequency, duration). It is therefore difficult to determine the optimal exercise program for South Asians with T2DM.

3.5 Discussion

This is the first systematic review to specifically consider exercise interventions targeting South Asians with T2DM. Overall, in line with systematic reviews involving mainly white European participants with T2DM (Yang et al., 2013; Balducci et al., 2014; Schwingshackl et al., 2014), the evidence presented within this review was positive regarding the efficacy of exercise in South Asians with T2DM. Exercise was also well tolerated by participants (Nayak et al., 2005; Arora et al., 2009; Subramanian and Venkatesan, 2012; Hameed et al., 2012; Subramanian. et al., 2014; Hariharasudhan and Varunkumar, 2015).

Aerobic exercise alone or resistance exercise alone were the most common types of exercise investigated in South Asians with T2DM and were associated with improvements in glycaemic control, blood pressure, blood lipid profile, muscle strength, functional mobility, and quality of life (Arora et al., 2009; Shenoy et al., 2009; Sridhar et al., 2010; Paul and Mary, 2014; Guglani et al., 2014; Rekha et al., 2014). There was little evidence to support or refute the efficacy of balance or combined exercises on the majority of these outcomes. Balance exercise was investigated in only one trial finding improvements in functional mobility (Majeed et al., 2013). Combined exercise was explored in three trials reporting positive results in terms of improving glycaemic control and quality of life (Paul and Mary, 2014; Subramanian et al., 2014; Natesan et al., 2015). As such, more studies are required to investigate the impact of such types of exercise in a wide range of outcomes in South Asians with T2DM.

Exercise type and dosage variables (intensity, frequency and duration) have previously been found to be associated with the overall effects of exercise programmes in people with T2DM (Boule et al., 2001; Umpierre et al., 2013). In the current review, however, there was a dearth of trials comparing different types, modes, or doses (frequency, duration, and intensity) of exercise on diabetes related outcomes, making it difficult to identify the most effective prescription of exercise to improve T2DM management among South Asians. Systematic reviews involving mainly white European participants with T2DM found that aerobic exercise was superior to resistance exercise programmes in terms of improving glycaemic control and blood lipid profiles, whereas combined interventions were more beneficial than either aerobic or resistance exercise alone (Schwingshackl et al., 2014). Yet, the results of the current review indicate that the generalisability and transferability of these finding to South Asians with T2DM may be limited.

Only one trial examined the impact of two different types of exercise on both glycaemic control and blood lipid profile (Arora et al., 2009). Arora et al., (2009) found that resistance exercise was more beneficial than aerobic exercise in terms of triglycerides, total cholesterol levels and general well-being. This finding is consistent with an RCT comparing the impact of aerobic and resistance exercise on people of white European backgrounds and African Americans with T2DM, the latter being another ethnic group disproportionally affected by T2DM (Winnick et al., 2008). This study showed that resistance exercise was more beneficial for African Americans in terms of glucose metabolism. However, more studies of good methodological rigor are required to compare the impact of different types of exercise on South Asians with T2DM

Although optimal dosage variables cannot be determined based on available literature, the majority of studies included in this review adhered to the widely recommended dosage of aerobic and resistance exercises for people with T2DM (Colberg et al., 2010; Mendes et al., 2015). It is recommended that people with T2DM undertake 150 minutes of moderate aerobic exercise weekly, in bouts of at least 10 minutes (Mendes et al., 2015). In addition, progressive resistance exercise programmes, involving the main muscles should be undertaken 2-3 times weekly (Colberg et al., 2010; Mendes et al., 2015).

Furthermore, the current review indicates that obese South Asians with T2DM with physical limitations may even benefit from lower doses of aerobic exercise e.g. light intensity walking of five minutes every hour. Seshadri et al., (2012) examined the impact of a light intensity walking programme of five minutes per hour for most waking hours and found improvements in glycaemic control and functional mobility as measured using six-minutes walking test. Since South Asians have been identified as less active than white Europeans with greater complications associated with T2DM (Shah and Kanaya, 2014), it is possible that exercise with short bouts, at a light intensity of aerobic exercise, may be effective. However, this evidence emerged from only one study of a small sample size and poor methodological quality. As such, further studies with larger sample sizes are required to confirm the benefits of light dose of aerobic exercises for South Asians with T2DM.

None of the studies included within this review reported significant improvement in BMI or weight. The impact of exercise alone on weight and BMI remains minimal (Thomas et al., 2006; Qiu et al., 2014). To reduce weight, interventions incorporating diet and exercise produce better results than those comprising of exercise alone (Foster-Schubert et al., 2012).

The evidence, however, should be interpreted with caution due to the methodological limitations. In addition, changes to diet and medication may confound the effect of exercise on some outcomes such as glycaemic control, blood pressure, and blood cholesterol (Post et al., 2012), yet this was not reported in any of the included trials. Furthermore, the findings regarding the impact of exercise on blood lipids profiles, muscle strength, neuropathy, and functional mobility were based on a limited number of trials (Shenoy et al., 2009; Hameed et al., 2012; Dixit et al., 2014a). There is a paucity of studies reporting a wide range of T2DM related outcomes. The majority of studies were conducted in India with Indian participants therefore, the findings may not be generalised to those of other South Asian backgrounds or those living in western countries.

3.5.1 Limitations

This review has a number of limitations. The majority of the included trials were of poor methodological quality. Confounding variables such as physical activity levels and diet were not monitored in the included studies. Changes in these variables have the potential to influence the outcomes either positively or negatively. In addition, none of the included studies reported adherence to the exercise interventions. Adherence is an important outcome as poor adherence can lead to little gain or even deterioration of function. As such, future trials should monitor physical activity levels, diet and adherence rigorously. Furthermore, this review did not include unpublished studies. It was further limited by the broad spectrum of interventions and outcomes which limited recommendations for exercise prescription. In addition, two authors were contacted for clarification, but no reply was received.

3.6 Conclusion

This systematic review supports the benefits of exercise for South Asians with T2DM. All types of exercise were associated with improvement in at least one factor related to T2DM management in South Asians which included glycaemic control, blood pressure, WC, blood lipids, muscle strength, neuropathy progression, functional mobility, and quality of life. It was difficult to determine the best exercise prescription for South Asians with T2DM. Future studies of good methodological quality are required to further investigate the impact of exercise type, dosage and long-term effect on T2DM management in South Asians.

3.7 Update to the review

To update this review, the search strategies were rerun on March 2019. Two more articles met the inclusion criteria for this review (Shakil-Ur-Rehman et al., 2017a; Shakil-Ur-Rehman et al., 2017c) However, both articles were additional outcomes from an RCT already included in the current review (Shakil-Ur-Rehman et al., 2017b). While the original RCT demonstrated that a 25-week aerobic exercise significantly improved blood lipids in South Asians with T2DM, the two new articles showed that the same intervention also significantly improved BMI, HbA1c, fasting blood glucose levels, insulin resistance, plasma insulin level, level of exertion and maximum oxygen consumption. The results of these two publications support the evidence presented in the published review. Despite this the conclusion remains the same and further studies of good methodological quality are still required to investigate the impact of different exercise types and dose in South Asians with T2DM.

Chapter 4 – A user-centred design study to customise and refine an existing web-based physiotherapy platform for South Asians

This chapter presents the second study in this PhD project which aimed to refine and customise an existing web-based physiotherapy platform in order to make it become more accessible and culturally relevant for people with South Asian backgrounds. This study resulted in an accessible and culturally relevant web-based exercise platform, that was used to deliver a 12-week web-based exercise interventions for South Asians with T2DM, the feasibility, the acceptability and the likely effect of which are presented in the following chapters [Chapters 5-8]

4.1 Background

As highlighted in chapter 2, people's beliefs, values and cultures play a role in how they react, accept and use the Internet (Lee et al., 2007). For this reason, the literature advocates taking people's views into consideration when designing technology-based health interventions. Several studies in Western countries have developed Internet-based exercise platforms with input from end-users (Lawrentschuk et al., 2012; Middelweerd et al., 2015; Willcox et al., 2015; Van Kessel et al., 2016; Peng et al., 2016). However, these studies mainly involved white Europeans and little has been done to explore the views of ethnic minorities living in these societies, despite the need for innovative approaches to promote exercise among such ethnic groups (Benitez et al., 2015; Tatara et al., 2016). Individuals from ethnic minority groups still lack equal access to technology-based health interventions due to the scarcity of culturally and linguistically sensitive platforms (Christopher, 2011; Isaacs et al., 2016). Therefore, prior to examining the effect and acceptability of such interventions on South Asians with T2DM, it was essential to customise an existing web-based exercise to be accessible and relevant for those people from South Asian communities.

4.1.1 Web-based physiotherapy platform

Web-based physiotherapy, (www.webbasedphysio.com) now, (www.giraffehealth.com) is a platform developed by Professor Lorna Paul, Dr Elaine Coulter and their colleagues. The main aim of this platform is to deliver personalised structured exercise programmes for people with chronic diseases in order to improve health outcomes such as muscle strength, functional mobility, metabolic profile, and quality of life. In terms of diabetes management, structured exercise interventions are recommended for people with T2DM. Structured exercise has the potential to improve glycaemic control, blood pressure, muscle strength, functional mobility and quality of life. People with T2DM are usually referred to community-based exercise classes in local gyms or leisure centres (see for example Edinburgh Leisure Referral Scheme provided by community physiotherapy service) (NHS Lothian, 2019). However, many people face barriers to take part in such mode of delivery due to work, cultural issues or living in rural areas. In addition, people with T2DM often have other health problems such as joint limitations, stroke, osteoarthritis, mobility problems and/or peripheral neuropathy. In these cases, the exercise programmes need to be tailored to the need and ability of people with T2DM where physiotherapists play a major role (Cade, 2008; Charted Society of Physiotherapy, 2019; NHS Networks, 2019). Using the web-based physiotherapy platform may provide an alternative way to prescribe and deliver tailored structured exercise programme that can expand the reach of structured exercise interventions to those people who face difficulties in accessing both community-based exercise classes and clinical services.

The web-based physiotherapy platform consists of exercise videos, an exercise diary and an advice/education section. The platform can be accessed by both physiotherapists/healthcare professionals and participants/patients. The platform allows physiotherapists to design, manage and monitor personalised exercise programmes for every participant. The physiotherapist is provided with a unique username and private password (admin account). This account allows the physiotherapist to create an account for participants using the participant’s name and email address. After adding a participant, the physiotherapist develops a personalised exercise programme for that participant based on their need and ability. The personalised exercise programme is set up by selecting appropriate exercises from a library of exercise video clips embedded within the platform. This library consists of different types of exercises with different levels of difficulty. The physiotherapist can also add written instructions next to each selected exercise video clip. The physiotherapist can also add a general advice section for participants.

Once the physiotherapist has added a participant, a confirmation link is sent to the participant’s email from which a private password can be set up. The platform then allows the participant to see their own exercise programme which is supported by exercise videos, written instructions and advice section. The participant can also write notes for the physiotherapist in their exercise diary and to follow up any updates made by the physiotherapist in response to their notes or any phone call.

The effectiveness of exercise interventions delivered using the web-based physiotherapy platform has been examined for individuals with different chronic diseases such as spinal cord injuries, chronic obstructive pulmonary diseases, stroke and axial spondylarthritis; and showed promising results (Paul et al., 2014; Coulter et al., 2015a; Coulter et al., 2015b; Paul et al., 2016; Coulter et al., 2016; Paul et al., 2018). However, similar to other technology-based exercise platforms, this platform was developed with the main input coming from white Europeans. The focus on one ethnic group results in exacerbating existing healthcare disparities (Christopher, 2011) As such, the platform design, language and exercise video clips may be presented to South Asians in forms that are not necessarily acceptable (Kreuter and McClure, 2004; Morey Mls and Morey, 2007). Therefore, to overcome problems such as a lack of acceptance and a lack of use, it was essential that the platform, prior to implementation, be customised and adapted to be accessible and culturally relevant for South Asians.

4.2 Aim

This aim of this co-production study was to inform and guide the refinement and customisation of web-based physiotherapy platform to be accessible and culturally appropriate for South Asians.

4.3 Research questions

In order to inform and guide the refinement adaptation of the web-based physiotherapy platform to be accessible and culturally relevant for South Asians, this research had the following objectives:

- What are the views of, attitudes towards, and barriers to exercise in people of South Asian ethnicity?

- What are the views of South Asians on using technology for health and exercise purposes?
- What are the views of South Asians on the current web-based physiotherapy platform?
- What modifications are need to be made to the web-based physiotherapy platform to be culturally relevant and acceptable for people of South Asian ethnicity?
- What are the views of South Asians on the web-based physiotherapy platform following modification?

4.4 Ethical approval

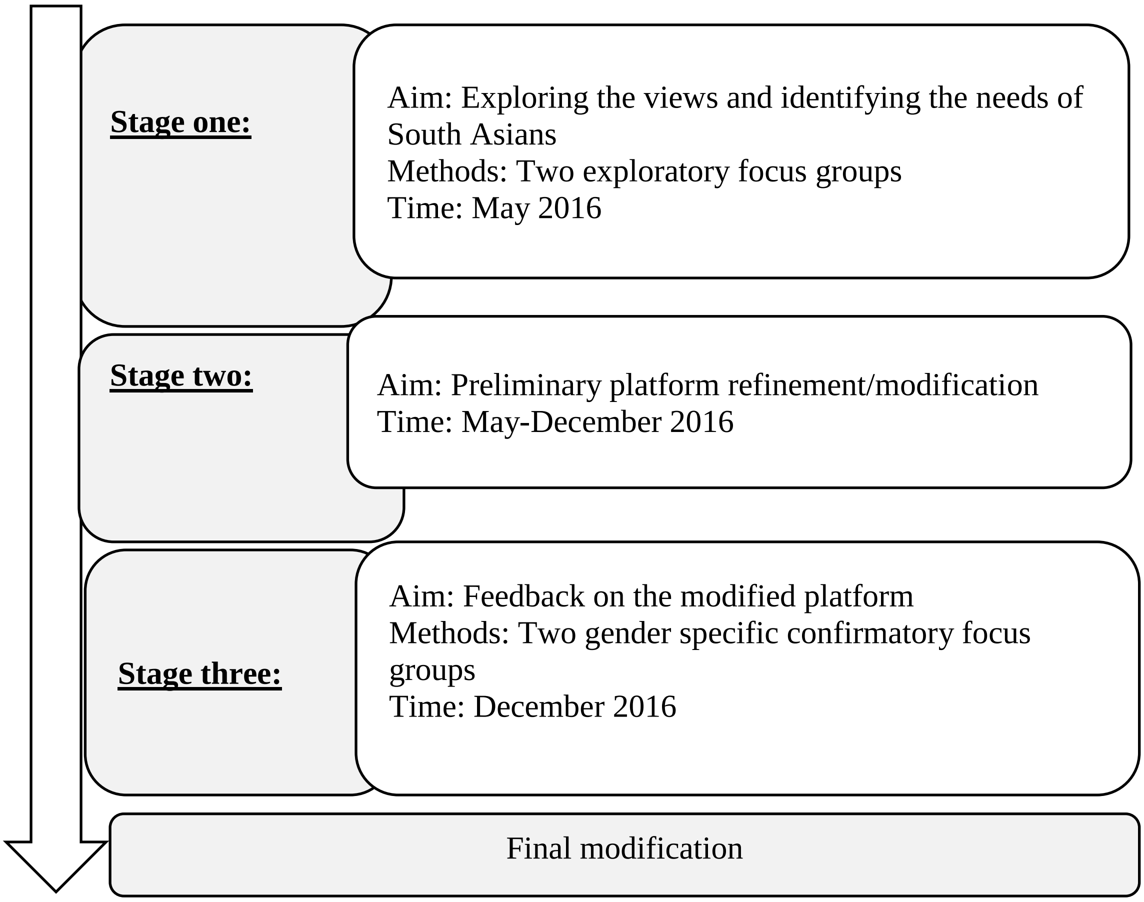
Ethical approval was obtained from the University of Glasgow, College of Medicine, Veterinary and Life Science Research Ethics Committee (application number: 200150107). Written informed consent was obtained from all participants (Appendix 1). All participants were free to withdraw from the study, without being obliged to give notice or provide any explanation.

4.5 Methods

A user-centred design approach was undertaken to refine and adapt the current version of the web-based physiotherapy platform to be accessible, and culturally relevant for people from South Asian backgrounds living in the UK. User-centred design approach is a bottom-up approach in which end users are considered active participants and their views and needs are a central part in the development process (Durand et al., 2016; Osborne et al., 2016; Lwembe et al., 2018). This approach rejects the top-down traditional model where users are seen as passive receivers (Durand et al., 2016; Lwembe et al., 2018). Data collection was undertaken between May and December 2016.

In this study, a three-stage life cycle method was employed which has been found to be satisfactory when developing web-based rehabilitation interventions based on a user-centred approach (Cnossen et al., 2015). These three stages were: 1- gathering the end-users' views and identifying their needs, 2- preliminary platform modifications, 3- evaluating and testing the modified platform with end-users. These three steps were then followed by the final platform modification as summarised in Figure 4.1 and described in the upcoming sections.

Figure 4.1 A three-stage life cycle method.



4.5.1 Stage one: Exploring the views and identifying the needs of people from South Asian backgrounds

The aim of this phase was to gain an insight into the perceptions of South Asians regarding exercise, using technology for exercise and health purposes, the current version of the web-based physiotherapy platform, and what modifications were needed to make the platform accessible and culturally relevant. This would inform the refinement process of the web-based physiotherapy platform to meet the needs of the South Asian population (stage 2).

4.5.1.1 Methods used to explore views and identified needs

To explore the views of South Asians on the topics of interest two exploratory gender-specific focus groups were used. Focus groups have long been utilised to explore people's views and identify their needs to co-design web-based health interventions (Ferney and Marshall, 2005; Papi et al., 2015; Avis et al., 2015). A focus group is an organised discussion, led by a moderator team, in a safe environment with a small group of people about their perceptions, attitudes, feelings and ideas on a specific topic or product (Liamputtong, 2010).

Focus groups were selected because, in contrast to in-depth interviews, focus groups are flexible and allow participants to respond to each other and make comments during the discussion (Liamputtong, 2010). This provides an opportunity to discover new issues that would not appear if the discussion were with researchers alone (Stewart and Shamdasani, 2014). Consequently, this leads to deeper understanding of the participants' perceptions of the topic (Stewart and Shamdasani, 2014). The aim of separating men and women into different groups was to show respect to the gender segregation in South Asian culture (Quay et al., 2017).

4.5.1.2 Recruitment

Participants in studies using a user-centred approach are usually selected from those who might use the intervention themselves (i.e. end-users) (Morrison et al., 2015). In this study, end users were defined as adults with a South Asian background living in the UK. The health status (i.e. having T2DM) was not considered an important element when defining the end users as the aim was to make the platform "culturally" relevant. In addition, it was expected that due to the high prevalence of T2DM among South Asians, a considerable number of participants would be living with T2DM, or at least have a family member with T2DM.

The optimum number of participants in each focus group varies within the literature. However, there is general agreement that the minimum number is 4 and the maximum 12 participants (Carlsen and Glenton, 2011). As such, this study aimed to recruited 4 to 12 participants in each focus group. To identify and recruit potential participants, a South Asian community support worker at the REACH Community Health Project, a third sector organisation in Glasgow, Scotland, facilitated recruitment by contacting potential participants and providing them with a participant information sheet (Appendix 2). The collaboration with REACH Community Health Project facilitated access to this hard to reach population.

Participants were included if they were 18 years or over, identified themselves as being South Asian, and a UK resident. People were excluded if they were unwilling to take part in a gender-specific focus group that was audio-recorded or were unable to provide written informed consent. Since ‘‘South Asian’’ is a term used to describe a group of people who come from different countries and faiths, an effort was made to invite people from different South Asian countries and faiths. An effort was also made to invite people of different ages, and with different immigration history. This would allow the capture of as wide a range of perspectives as possible. To show respect for South Asian culture where the female the main care giver, and to aid the recruitment, participants who had childcare responsibilities were assured that their children were welcome to be present during the focus group discussion

4.5.1.3 Focus group moderator team

The literature in qualitative research methodologies emphasises the importance of a moderator as the success of focus groups rely heavily on the moderator’s skills and experiences (Prince and Davies, 2001). In this stage, each focus group had a moderator team consisting of a moderator and a note taker. Since the study involved participants whose first language was not English, the moderator team also had a translator who was fluent in English and other south Asian languages e.g. Punjabi and Urdu.

For this study, a male moderator led the male focus group and a female moderator lead the female group. The female moderator was a Senior Physiotherapy Researcher (LP) and experienced in the field, while the male moderator, the Principal Investigator, was the PhD student [HA]. Before commencing the study, training on conducting focus groups was provided to the PhD student. As such, he undertook two pilot focus groups with a group of PhD students from different ethnic backgrounds, under the supervision of the second supervisor who is experienced in the field (EC).

The responsibilities of the moderator were to: (1) lead the discussion, (2) facilitate discussion and encourage participants to speak, (3) record the discussion on 2 digital Dictaphones (including a back-up recording). The note taker responsibilities were to: (1) taking field notes, (2) ensure the topic was covered while assisting in time keeping (3) assist in facilitating discussion if necessary, and (4) give feedback to the moderator to improve his/her performance in the future.

4.5.1.4 Developing the topic guide for the exploratory focus groups

To direct the focus groups discussions toward the objective of this phase, a topic guide was developed. This topic guide was developed by the PhD student, based on the research aims and previous research in the topics of exercise, technology use for health and exercise, development of digital health platforms, and adaptations of health interventions for ethnic minorities (Demiris et al., 2004; Ferney and Marshall, 2005; Domenech Rodríguez et al., 2011; Liu et al., 2012; Jacobs et al., 2014; Davies et al., 2015). The topic guide was then discussed with the supervisors and was amended as appropriate. The topic guide covered the following topics: attitudes toward and views of exercise, using technology for exercise and health, the current version of the web-based physiotherapy platform and how to make this platform more accessible and culturally relevant for South Asians. This topic guide was piloted among a group of PhD students from different ethnic backgrounds to ensure usability and to estimate time to complete (Appendix 3).

4.5.1.5 Exploratory Focus Groups procedure

The two gender-specific exploratory focus groups were conducted in May 2016, with only one week between the male and female focus groups to maintain consistency. The focus groups took place at the REACH premises in Glasgow, UK, to minimise travel for participants. REACH was also a familiar location for participants. Before the start of each focus group, the moderator team greeted participants, introduced themselves, explained the aim of the study, obtained informed consent and permission to audio-record the discussion. A formal translator was available, however, participants preferred to translate for each other and their preference was respected.

Each exploratory focus group was planned to last approximately 60 minutes. Participants were asked to use first names during the discussions however they were assured that their names would not be used in the transcript. The discussion started by asking participants general questions which covered their views on exercise and using technology for exercise and health. Participants were then asked about their views on the current version of the web-based physiotherapy platform. To aid participants in expressing their views on the current version of the platform, the platform was presented to participants, using a laptop and a projector, and participants were asked to comment on the concept, its content and also to provide ideas on how to make it accessible and culturally relevant for South Asians. At the end of each focus group, participants completed a brief questionnaire regarding demographic information, health status and internet usage. A £10 gift voucher was offered to participants as an appreciation of their participation.

4.5.1.6 Analysis of exploratory focus groups

The recorded discussions, transcripts, and notes written by the note taker were all considered to be data sources for the focus group analysis. After each focus group, the recorded discussions were transcribed verbatim. The accuracy of the translation was verified by an independent translator. Once the recorded discussions were transcribed and the translation accuracy was verified, the data were analysed using thematic content analysis as described by Burnard (Burnard, 1991). This approach consists of 5 stages. These stages were:

1- Open coding. This included writing short phrases (codes) in the margins of each transcript to provide summary statement for elements discussed.
2- Collecting the short phrases written in stage one on to a clean set of pages to remove duplication and to create shorter list of categories.
3- Creating a shorter list of categories/themes by grouping similar categories together, based on analytical and theoretical ideas developed during the research.

4- Allocating each of the categories/themes identified in step three to a specific colour. The transcripts were then read again and data that fitted under a particular theme/category was marked with the assigned colour

5- Every theme/category with its relevant data was moved and saved in a Microsoft word file.

To make the analysis rigorous and reduce bias, the data were re-analysed, discussed, refined and agreed with the supervisor (LP).

4.5.2 Phase two: preliminary platform modifications

The aim of this phase was to use the results which emerged from the exploratory focus groups, to modify the current version of the web-based physiotherapy. It was planned that upon completion of the exploratory focus groups, data would be analysed as described in the previous section. The research team met to discuss the results. If the results indicated that the current web-based physiotherapy platform was suitable and accepted culturally, the study would end at this point. However, if the results showed that there was a need for modifications and improvements, the research team would make an effort to develop the platform to accommodate the needs of South Asian people.

4.5.3 Phase three: Feedback on the modified platform

The aim of this phase was to obtain feedback on the modifications made to the web-based physiotherapy platform in the previous stage. This phase was to gather the views of participants on the modifications made, and to suggest further modifications, prior to the final modifications.

4.5.3.1 Methods used in the third stage

To obtain feedback regarding the modified platform, two gender-specific confirmatory focus groups were undertaken. These two confirmatory focus groups were conducted and analysed using similar procedures as described for the stage one: the exploratory focus groups and facilitated by the same moderators to ensure consistency. The topic guide was modified to reflect the aim of this stage with the addition of an introduction explaining the aim of the project and a summary of the key findings from stage one and two. The focus group involved asking participants to review each section of the modified web-based physiotherapy platform and obtaining their views and overall opinions regarding the modifications (Appendix 3). A projector was used to display the modified web-based physiotherapy platform.

4.5.4 Final modifications

The results from stage three were used to inform the final modifications of the platform.

4.6 Results

This section describes the results of the three phases of work that were undertaken to modify the web-based physiotherapy using a user-centred design approach.

4.6.1 Phase one results: South Asians views and needs

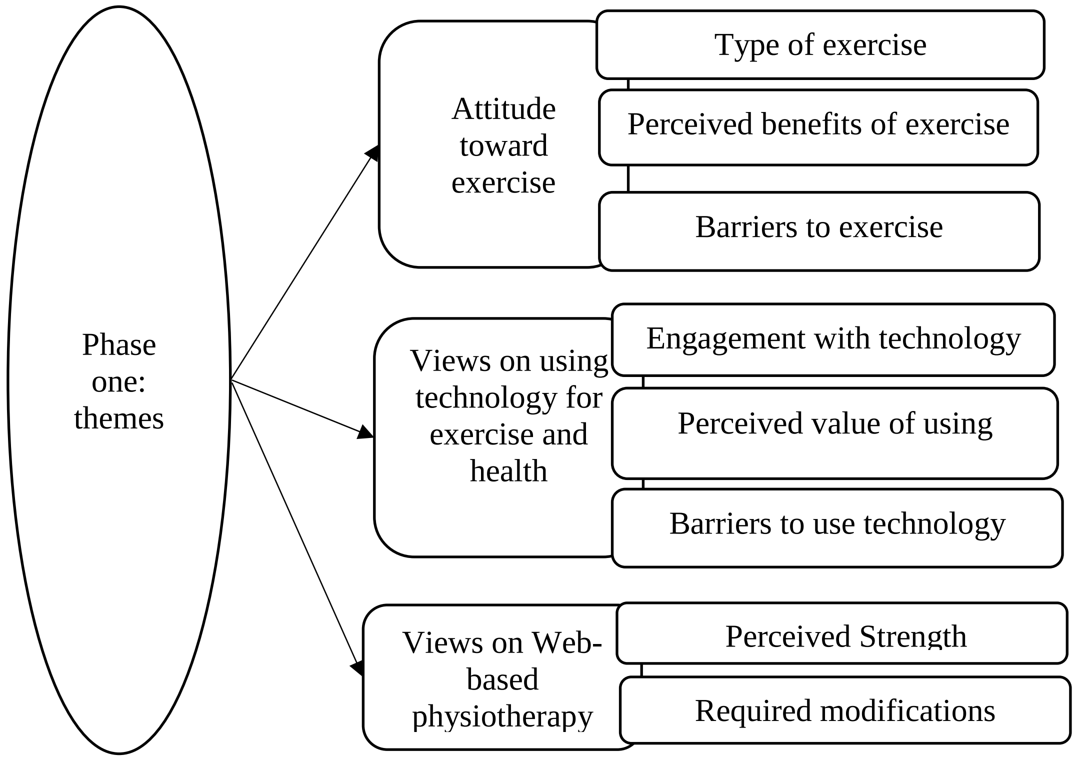
Seventeen participants with South Asians backgrounds took part in the two gender-specific exploratory focus groups (female=9, male=8). The mean age was 38 ± 11 years (range: 23 - 57 years). Participants were heterogeneous in terms of age, immigration history, country of origin, country of birth, use of the internet, educational levels and religious beliefs (Table 4.1). All participants reported that they had access to the Internet (Table 4.1).

Table 4.1 Exploratory focus groups: participants characteristics

Participants characteristics	**Exploratory female group (n= 9)**	**Exploratory male group (n= 8)**
Age (years)	39 ± 14	38 ± 9
Originally from Pakistan (n)	8	2
Originally from India (n)	0	4
Originally from Sri Lanka (n)	1	1
Originally from Bangladesh (n)	0	1
Born in UK (n)	3	1
Born in a South Asian country (n)	6	7
Muslim (n)	8	2
Other religion (n)	1	4
Speak English only (n)	1	0
Speak English and a South Asian language (n)	8	7
Speak Limited English (n)	0	1
Completed Primary school or lower (n)	2	3
Completed secondary school or higher (n)	7	5
Use the Internet frequently (n)	7	7
Never or occasionally used the internet (n)	2	1
Have Diabetes (n)	2	2
Have Hypertension (n)	2	2
Heart disease (n)	2	1

The stage one focus groups yielded three main themes and eight subthemes (Figure 4.2). The three main themes were attitude toward exercise, views on using technology for exercise and health purposes, views web-based physiotherapy. The views within each theme did not vary depending on the characteristics of the participants or the group that they attended, unless stated otherwise.

Figure 4.2 Stage one: themes



4.6.1.1 Theme 1. Attitude toward exercise

This theme explains participants views on exercise. Under this theme participants discussed the type of exercise they engage in, the perceived benefits of exercise and barriers to maintain or engage in exercise.

Type of exercise

Participants demonstrated a positive attitude to exercise in general. They reported taking part, currently or previously, in different types of exercises including walking, running (outdoors or treadmill), yoga, cycling, gym-based and Zumba dancing. In contrast to men who undertook these exercises at home, in gyms, and public places, women participants preferred to do these exercises at home or within gender-specific groups as they felt more comfortable in these environments.

> *"You cannot do the running outside. It is safe to go to the gym to do your exercise. And there are women classes in there. So it is good."* (PFG3: Pakistani female)

> *"That is fine, I have to do it [exercise] at home. so nobody can see you"*(PFG3: Pakistani female)

Perceived Benefits of exercise

All participants recognised the physiological, psychological and physical benefits of exercise. They reported that exercise had helped them to manage their weight, physical ability, general health, mental health, sleep quality and/or manage their health conditions. These benefits were also considered the main motivational factors to initiating and maintaining exercise.

> *"I had gestational diabetes but mmm…it carried on. It usually stops but mmm … so I'm on Metformin just now. I find if I'm more physical, my sugar levels is really good mmm…and if I give it up then it is high always. Plus it [exercise] wears you out and sleep better as well"* (*PFG1:* Pakistani female)

> *"yeah, it's helping to keep a mind fresh. If I am in stressment [stressed] I would straightaway go to the gym. It make me so relaxed."* (HMG2: Indian male)

Barriers to exercise

Participants reported several barriers to engage in or maintain exercise. These barriers included gym-related cost, poor weather conditions, fear of walking alone, fear of injury, feeling unsafe due to criminality, family commitments, and lack of time due to work and study.

" If you don't do properly exercise, it will affect your body" (HMG3: Indian male)

"I used to do Zumba, I quite liked Zumba before that, but then having the kids and the childcare then nothing" (PFG5: Pakistani female)

"yes, I tried to go by myself. In the morning I am mostly busy with just my kid. I can go by myself but I feel inside a bit unsecure to go alone to the park, then I just go to grocery and then come back home." (PFG3: Pakistani female)

In particular, female participants expressed that in the South Asian culture women are considered the primary caregiver and as such, husbands and the wider South Asian community expect them to stay at home and perform their duties. As a result, the social stigma attached to women leaving their homes to exercise outdoors was reported as a barrier to exercise.

"If the Asian woman is going walking, if she is alone, [other Asian people would say] "look why she is going alone?". They [other South Asian people] feel...you know they feel awkward, you know and they feel them do awkward you know" (PFG2: Pakistani female)

4.6.1.2 Theme 2- Views on using technology for exercise and health purposes

This theme explains South Asians views on using technology for exercise and health purposes. Under this theme, there were three sub-themes highlighting the type and source of health information they sought technology for, perceived values of using technology and issues associated with using technology.

Type and source of health information sought

Most participants (n=15) expressed familiarity with using technology to find information about different aspect of health including information about signs and symptoms of disease, treatment and complications of conditions affecting them or their family. Information on how to achieve a healthy lifestyle, including healthy recipes, diet plans and exercise programmes, was reported as the most common topic.

> *“yeah yeah. When my GP told me that I've got the Vitamin D deficiency, then I read everything about that on the Internet”* (PFG2: Pakistani female)

> *“I used an app called "beaster" that counts how many steps you take and how many calories you burn”* (PFG4: Pakistani female)

> *“I did Slimming World [online]. It’s quite good. I have a look at some healthy recipes.”* (PFG8: Pakistani female)

To find such information, participants used a variety of sources, including websites found by searching through Google, websites run by recognised organisations, popular exercise websites, Facebook, YouTube and mobile apps.

> *“yeah. We used [the Internet]. We go to the YouTube watching the exercises. They are giving what I am doing some time.”* (HMG1: Indian male)

> *“bodybuilding.com. You can use the bodybuilding.com … it lets you to know everything: which one [exercise] you want, you use a weight you lose a fat everything. It is good.”* (PMG2: Pakistani male)

> *‘’we just Google whatever.’’* (PFG1: Pakistani female)

Perceived value of using technology for exercise and health purposes

Generally, using the internet for exercise delivery appeared to be well received by the participants in this study. Participants highlighted several benefits of using such an approach. Being accessible was the primary benefit identified by participants. In contrast to gym or rehabilitation clinics, participants felt that technology provided easily accessible interventions that could be accessed anywhere and at any time.

> *"right, well, all you had to do the exercise but this sort of exercise is like you can do anywhere, women or men or whatever it is simple and basic. You can do it in house, you can do it in your office and you can wear basic clothes … and you can do with Hindu, Muslim, Christian, anybody can do it."* (BMG1: Bangladeshi male)

Participants also thought that using technology to deliver exercise interventions would be convenient as it would save their time and reduce costs associated with attending gyms or going to health centres clinics.

> *"it's [going to gyms] too much expensive. This is take 40-45 pounds for half an hour [instructor cost]. Better you get for the information from Internet… It lets you know everything"* (PMG3: Pakistani male)

Furthermore, participants highlighted that technology-based exercise programmes provide an alternative option for those who feel shy when exercising in public places due to personal or cultural barriers as few female participants highlighted that they feel insecure when doing exercise outside.

> *"Some people cannot go outside. Some people feel shy to come to the clinic. Some people try to go to the gyms to... they don't want to be with the people, they want to do [exercise] separately. It is good for them to do in the home [using the Internet], it is good."* (HMG3: Indian male)

In addition, participants thought that using technology as a delivery mode provides a method that they can use to persuade their family members to engage in exercise, especially those members who do not know how to perform the exercise.

> *"we can teach to our family members. We can show that [internet-based platform], if having some problems. We can talk to them you can do these*

exercises in your home, like that, we can recommend to them also. It is good." (HMG2: Indian male)

Issues with using technology for exercise and health purposes

Participants who frequently use technology raised some issues obtaining information about exercise and health. A lack of culturally and linguistically appropriate content was an issue highlighted by participants, potentially preventing them from continuing to use health technology resources. 'Content' included all information provided in written, oral, or visual form that is encountered as part of the user experience on the Internet (CTI Reviews, 2016). For example, one participant reported attempting to use a healthy eating mobile application, but she was unable to continue using it as this application was based on a Western diet.

> *"the one app.. is the healthy cooking every day. I used to, but the kids don't like it to be honest. They used to curry and Naan or Raka like that. Every day they want it [laughter]"* (PFG4: Pakistani female)

Notably, participants highlighted concerns about the suitability of information provided on existing technology-based exercise platforms. Participants felt that existing resources tend to adopt a "one-size-fits-all approach" which they thought may lead to physical injuries as they wanted to know when, how and in which order to perform exercises.

> *"we also cannot totally rely on the exercise videos [over the Internet] because we have to know when this exercise should be do [done]"* (HMG5: Indian male)

Having commercial exercise platforms with misleading advertisements was another negative point. Participants referred to some platforms presenting misleading images and videos of bodybuilders to attract users. Participants thought that such resources would result in people setting unrealistic health goals, and consequently lead to negative health consequences.

> *"there is a dis-advertisement …. There is show that it's already grown up like a good body like that. After seeing that, it is a motivation but some people will take over thing, over motivation. They will do more, more, I*

want to gain like that guy. They will spoil their bodies very bad." (HMG1: Indian male)

4.6.1.3 Theme three- Views on the current version of the web-based physiotherapy platform

When shown the web-based physiotherapy platform, participants discussed their views and preferences for content and features to accomplish the exercise programmes. Participants highlighted the features that they liked, strengths, weaknesses, and suggested modifications.

Strength of the current version

Overall, participants were positive about the platform. They stated they would be willing to use it and recommend it to other people from South Asian communities. They reported that they liked the design, colour, layout and the ease of navigation around the site.

> *"yeah user friendly I think. It's quite easy."* (PMG1: Pakistani male)

Participants felt that this platform would minimise the risk of physical injuries due to doing unnecessary exercise, or not doing the exercises properly, as it provides personalised access to a tailored exercise programme with videos explaining when and how to perform the exercise.

> *"when people accidently come to that and find all of that exercises [online] and do all of that exercises and then they can damage as well… you cannot stop that. I don't think you will be able to stop people from going to different pictures you know… but if it is special, tailored then that is fine"* (PMG1: Pakistani male)

Participants also perceived the online diary accompanying the exercise as an attractive feature that could encourage them to adhere to web-based exercise interventions as they could write notes and express their thoughts regarding the exercise. Without this feature participants thought they may ignore the exercise as nobody would know that they completed it.

"this [online exercise diary] makes us bounder [expressed this statement in a very positive way: encourage us to adhere]. We have to write inside and then we have to do this in a regular basis. Because when we do things on our own [without the diary], we sometimes go ooh I have to do this. So just skip the exercise" (PFG8: Pakistani female)

Required modifications

To make the platform more culturally relevant for South Asians, participants showed preference for a few modifications. First, participants agreed that the content of the platform (i.e. pages, exercise videos, exercise instructions and the audio explaining the exercise) should be translated to an alternative language as many people from South Asian communities do not speak English. They suggested providing these translated versions as an option to those who do not speak/read English. However, when they were asked what language they prefer they suggested different languages including Hindi, Urdu, Tamil, Punjabi, and Bengali.

"Punjabi or Urdu" (PFG7: Pakistani female)

"Most people speak Urdu" (PFG8: Pakistani male)

"Hindi" (HMG1: Indian male)

"My language is Tamil. It is common as well, it is very old language as well, it is one of the first languages in the world" (SFG1: Sri Lankan female)

Second, participants in both groups felt that the characteristics of models appearing in exercise videos should be carefully considered when targeting South Asians. Three characteristics related to models appearing in exercise videos were highlighted; ethnicity, clothing, and gender. With regards to clothing, both men and women preferred models to be wearing modest clothing. However, there were disagreements between the male and female groups in terms of the preferred gender and ethnicity of models. Female participants preferred female actors, regardless of ethnicity. In contrast to female participants, male participants preferred models to be from different ethnic backgrounds but did not express a gender preference as long as models were wearing modest clothing covering the majority of their bodies.

> *"yeah. I prefer it to be women"* (PFG4: Pakistani female)

> *"I think yeah have various people [different ethnicities], many of people, mixture yeah, to make it look appealing, yeah motivating, motivation I think"* (PMG1: Pakistani male)

> *"we are just concentrating only on the exercise, not seeing if it is a girl, how she looks. It is not a matter but for what he is saying it's not "expose" it will be good to learn [teach] us. And mmm… like man or women it's not a problem but it is good what he is saying not exposed, it is good."* (HMG2: Indian male)

Third, participants indicated that exercise videos should be filmed using homely backgrounds. They felt that such backgrounds convey a positive message regarding the possibility of exercising at home and this would make the platform more realistic.

> *"It looks reality, that means people get to know that we can do [exercise] at any place. We can do in our home also. If you're showing something like a clinic or something like that, they feel that we have to go there only"* (HMG3:Indian male)

Fourth, participants also highlighted that the dark background in the exercise video clips made it difficult to concentrate on the video. Therefore, they suggested paying attention to the video background when filming new exercise videos.

> *"I think sorry aaa… maybe see this aa. Looking at that, it's a little bit dark. Look at the shirt and the sofa it's dark, I can't you …know it should be something lighter".* (PMG1: Pakistani male)

“The sofa having the same colour and what he is wearing the same colour. It should be a different, opposite, you can absorb you can concentrate on that thing properly” (HMG2: Indian male)

Finally, participants who reported using technology to obtain diet plans also suggested adding calories calculator to the platform.

“did they explain about calories as well, how many calories you burn… It is very mmm… helpful. If you know that by yourself about how many calories and how many burn and how many, you have achieved your goal like that” (PFG2: Pakistani female)

4.6.2 Phase two results: preliminary platform modifications

At this stage, an effort was made to modify the web-based physiotherapy platform, based on participant views gathered during the previous stage (Table 2). Once the data was analysed, the PhD student and the supervisors (LP and EC) met to discuss the findings and the possibilities of implementing the modifications required by participants, as presented in Table 4.2 and 4.3. During the discussion, consideration was given to the time and cost associated with modifications, as well as how other users would be impacted by such modifications. After the discussion, an action plan was agreed with the supervisors and the modifications were applied to the platform. Figure 4.3 shows examples of the modifications made.

Table 4.2 Interpreting themes/sub-themes to inform the refinement process

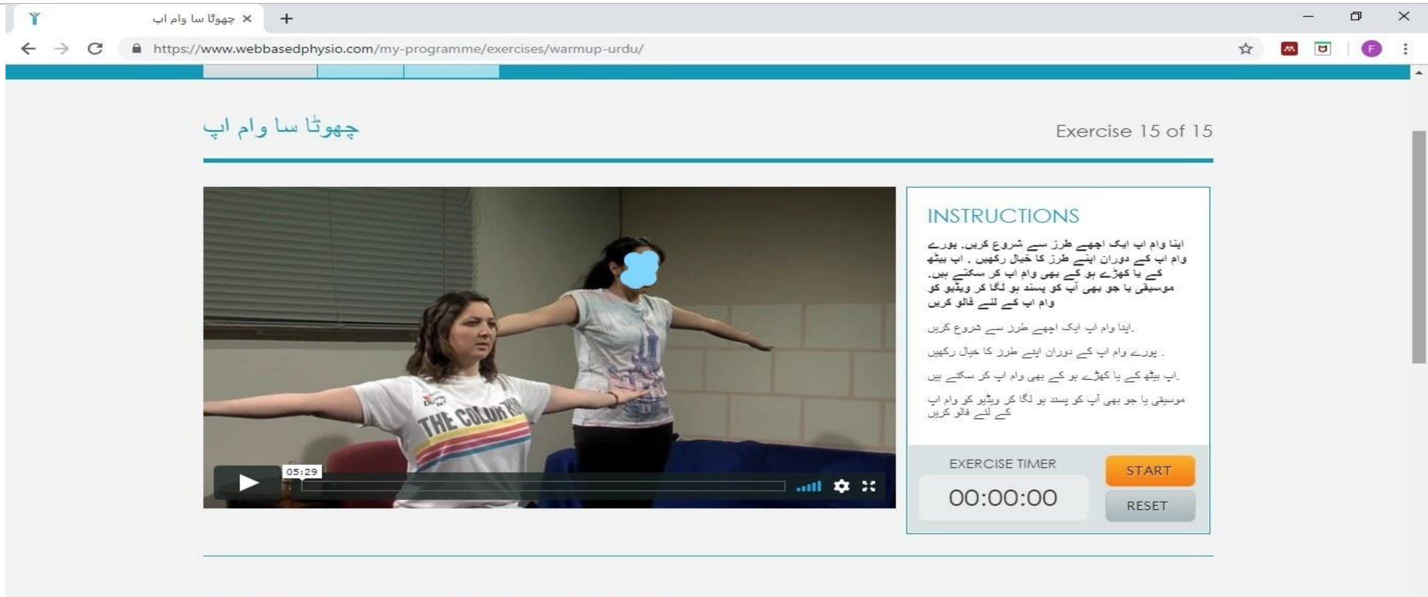
Themes/	**Subthemes**	**How the Theme/Subtheme was Used**
Participants views on exercise	Type of exercise in which they engaged.	Allowed us to understand what type of exercise South Asian people engage in. This was important to understand what exercise was acceptable and therefore, used in the platform and for future interventions.
	Perceived benefits of exercise.	Allowed us to understand how people from South Asian communities perceive exercise. If they did not recognise the benefits of exercise, we would have considered educational materials as a main component in the platform.
	Barriers to exercise.	The barriers to exercise confirmed the need for an innovative approach to delivery. It also reassured us that technology-based exercise platforms could be a solution.
Views on using technology	Type and source of health information.	This allowed us to understand what type of health information South Asians search for on the internet: what type of platforms they use.
	Perceived value.	This allowed us to ensure the suitability of using technology as a delivery mode for South Asian people.
	Issues with using technology for exercise and health purposes	Confirmed the need for refining the technology-based health platform to meet the need of South Asians. Highlighted the issues that might prevent participants from using the platform.
Views on the current version of web-based physiotherapy	Strength of the current version.	Highlighted the strength of the current platform. Confirmed the suitability of the design, the colour and the importance of personalised exercise programmes.
	Required modifications.	Highlighted the modifications required to make the platform more appropriate for people from South Asian communities.

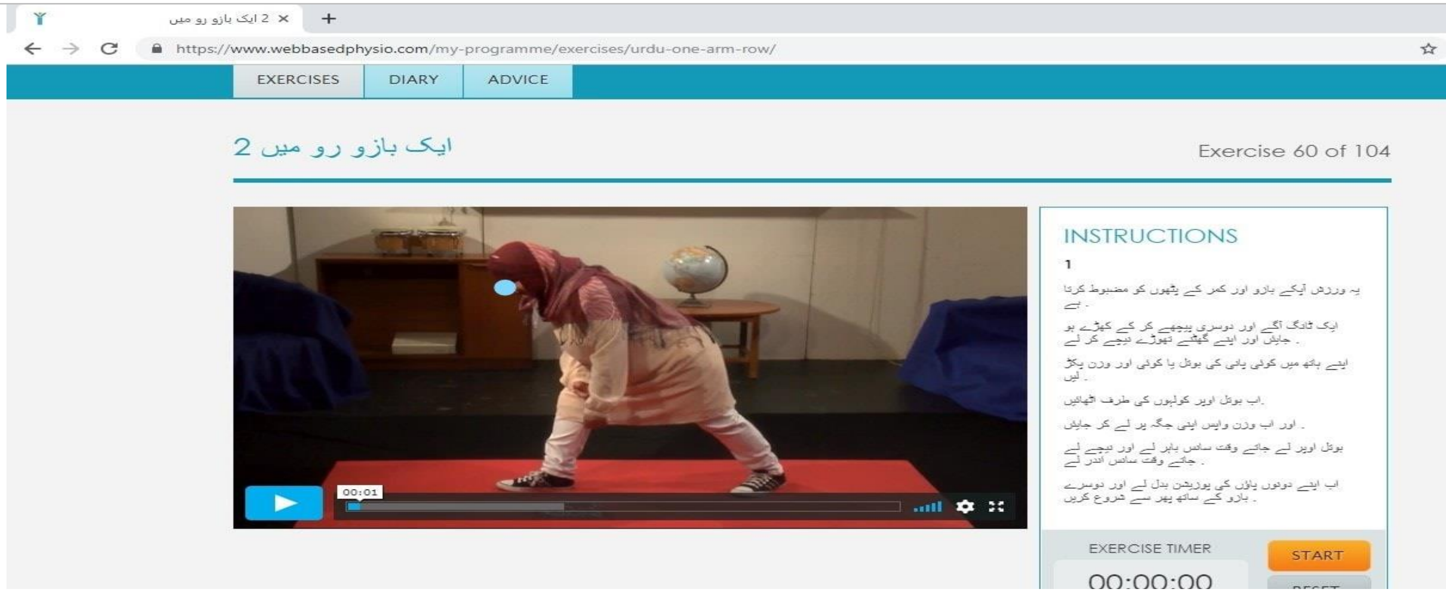
Table 4.3 The suggested modifications, potential implementation and actions performed.

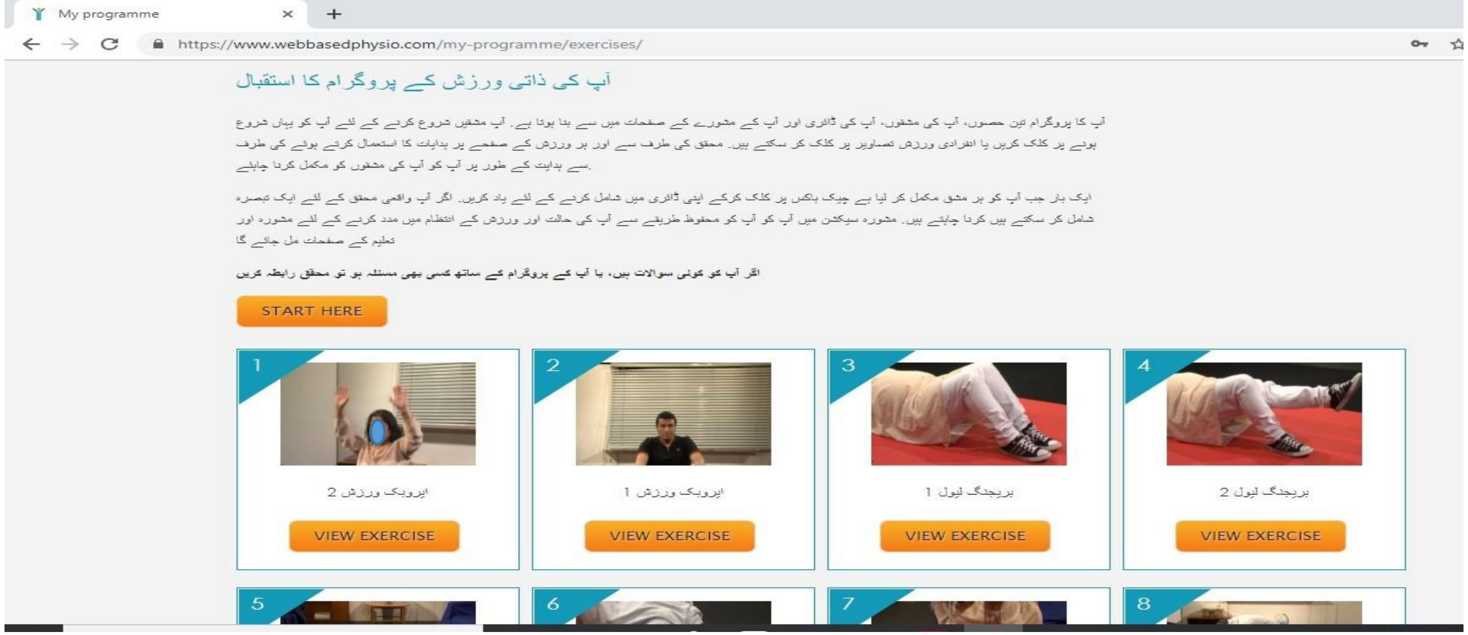
	Required Modifications	**Possible Implementation**	**Actions**
1-	Content of the platform should be translated to a South Asian language (i.e., pages, exercise videos, exercise instructions and the audio explaining the exercises in question).	It was difficult to provide all the suggested languages due to cost and time constrains. Therefore, it was decided that a partial solution be provided by translating some of the exercise pages into Urdu, which is the most common language among South Asian communities. This decision was made after a discussion with the manager of REACH community health project	Volunteers from REACH community health project translate the content into Urdu. A volunteer from REACH recorded the translated voice over at a studio at the University of Glasgow. The PhD student added the translated content to the platform.
2-	Actors in exercise videos should wear modest clothes.	Possible. The exercise-video catalogue already contains actors with modest clothes. However, we were not sure what the exact definition of 'modest' would be from a South Asian perspective. Therefore, we decided to film new exercise videos with female actors wearing clothes that covered their whole body, up to their head. We also decided to avoid exercise videos that had male actors wearing shorts.	New exercise video clips were filmed with female actors wearing traditional South Asian dresses and clothes that covered their whole body, up to their head (except the face and hands). The PhD student added the new translated content to the platform. New exercise video clips were also filmed with male actors wearing clothes trousers instead of shorts

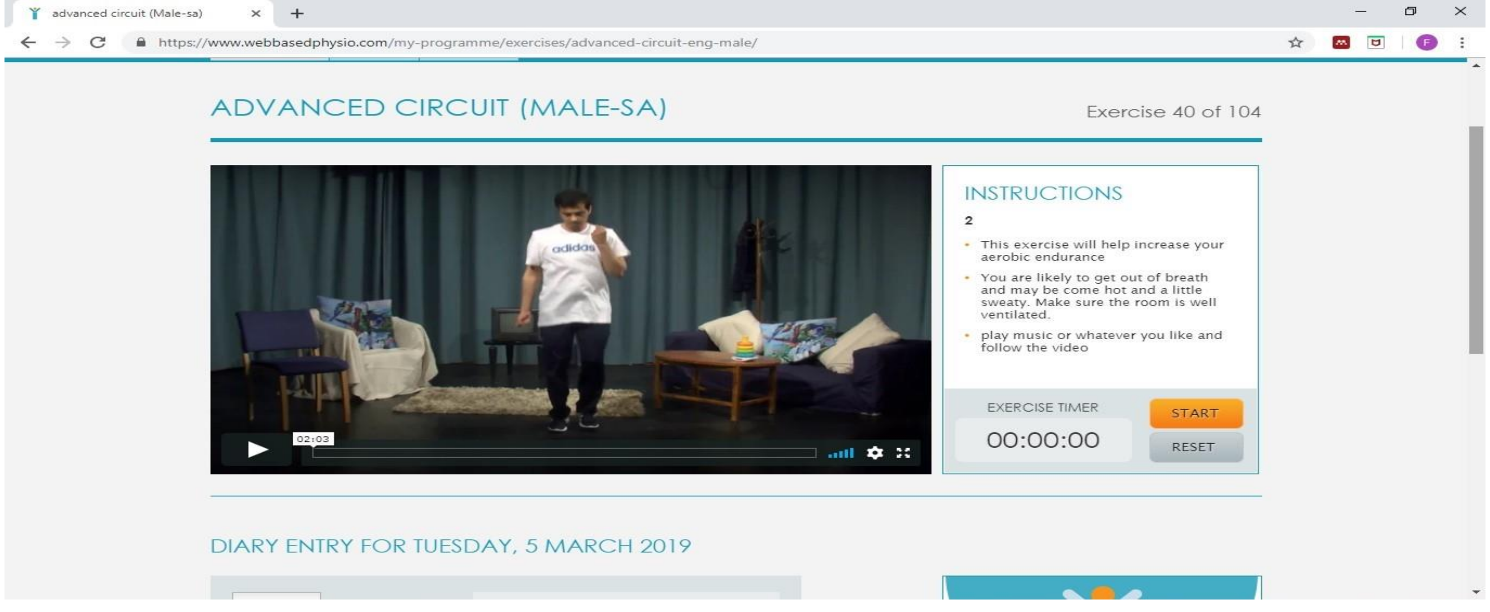
	Required Modifications	Possible Implementation	Actions
3-	Female actors for exercise targeting South Asian women.	Possible. However, it is difficult to find South Asian female actors. We decided to invite South Asian volunteers from both the university and from REACH community health projects	New exercise video clips were filmed with two female actors, one from REACH and one student from University of Glasgow.
4-	Actors should be people from different ethnic backgrounds for exercise clips targeting South Asian men.	Possible. We decided to invite volunteers from different ethnic backgrounds (i.e., South Asians, Arabs and Europeans).	New exercise video clips were filmed with people from different ethnic backgrounds (i.e., the author, other PhD students and the supervisors (LP and EC)).
5--	Homely background.	Possible. The platform already contains some exercise video clips filmed in homely locations. We decided to set up the studio to reflect a 'homely background'.	The studio at the University of Glasgow was set up with a 'homely background' when filming the exercise sessions.
6-	Video clips quality. i.e. attention the dark backgrounds	Possible. We decided to avoid dark backgrounds when filming the exercise clips	Greater lighting was used when filming the exercise clips and used light colours in the background.
7-	Adding a calorie calculator.	This suggestion might conflict with other users of the platform. In addition, it is difficult to calculate calories in individual exercise programmes	No action

Figure 4.3 Examples for the modifications made to the platform

	Example for the modification made
Female actors for female users	

Modest clothes	

Urdu language	

Homely background.	

4.6.3 Phase three results: feedback on the modified platform results from two gender-specific confirmatory focus groups

To obtain feedback on the modifications described above, two gender-specific confirmatory focus groups were undertaken on December 2016. An effort was made to include some of the participants from the exploratory focus groups. However, arranging a subsample of the same participants to return for the confirmatory focus groups was not possible due to time constraints, and difficulty in contacting participants. As a result, the confirmatory focus groups were held with a different group of participants from South Asian communities living in the UK (female=5, male=4). In contrast to participants in stage one, all new participants were originally from Pakistan. Participants were also younger as compared to those who had taken part in stage one (Table 4.4).

Table 4.4. Confirmatory focus groups: participants characteristics

Participants characteristics	**Confirmatory female group (n= 5)**	**Confirmatory male group (n= 4)**
Age (years)	36 ± 8	31 ± 10
Originally from Pakistan (n)	5	4
Originally from Bangladesh (n)	0	1
Born in UK (n)	2	0
Born in a South Asian country (n)	3	4
Muslim (n)	5	4
Speak English and a South Asian language (n)	4	3
Speak Limited English (n)	1	1
Completed Primary school or lower (n)	3	1
Completed secondary school or higher (n)	2	4
Use the Internet frequently (n)	4	3
Never or occasionally used the internet (n)	1	1
Have Diabetes (n)	2	2
Heart disease (n)	1	1

4.6.3.1 Confirmatory focus group theme: Views on the modified web-based physiotherapy platform

The discussion with participants in the confirmatory focus groups yielded one theme with two sub-themes reflecting their opinion about the modified platform.

General impression about the modifications

Participants were positive about the modified web-based physiotherapy platform. They approved and expressed satisfaction with the modifications made. In terms of the translations made to exercise videos and exercise instructions, participants stated that the selection of Urdu as a choice for those with limited English would facilitate the engagement of a wide range of users from South Asian backgrounds, as the majority of South Asians understand Urdu even if they speak Hindi or Punjabi.

> *"that's a good thing because Indians also speak Urdu so people who don't understand English can use this website. It is good, yea definitely... there will be no language barriers for them... people from different communities... see if a Panjabi person [Punjabi speaker] is watching the videos [translated to Urdu] as well, he can definitely understand Urdu as well"* (CMG4: Pakistani male)

Participants also expressed satisfaction with the considerations given to the characteristics of the models appearing on the exercise videos (i.e., modest clothing, people from different backgrounds, female models for female participants). In terms of clothing, participants highlighted that modest clothes were important, but this does not mean that the faces/heads of actors need to be covered. Rather, this simply means that clothes should not be very tight, nor should they show body details.

> *"you know in every religion there are different rules, in most of the time it doesn't matter but just some people think that it is better to cover her head, still if they are covering their full bodies it is fine... even less clothes also is ok, but if there was some in tight clothes, people would say ooh look how... do you know what I mean, especially if it was targeted toward a South Asian community" (CFG1: Pakistani female)*

"if you are doing it at home, even for Islam, in Islam if you are at home you don't need to cover your head inside your home" (PFCG2:Pakistani female)

In terms of gender, female participants perceived the consideration given to gender as being very important, since they believe that women participants would not perform the exercise if the actor was a man. Men participants confirmed that the actor gender is not important.

"I think if ladies saw the videos they might just click on the women exercises ones, they might think aha that is a ladies exercise … yeah they might think the other videos are for men" (CFG3: Pakistani female)

"see I can be ok with any, like I will be ok with women as well, see for me I just want to get the exercise I don't care whether a woman is teaching me or a man is teaching me . So for me it does not a matter" (CMG4: Pakistani male)

Male participants, however, did not approve the effort made to improve the video quality. They felt the background colours were still dark.

"See the lady, she is wearing clothes of same colour as the wall, so if someone does not have proper eye sight or some problem….can't see" (CMG3: Pakistani, male)

"see for me it is not a problem but if you think from that point of view, yeah, because you have to follow people [in the video] see the floor, wall, and clothes three things of the same colure, but that is ok for me I don't mind. but if you look at it from different point of view, that some people might have problem but I think as it is overall it looks fine" (CMG5: Pakistani, male)

Participants also felt that there was still room for improvements and suggested adding testimonials in the form of a narrative depicted in pictures.

"Yeah successful stories, have you seen the pictures, like, before they start the gym and after they start the gym, those pictures, yeah something like that!" (CMG3: Pakistani male)

Intention to use

The majority of participants (7/9) reported that they would be happy to use the modified platform if advised. They reported that this platform would minimise travel time and would be convenient.

"I would use it, I would if I had a problem" (CMG5: Pakistani male)

"I remember once I got an appointment it was 9 clock in the morning, I thought alright I have to go and leave the kids, so I left them early so I can get to my appointment.. Parking space … things like that... but if I've been once and they tell you what to do in the house and then if there was a video... I think that is enough" (CFG3: Pakistani female)

"it is actually maybe good very very (good for) people who can't go for the hospital so it maybe good for them and that is good having it in Urdu and then they can try and follow it" (CFG1 Pakistani female)

Only two participants stated they would not use the platform. However, the lack of interest in using this platform was not related to the platform nor to the modifications made. Rather, one participant stated no interest in using technology in general, while the second participant stated that using technology is difficult for them. Based on their demographic data these two participants were less educated and infrequent internet users compared to other participants.

"because see technology is going quite fast and it's quite hard to keep up with it, because you could do some tasks and struggle to keep on with it and not everybody finds it easy to go to the Internet and find stuff"
(CFG2: Pakistani female)

"I do not have any interest in using these apps and websites" …… it is a good way but I have not used any applications or websites" (CMG1: Pakistani male)

To help people with low level of technology experience overcome difficulties of use participants suggested including a family member who would be able to guide their relatives on how to use the platform or providing tutorial videos explaining how to use the platform. Some young participants explained that they had previously successfully used these strategies with their relatives.

"old people, they don't know how to use modern technology, they find it hard to use iPhone for them, but my mum she has iPhone, she found it hard, troubled with the iPhone, which features to use ... So she learned from watching videos that teach them how to use them" (CMG2: Pakistani male)

"sometimes when my mum is having a problem with using the iPhone, she asks me how I should do that, I used to teach her. And see this is not difficult, see when I teach her, she then goes on her own very good" (CMG4: Pakistani male)

4.6.4 Final modifications

Based on the results of the previous stage more exercise clips were filmed, translated and uploaded to the platform. Further considerations were given to the quality of exercise video clips. It was not possible to add testimonials, however that was considered a possibility for future development.

4.7 Discussion

This study aimed to refine and adapt an existing web-based physiotherapy platform in order to make it more accessible and culturally relevant for people from South Asian communities. Unlike platforms developed based on experts' views, this study used a user-centred design approach, in which potential user views were considered central to the refinement process.

Previous studies in the field, that have used such an approach to develop or modify technology-based exercise platforms, have reported satisfactory results (Schaarup and Hejlesen, 2015; Coulter et al., 2015b). For example, Schaarup and Hejlesen (2015) developed an online diabetes exercise system in Norway based on user-centred design principles and reported satisfactory results. Coulter *et al.*, (2015b) also used a user-centred approach to modify the platform used in the present study to be accessible and suitable for people with spinal cord injuries. However, studies targeting or including a substantial number of South Asians are scarce.

Exploring participants views as a starting point in this study contributed to a better understanding of the understudied area of using technology to deliver exercise interventions targeting South Asians. It also provided a good basis for informing the refinement process. Participants' views on exercise were used to confirm the need for an innovative exercise delivery approach when targeting people from South Asian communities living in the UK. In line with a study conducted by Jepson et al. (2012), the current study indicated that South Asians engage in different types of exercise and they recognise the benefits of such exercises. However, South Asians still face a number of exercise barriers. The presence of these barriers justified the importance of using technology as a novel approach to deliver exercise interventions to people from South Asian backgrounds.

The barriers to exercise reported in this study (i.e. lack of time, poor weather, fear of injury, expensive gym-membership, childcare and household responsibilities, feeling unsafe due to criminality, and the social stigma associated with leaving the house to do exercise), confirmed the barriers reported in previously published studies investigating exercise behaviour in South Asian populations (Johnson, 2000; Lawton et al., 2006; Galdas et al., 2012; Ruth et al., 2012; Vahabi et al., 2012; Horne et al., 2013; Singhal and Siddhu, 2014; Lisa et al., 2015; Koshoedo et al., 2015; Sohal et al., 2015; Cross-Bardell et al., 2015; Rajaraman et al., 2015). Previous studies also found that cultural barriers such as the religious requirement for modesty and cultural rejection of wearing sport dress in public and a lack of gender-specific facilities, particularly for women were the main barriers to exercise (Sriskantharajah and Kai, 2007; Jepson et al., 2012). However, the latter factor was not considered a barrier in the present study perhaps due to the adequate provision of women-only exercise classes in the local area.

Participants views on using technology for exercise and health were used to determine the suitability of using technology-based exercise platforms when targeting people from South Asian communities. The degree to which people perceive using technology as being beneficial to them is strongly associated with acceptance and use of technology (Rho et al., 2014; Ahadzadeh et al., 2015; Zhang et al., 2017). The technology acceptance model highlighted that the perceived usefulness is a main factor that influences people's decision about using technology. In line with other studies involving white Europeans, participants perceived using these platforms for health and exercise purposes to be accessible, convenient and cost-effective (Vermeulen et al., 2013; Middelweerd et al., 2015; Peng et al., 2016; Van Kessel et al., 2016). However, in contrast to other studies, this study highlighted a unique benefit to use technology as a delivery mode within South Asian populations. In this study, participants stated that using technology could facilitate the engagement of individuals who feel shy/insecure about exercising in public.

Avoiding exercise in public has been reported to be a barrier to exercise in this study as well as other studies involving people from South Asian communities (Babakus and Thompson, 2012). Several factors related to the South Asian culture may explain why South Asians avoid exercising in public places. These factors include a cultural rejection of wearing exercise clothing in public, the cultural expectation that women should be at home looking after the family, the religious beliefs concerning modesty, and feeling unsafe due to criminality (Lawton et al., 2006; Galdas et al., 2012; Horne and Tierney, 2012; Horne et al., 2013; Singhal and Siddhu, 2014). Using the internet to avoid public criticism or stigma has been frequently utilised by people suffering from perceived stigmatised health conditions, such as acquired immune deficiency syndrome (Berger et al., 2005) and therefore may be an exercise solution for people from South Asian backgrounds.

The issues that participants face when using existing online health resources were used to confirm and justify the need for refining the web-based physiotherapy platform. Participants reported a few barriers, such as the lack of a personal exercise programmes misleading advertisements and the lack of culturally appropriate content on the internet. The presence of these barriers, particularly the lack of culturally relevant content, justified and confirmed the need for refining technology-based health platforms to meet the needs of people from ethnic minorities (Yardley et al., 2010; Liu et al., 2012). Evidence suggests that technology-based health platforms that have been created for ethnic minority groups are scarce (LaVertu and Hendler, 2008). Failing to address the cultural and linguistic needs of ethnic minorities in health settings was found to be strongly associated with poor access to health care, poor adherence to medications and poor adherence to healthcare providers' advice (Ahmed et al., 2015).

Participant's views regarding the web-based physiotherapy platform provided useful guidance to how to make it more relevant from people from South Asian communities. Participants highlighted the strengths and weaknesses of the platform and provided suggestions to improve the weaknesses. These views were strongly associated with either the identified barriers to use technology for exercise, or those barriers related to exercising in general. To overcome the lack of appropriate linguistic and cultural content, participants showed a preference for translating materials to different South Asian languages especially Urdu. In addition, the desire for exercise videos with homely backgrounds was perceived to convey a positive message regarding the possibility of doing the exercises at home, as leaving the home and family commitments were also perceived to be barriers to exercise by South Asians. (Lawton et al., 2006; Galdas et al., 2012; Horne and Tierney, 2012; Horne et al., 2013; Singhal and Siddhu, 2014). Furthermore, the benefit of personalised exercise programmes with videos explaining each exercise was related to the belief that they minimise the risk of physical injuries, since this was considered to be a barrier to exercise for South Asians in this study and other studies involving South Asians (Lawton et al., 2006; Galdas et al., 2012; Horne and Tierney, 2012; Horne et al., 2013; Singhal and Siddhu, 2014).

Participants also highlighted the importance of considering the characteristics of models appearing in exercise videos to be culturally acceptable. A previous study using the user-centred approach, with white Europeans, emphases the importance of the characteristics of actors appearing in exercise videos (Coulter et al., 2015b). In this study, participants showed preference to actors with similar health conditions (Coulter et al., 2015b). In the current study, participants showed a desire for characteristics that were strongly associated with South Asian culture (i.e., actors wearing modest clothes and female actors for exercises targeting South Asian females).

Gender issues and religious beliefs about modesty are common in South Asian communities. South Asians in previous studies stated a preference for same-sex healthcare professionals and a desire to avoid mixed-gender exercise facilities, such as open sessions in swimming pools (Lawton et al., 2006; Galdas et al., 2012; Horne and Tierney, 2012; Horne et al., 2013; Singhal and Siddhu, 2014). This may explain why participants showed a desire for actors wearing modest clothing and why specifically female participants expressed a desire for female models. Seeing a model with similar characteristics to the target population doing the exercise may enhance their confidence in their ability perform the exercise. According to Bandura, (1994) observing of others' performance is a source of self-efficacy/confidence. This source is powerful, especially when people observe those whom they believe to have the same capability and limitations as themselves (Järvelä, 2011).

Some of the improvements required by participants to make the web-based physiotherapy platform more acceptable and accessible were challenging. One suggestion that was particularly difficult to implement due to time and resources constrains was the desire to translate the content to different South Asian languages. However, it was possible to provide a solution by translating the content to Urdu which was the most common language among South Asian. Another suggestion that was not implemented was adding a calorie calculator. It was found that this feature would benefit only those who would use the platform for weight reduction purposes, as such it might conflict with other users. In addition, it is difficult to add a calorie calculator in a platform designed to deliver personalised exercise programmes as calories burned can vary depending on the dose of the exercise programme (Brown et al., 2016).

Using confirmatory focus groups in the third stage contributed greatly to understanding participant views on the modifications made to the platform prior to implementation. This stage allowed participants to approve or disapprove the modifications made. According to the literature, testing early design ideas with end-users is a cost-effective way to avoid usability issues (Ross et al., 2018). Overall, participants confirmed the suitability of the modifications made. Participants who frequently use the internet and who are educated reported they would use the platform. However, participants who rarely used the internet stated that they were less likely to use the platform. This was expected, as other studies have shown that one's intention to use such a platform is dependent (partly) on one's ability to use technology-based health resources. This means that elderly people and people of a low educational level may be less likely to use technology for health purposes (Mead et al., 2003; Hiratsuka et al., 2013; Moore et al., 2013; Willcox et al., 2015; Van Kessel et al., 2016; Peng et al., 2016). As such, educating South Asians about technological-based exercise platforms (and how to use them) might be required to increase the widespread use and acceptability of these approaches (Mead et al., 2003).

4.7.1 Limitations of this study

The study presented several limitations that should be considered. Although efforts were made to recruit people from different South Asian backgrounds, we were unable to recruit any Indian or Bangladeshi women. In addition, all participants were aged less than 57 years old. As such, the generalisability of the findings may be limited. Due to the relatively large number of participants within the exploratory focus groups, some participants dominated discussions, while others provided only short, verbal comments or used non-verbal impressions to state agreement or disagreement within discussions, despite the moderator's efforts to engage all participants. In addition, to aid the recruitment of female participants who had childcare responsibilities, children were present during the focus group discussion. As such, the level of background noise made hearing some participant comments difficult (i.e. during the focus groups and when transcribing) and may have affected the concentration of those in the female focus groups. Furthermore, participants were not able to try out the platform prior to either the exploratory and the confirmatory focus groups. As such, the discussions did not reveal any theme related to the practical aspects of the platform.

4.8 Conclusion

This study chapter described the efforts made to make web-based physiotherapy accessible and culturally relevant from South Asian communities living in the UK. The user-centred approach used in this study contributes to a better understanding of the needs and views of South Asian participants and consequently allowed to use this information to refine and customise the platform based on their needs.

Chapter 5 – A randomised, controlled pilot study of a 12-week Web-based exercise intervention for South Asian people with type 2 diabetes

Following the customisation made to the web-based physiotherapy platform in the previous chapter, the upcoming Chapters (i.e. 5 - 8) will describe the final study in this PhD. This study was a randomised controlled pilot trial embedded with interviews conducted to investigate the feasibility, the acceptability and the likely effect of a 12-week web-based exercise delivery using the modified web-based physiotherapy platform for South Asians with T2DM. This chapter will outline the objectives of this pilot study before describing the protocol. The results will be presented in the next chapter (Chapter 6).

5.1 Introduction

As discussed in chapter 2, regular structured exercise is a fundamental strategy to control T2DM and prevent associated complications (De Feo and Schwarz, 2013; Balducci et al., 2014). The systematic review presented in Chapter 3 also shows that exercise can improve factors strongly linked to T2DM and its complications in South Asians with T2DM including glycaemic control, muscle weakness, functional mobility decline, abnormal blood lipid profile, and high blood pressure. However, as highlighted in chapter 2, South Asians are less likely to engage in exercise due to personal and cultural barriers. Cultural barriers include lack of gender-specific facilities, the religious requirement for modesty and cultural rejection of wearing sports clothing in public (Lawton et al., 2006; Galdas et al., 2012; Horne et al., 2013; Singhal and Siddhu, 2014). Personal barriers include a lack of time due to work and study, family commitments, and adverse weather conditions (Horne and Tierney, 2012).

As discussed in Chapter 2, using the Internet to deliver web-based exercise interventions instead of face to face exercise interventions may help South Asians with T2DM to overcome both personal and cultural barriers and consequently engage in exercise on a regular basis. Web-based interventions are available 24 hours a day and can be accessed at anytime from anywhere. Eighty-one percent of adults living in the UK have access to the Internet and South Asians tend to use the Internet more than their White British counterparts (Ofcom, 2013). A recent study investigated the impact of a web-based exercise intervention in people with T2DM and reported positive results (Akinci et al., 2018). In this study, 65 participants with T2DM were randomised into three different groups; a control group, receiving a physical activity counselling brochure, a supervised exercise group undertaking a group-based combined exercise programme three times per week for eight weeks, and a web-based exercise group following the same exercise routine as the exercise group but delivered via the Internet. At the end of the intervention, both the web-based exercise group and the group-based exercise group showed significant improvements as compared to the control group in glycaemic control, blood lipids, waist circumference and quality of life. However, this study did not include people of South Asian backgrounds. In fact, to date there is no study that has investigated the effect of a web-based exercise intervention for South Asians with T2DM.

The Medical Research council (MRC) framework recommends four main stages for developing and evaluating complex health interventions (Craig et al., 2013). These stages are (1) development; (2) feasibility and piloting; (3) evaluation; and (4) implementation. As such, in keeping with stage two of the MRC framework, this study aimed to address the feasibility, the likely effect and the acceptability of a 12-week personalised web-based exercise intervention in South Asians with T2DM.

5.2 Research objectives

5.2.1 Primary objective

- To determine the feasibility of a personalised 12 weeks web-based exercise intervention in South Asians with T2DM compared to usual care. The aspects of feasibility measured were recruitment and attrition rates, adherence to the intervention, and adverse events.

- To examine the likely effect of a 12-week personalised exercise programme delivered using a web-based exercise platform, compared to usual care, on glycaemic control, muscle strength, functional ability, blood lipid profile, blood pressure and quality of life in adult South Asians with T2DM.

- To qualitatively explore the experience of participants in the intervention group on the web-based intervention in terms of acceptability and barriers to adherence.

5.2.2 Secondary objectives

- To compare any change in glycaemic control, muscle strength, functional mobility, blood lipid profile, blood pressure and quality of life after 8 weeks of completion of the intervention in those who received the intervention and those who received usual care.

5.3 Methods

5.3.1 Study design

To achieve the research objectives, a mixed methods pilot research study was undertaken. A pilot is a small study undertaken to inform further a larger study (Arnold et al., 2009). In the current project a pilot study was undertaken as it was yet unclear how well web-based exercise interventions would be received by South Asians with T2DM. Therefore, the results of this study would inform a larger definite RCT.

Mixed methods research refers to research that collects and analyses both qualitative and quantitative data in a single or series of studies (Curry et al., 2009; Tariq and Woodman, 2013). Quantitative methodology is the predominant approach in healthcare (Tariq and Woodman, 2013). This approach involves research designs and methods that collect, analyse and interpret quantitative data (data in numerical forms) (Tariq and Woodman, 2013). Quantitative data allows researchers to establish statistics that facilitate comparison among groups, determine changes overtime, or establish cause and magnitude of effects (Curry et al., 2009). In contrast, qualitative methodology refers to research designs and methods that collect, analyse and interpret non-numerical data (e.g. usually people's beliefs, views and meanings) (Tariq and Woodman, 2013). Compared to quantitative methods, qualitative methods are more appropriate to explore people's views, preferences and experience (Tariq and Woodman, 2013).

The quantitative component in this study consisted of a single blind, pilot randomised controlled trial (RCT), which was adopted to determine the likely effects of the intervention on glycaemic control and other outcomes i.e. muscle strength, functional ability, blood lipid profile, blood pressure and quality of life. RCTs are considered the gold standard design for evaluating the effectiveness of interventions. Other experimental designs (e.g. non-randomized clinical trials) are able to detect the possible effects of the interventions. However, RCTs have several advantages over other experimental designs including minimising allocation bias by randomisation as well as assessment bias by blinding assessor (Karanicolas et al., 2010).

The qualitative component in this study was adopted to explore the views of participants regarding acceptability as well as barriers affecting adherence to this intervention. There are several methods to collect qualitative data such as one-on-one individual interviews and focus groups. Individual interviews were more appropriate for this study as they allow more time for every participant to explain their personal experience as oppose to focus groups in which participants opinions may influence by other participants (Gill et al., 2008). Using qualitative approaches alongside quantitative approaches enhances the findings for a deeper understanding of the research context (Lewin et al., 2009). It also provides a method to develop the work further and thus informs more effective interventions in the future (Lewin et al., 2009).

5.3.2 Sponsor

The study was sponsored by NHS Greater Glasgow & Clyde.

5.3.3 Ethical approval and trial registration

The trial protocol was registered on ClinicalTrials.gov (Identifier: NCT03203278). Ethical approval was obtained from the West of Scotland Research Ethics Committee on 3rd August 2017 (REC Reference: 17/WS/0152). Research and Development approval was obtained from NHS Greater Glasgow and Clyde Research and Development on 7th September 2017. All participants were informed that taking part in the research was entirely voluntary and they were free to withdraw from the study at any time without being obliged to give notice or provide any explanation, any data collected before their withdrawal would be considered in the analysis.

5.3.4 Inclusion and exclusion criteria

This trial aimed to recruit 40 participants who fulfilled the inclusion and exclusion criteria detailed below. This number of participants is based on a recommendation by Kieser and Wassmer, (1996) who suggested a sample size of between 20 and 40 participants for overall pilot sample size of a two armed trial. In addition, based on a sample calculation this number was predicted to be sufficient to detect a clinical important change in glycaemic control which is the main treatment target in people with T2DM. In this sample size calculation, HbA1c% was the primary outcome variable. A difference in group means of 0.5% was considered an important change for people with T2DM. Based on data from an exercise intervention conducted on South Asians with T2DM, a standard deviation of 0.44% was chosen (Subramanian et al. 2014). With a power of 0.9, a significance level of 0.05 and a presumed dropout rate of 20%, a total of 20 participants per group were needed.

5.3.4.1 Inclusion criteria

- Diagnosed with T2DM by a physician, more than 6 months previously
- Defined themselves as South Asians
- Aged 25-65 years.
- Body mass index (BMI) of 21-30 kg/m2.
- Had access to computer/tablet, smart phone or smart television with an email address and Internet connection
- Able to understand English or Urdu

5.3.4.2 Exclusion criteria:

- Type 1 diabetes
- Any medical condition that would affect adherence or contraindicate exercise as explained in the check list provided in (Table 5.1)
- People using insulin who did not have a self-monitoring glucose device or were unable to use such devices. This was to minimise the risk of hypoglycaemia
- Engaging in exercise training of 150 minutes a week or more
- Participating in other interventional studies aiming to improve glycaemic control
- Unwilling to be randomised to the control group

Table 5.1 Checklist for contraindicated medical conditions, adapted and expanded from (Thomas et al., 1992)

Checklist for contraindicated medical conditions			
General medical risk		**Yes [1]**	**N0 [0]**
1-	Has participant ever been advised to only do medically supervised physical activity?		
2-	Does participant feel pain in his/her chest at rest, during their daily activities of living, OR when he/she does physical activity?		
3-	Does participant have a bone or joint problem that could be made worse by becoming more physically active?		
4-	Does participant lose balance because of dizziness OR has s/he lost consciousness in the last 12 months? Please Tick NO if the dizziness was associated with over-breathing (including during vigorous exercise).		
Specific medical risk **Does participant have one of the following conditions?**			
1-	Unstable angina		
2-	Uncontrolled hypertension (>180/ 100mmHg)		
3-	Acute myocardial infarct		
4-	Heart failure		
5-	Current fracture or fracture caused by osteoporosis or cancer		
6-	Peripheral neuropathy (with foot wound or ulcer in lower extremities)		
7-	Pregnancy		
8-	Using insulin therapy without having a self-monitoring glucose device or are unable to use such devices		
9-	Severe impairment in walking or mobility		
If the participant answered yes to one of the questions listed above they should be excluded			

5.3.5 Recruitment and screening

Participant recruitment in clinical trials is challenging, especially when ethnic minority groups are concerned (Douglas et al., 2011). To plan participant recruitment in this study, the Chief Investigator (the PhD student) read published articles on recruiting South Asians for research studies (Sheikh et al., 2009; Douglas et al., 2011; Z. Morrison et al., 2014). These articles emphasised several strategies to facilitate South Asian participation in health research. These strategies included using community-oriented recruitment approaches and providing flexible appointments. Ideas were then discussed with the supervisors and others who were experienced in working with ethnic minority groups. The following approaches were then taken to recruit potential participants:

I. NHS Greater Glasgow and Clyde Weight Management Service staff and the Diabetes care team within the Diabetes Centre at Gartnavel Hospital and Queen Elizabeth University Hospital were asked to inform potential participants about the study during their routine clinical appointments. Interested potential participants identified by this approach were giving a participant information sheet (PIS) by the health care team and were asked to contact the research team using the contact details in the PISs. The PISs were available in English or Urdu (Appendix 4 A, B).

II. Posters about the study (written in English and Urdu, See Appendix 5) were placed in waiting areas of local general practitioner surgeries and places of worship. Potential participants who responded to posters contacted the research team using the contact details in the posters and were given a participant information sheet (PIS) by the Chief Investigator.

III. ‘REACH Community Health Project’, a third sector organisation in Glasgow, informed their clients from South Asian communities about the study. A South Asian community support worker at REACH contacted potential participants either by phone or face to face during their regular visits. Participants identified by this approach were giving a PIS by the social community worker from REACH and were asked to contact the research team using the contact details in the PIS.

IV. The Chief Investigator, (i.e. the PhD student), also approached 10 local faith centres leaders and explained the aim and the protocol of the study (see table 5.2). Local faith centres leaders were then asked to display posters and pass on information to their members. Interested potential participants identified by this approach contacted the Chief Investigator using the contact details in the posters. On many occasions, the faith centres leaders contacted the Chief Investigator, on behalf of the interested potential participants, asking him to come and speak to individuals in person as many interested potential participants wished to discuss their participation face to face. All participants identified by this approach were given a PIS by the Chief Investigator.

Potential interested participants, who read the PIS and were still interested in taking part in this study, were invited to meet the Chief Investigator at a suitable place and time. To facilitate recruitment, flexible appointments (e.g. late evening and weekend) were provided. Depending on potential participants' preference, this meeting took place in one of the places in Table 5.2. These places were familiar to South Asians living in Glasgow and were used for study appointments for the convenience of study participants to reduce their travel. Permission to use these places was sought before and during the study. At this meeting, the study purpose was explained to the interested potential participants and they were given the opportunity to ask further questions. Individuals who were still interested in taking part were screened for inclusion and exclusion criteria. If necessary, translation services were arranged for those with limited English throughout the study. Translation and interpretation were provided by an interpreter from REACH community health project who was fluent in English and Urdu.

Recruitment for this study took place from August 2017 to April 2018. Muslim volunteers were not recruited to take part in this study during the period from 15 February to 16 March to avoid booking post-intervention appointments (see section 5.3.11) during the Muslim holy month of Ramadan which started on 16 May 2018 and ended on 16 June 2018. Booking appointments during Ramadan would make taking part in this study inconvenient for participants as they would fast from dawn to dusk (2:30am to 10pm in Glasgow).

All participants who met the inclusion and exclusion criteria and were still happy to take part in this study were invited for baseline assessment. Participants were offered £20 for each assessment visit they attended to cover travelling.

Table 5.2 Venues for meeting and assessment

Venue	**Description**
University of Glasgow	A simulated clinical environment Lab
MAB Scotland Centre	Mosque and community centre
Al-farouq education and community centre (Mosque)	Mosque and community centre
Glasgow Central Mosque	Mosque and community centre
Baitur Rahman Mosque	Mosque and Community centre
Gurdwara Singh Sabha	The hub of the Scottish Sikh community
Alfurgan Mosque	Mosque and community centre
'REACH Community Health Project'	A third sector organisation aiming to provide culturally sensitive care for ethnic minorities
Tamil Church Glasgow - Emmanuel Christian Ministries	Church
Masjid Madressa Al Arabia Al Islamia (Mosque)	Mosque and community centre
Bearsden Muslim association community,	Mosque and community centre
Bishopbriggs Mosque and Community Centre	Mosque and community centre
Glasgow Gurdwara	A cultural, educational and religious hub for Sikhs and the wider community.

5.3.6 Baseline assessment (week 0)

Baseline assessment took place within one week of screening, depending on the availability of participants, the assessor and the venue. For the convenience of study participants, all assessment took place at the same venues as their screening visit. Before baseline assessment, the Chief Investigator confirmed that the participants had read and understood the PIS and asked if they had any questions. All participants who underwent baseline assessment provided written informed consent in English or Urdu (See Appendix 6). Consent was also sought to contact participant's GPs to inform them of their participation in the research study.

At the beginning of the baseline assessment demographic information was recorded: age, gender, religious belief, country of birth, country of origin, medical history, internet usage, educational level, preferred language(s), and smoking habits. After that, the following clinical outcome measures were taken: blood samples for glycaemic control and blood lipids profile, resting blood pressure, height and weight to calculate BMI, waist circumference (WC), muscle strength, functional mobility (Timed Up and Go and 10 Meter Walking test), and quality of life (detailed in Section 5.4 below). Clinical outcome measures were also collected at the end of the intervention (week =12) and at follow up (week=20) (See section 5.4)

5.3.7 Randomisation

Following baseline assessment, the participants were randomised to either the intervention group or control group using 40 opaque sealed envelopes inside which was written "control" or "intervention". The randomisation process was conducted as described by Doig and Simpson, (2005) in their practical guidance. First, 20 opaque sealed envelopes inside which was written "intervention", were created and placed in a pile. Other 20 opaque sealed envelopes inside which was written "control" were created and placed in another pile. Second, blocks of two and four were created from these envelopes. This was to ensure equal group sizes and to prevent anticipating the randomisation consequence (Doig and Simpson, 2005). Each block was shuffled thoroughly and placed in a separate pile. Finally, the separates piles of envelopes were placed on top of each other randomly. Once all the 40 envelopes were in a single pile, envelopes were numbered sequentially 1-40. The order of these envelopes was not changed during the study and the Chief Investigator gave the participants these envelopes consecutively.

5.3.8 Control Group

Participants in the control group were asked to continue their usual care and day to day physical activity routine. In addition, they were giving a leaflet from Diabetes UK containing general information about diabetes management. This information was written in either English or Urdu based on participant's preference. At the end of the study participants who wished to use the platform for exercise would be provided with access.

5.3.9 Intervention group (web-based exercise programme)

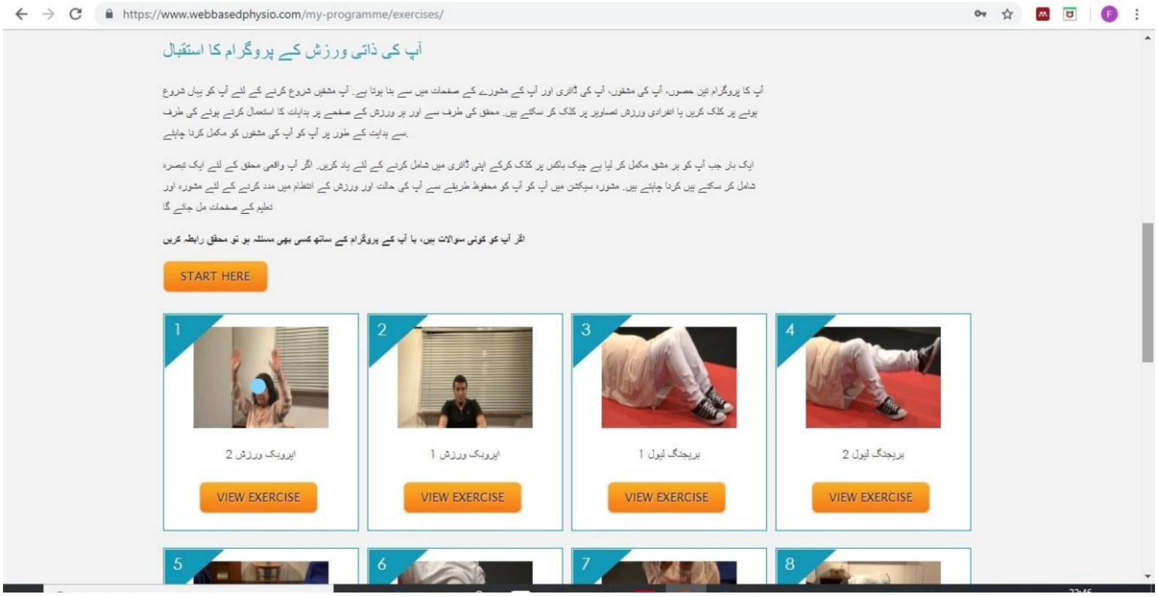
Participants assigned to the intervention group were asked to perform a personalised web-based exercise programme, undertaken three times a week on non-consecutive days for 12 weeks. The Web-based physiotherapy platform, www.webbasedphysio.com, (now giraffehealth.com) was used to deliver the intervention. The platform was modified to meet the need of people from South Asians communities as discussed in previous chapters, see Chapter Four.

Participants assigned to the intervention group met the Chief Investigator face to face immediately after randomisation. During this meeting, a brief assessment was undertaken, exercise goals and exercise preferences were discussed and agreed with participants. The assessment included brief medical history, past exercise experience, range of motion of main joints. This was mainly to identify restrictions and contraindications for exercise (Hansen et al., 2013). For example, to avoid prescribing push up exercise for those suffering from severe shoulder pain. A personalised exercise programme was then designed for each participant using the resources available on the web-based physiotherapy platform.

The exercise programme prescription and progression were in line with the American Diabetes Association (ADA) and American College of Sports Medicine (ACSM) guidelines (Colberg et al., 2016). As such, the programme was progressive and mainly involved aerobic and resistance exercise. Balance exercise was also selected for those with physical limitations. Balance impairments in people with T2DM are common, mainly due to aging and diabetes complications (Lee et al., 2013). To avoid developing muscle soreness or injuries, the duration of aerobic exercise and the volume of resistance exercises (number of repetitions and sets) were gradually progressed. The Borg Rating of Perceived Exertion (RPE) was used to guide the intensity of aerobic component of the programme (Borg, 1982; Unick et al., 2014). Table 5.3 describes the components of the exercise programme. The platform also contained advice sections. The advice section involved advise aimed to minimise the risk of exercise related adverse events including hypoglycaemia and hyperglycaemia, See appendix 7. For example, participants on insulin therapy were advised to check their blood sugar levels before, during and after exercise to make sure their blood glucose levels were within acceptable ranges.

The platform was explained to participants and each participant was provided with unique login details to the platform to view their own personalised exercise programme and relevant information about T2DM (example log in: sadiabetesexample@gmail.com, password: password). The platform consists of a home page, personalised exercise pages, exercise diary and an advice/information section. Each exercise page within the platform consists of a video demonstrating the exercise, text explaining the exercise, an audio description of the exercise and a timer. The platform also contains a catalogue of exercises including aerobic, resistance and balance exercises, each with different levels of difficulty, as well as a warm up and cool down. From this catalogue, a personalised exercise programme was set up for every user based on their needs and ability. The written and audio instruction describing each exercise was available in either Urdu or English, depending on each participant's preference.

Figure 5.1 Main exercise page example (Urdu)



Participants were asked to complete their online exercise diary following every session. The researcher contacted participants every two weeks via telephone to encourage them to continue with their exercise programme, ask about progress, and to deal with any technical issues that they might have faced while using the platform. Participants were advised to contact the researcher to request a change in their programme, when they found the exercise too easy or too difficult, or if a problem rose. The Chief Investigator made changes remotely (as required) and participants were informed of any changes by phone or email. The Chief Investigator frequently gave general exercise advice during the intervention and answered any specific questions the participants may have had regarding the exercise.

Table 5.3 Components of the exercise programme

	Aerobic exercise	**Resistance exercise**	**Balance exercise**
Mode	Based on participants' preference: Walking, treadmill, swimming, cycling or 1-6 rhythmic activities performed in bouts. Every bout lasted for 5-10 minutes.	5-10 resistance exercises targeting main muscle groups, using free weight, body weight, or resistance bands Exercise examples: floor or wall presses, lunges, squats, arm curls, triceps curls, abdominal crunches, bridges, shoulder abductions, calf raises, and arm rowing.	1-2 exercises Exercise example: core muscle strengthening exercises, one leg stand, toe to heel walking
Frequency	3 times a week on the same	3 times a week on the same day	3 times a week on the same day
Duration	Based on participants' ability, the duration gradually progressed 5-10 minutes every week until they reach 30 minutes.	1-3 sets of each exercise with 8-15 repetitions, with 90 to 120 seconds of rest between sets	2-10 repetitions
Intensity	Moderate (4–6 points) based on a rate of perceived exertion scale of 0–10points.	**Progression** Started at 1 set of each exercise using a weight or exercise position (antigravity or with gravity elimination) that allows for completion of 12-15 repetitions. Once the participant comfortably achieved this, a load that does not allow the completion of more than 8–10 repetitions and results in local muscle fatigue was selected. Participants were asked to complete 2 sets of each exercise with 8-10 repetitions, with 90 to 120 seconds of rest between sets. The number of sets was increased to 3 when participants felt comfortable.	Light

5.3.10 Blinding

Double blinding is difficult in trials examining active intervention. As such, participants and the Chief Investigator who designed the exercise programmes were not blinded to group allocation. However, the study was single blind in that the assessor was unaware of the group allocation. The assessor was an experienced physiotherapist and researcher (i.e. Dr Aleksandra Dybus). Participants were asked not to inform the assessor about their group allocation.

5.4 Outcomes

Based on the objectives of this study, the outcomes were categorised intro three categories, namely, (1) feasibility outcomes, (2) likely effect outcomes, and (3) acceptability of and barriers to the received intervention.

5.4.1 : The feasibility outcomes

To assess the feasibility of the trial the following outcomes were assessed: recruitment, attrition rates, platform usage, adherence to the intervention and adverse events.

5.4.1.1 Recruitment

To evaluate recruitment the following were recorded: Total number of people showed interest in the study; the number/proportion of interested people identified through each recruitment source; the number of people attended baseline assessment and consequently randomised, and overall recruitment rate (i.e. participants recruited/recruitment period in month).

5.4.1.2 Attrition and missing data

The number and proportion of completers and non-completers at post intervention (week=12) and at follow up (week =20, i.e. eight weeks after the end of the intervention), The number/proportion of missing data. The causes of attrition were recorded if possible.

5.4.1.3 Platform usage and adherence

The use of the platform was measured as the proportion of participants in the intervention group who logged in the platform and left a comment or recorded at least one exercise diary. Adherence were estimated using exercise diaries from the platform. Adherence to the intervention was calculated as the percentage of completed sessions out of the prescribed sessions every four weeks (12 sessions every four weeks). Participants who completed two thirds (8 sessions) or more of exercise sessions were considered adherent (Hawley-Hague et al., 2016). Whereas participants who completed less than two thirds of the exercise sessions were considered non-adherent (Hawley-Hague et al., 2016).

5.4.1.4 Adverse events

Adverse and serious events were recorded throughout the study. Adverse events include: musculoskeletal injuries, falls and hypoglycaemia events that do not require hospital admission. Serious adverse events included any of the following that could be attributed to the intervention: Life threatening incident, admission to hospital for any reason which necessitates an overnight stay, and an occurrence that results in significant disability or impairment.

5.4.2 The likely effect outcomes

To determine the likely effect of the intervention, clinical outcomes were obtained from participants at baseline and at the end of the intervention (week=12). These outcomes included glycaemic control, blood lipids profile, blood pressure, body anthropometry, functional mobility, muscle strength, and quality of life. To compare change in clinical outcomes after eight weeks of the completion of the intervention, the same outcome measures were also collected at follow up (week = 20). All assessment took place in the same venues listed in table 2. The assessments procedure, assessment order and outcome measures were as same as baseline assessment.

5.4.2.1 Glycaemic control

As discussed in chapter two, glycaemic control is the main treatment goal in T2DM management. Therefore, glycaemic control was considered the primary clinical outcome in this study. There are several biomarkers that can be used to monitor glycaemic control in people with T2DM including fasting plasma glucose, mean plasma glucose, postprandial plasma glucose, Glycated serum proteins and glycosylated haemoglobin (HbA1c%) (Kohnert et al., 2015; Krhač and Lovrenčić, 2019). These biomarkers estimate glycaemic control over different timeframes, ranging from two hours to three months (Kohnert et al., 2015).

In this study, glycaemic control was measured as HbA1c%. This marker is considered the gold standard measure for chronic glycaemic control (Sherwani et al., 2016). It reflects average blood glucose levels over 8-12 weeks, similar to the duration of this intervention (Sherwani et al., 2016). HbA1c is used in monitoring treatment as well as determining management decisions in people with T2DM, as it is strongly associated with T2DM complications (Kohnert et al., 2015; Krhač and Lovrenčić, 2019). A reduction in HbA1c by 0.5% or more is widely considered clinically important (Lenters-Westra et al., 2014). Unlike other tests which requires participants to be fasted for at least 8 hours, HbA1c is feasible and can be performed at any time during the day even after a meal (Kohnert et al., 2015; Krhač and Lovrenčić, 2019).

To measure HbA1c in this study, blood samples were extracted from participants by Dr Aleksandra Dybus or the Chief Investigator, who were trained in venepuncture and blood sample handling. Before starting the procedure, a disposable tray containing labelled blood sample bottles, alcohol wipes, gauze swabs, plasters, vacutainer holders, butterfly needles and tourniquet was set out. The procedure was explained to participants and verbal consent was obtained. Hand hygiene was then performed, and a tight elastic band was placed around the participant's upper arm. The skin was cleaned with an antiseptic wipe. The skin was allowed to dry for 30 seconds and then a needle, attached to vacutainer holder, was inserted into the antecubital vein. The blood was then collected into 4 millilitres EDTA tube.

Tubes filled with blood were inverted gently several times and were placed in an ice box and transferred to the BHF Glasgow Cardiovascular Research Centre, at the University of Glasgow within 12 hours, where they were stored at - 80^{oC} in an alarmed freezer for later analysis in pre-labelled storage tubes. At the end of the study, HbA1c was determined using standard automated enzymatic methods on a chemistry analyser (Cobas c 311, Roche, German).

5.4.2.2 Blood lipid profile

As discussed in chapter two, dyslipidaemia is considered a major cardiovascular risk factor and therefore a relative treatment target in people with T2DM (Girach et al., 2006). As such, blood lipids profile was an outcome in this study. Blood lipids profile measures the levels of specific lipids in the blood (i.e. total cholesterol, high-density lipoproteins (HDL), low-density lipoproteins (LDL), and triglyceride). To assess for these variables, blood samples were drawn into 9 millilitre EDTA tubes as described above. Blood samples were then centrifuged at 3000 revolutions per minute (RPM) at $4^{\circ C}$ to separate plasma. Samples were then stored at - $80^{\circ C}$ for later analysis in pre-labelled storage tubes. At the end of the study, samples were analysed using standard automated enzymatic methods on a chemistry analyser (Cobas c 311, Roche, German).

5.4.2.3 Blood pressure

Optimal blood pressure (<140/90) is a general target in T2DM management (chapter two). In this study, blood pressure was measured using a valid blood pressure and heart rate monitor (Omron 7051T, Omron Healthcare UK Limited, Milton Keynes, UK) (Chowdhury and Lasker, 2002; El Assaad et al., 2003). Participants were asked to relax in a chair for five minutes with both arms supported on a table at the level of the heart. Initially blood pressure was tested in both arms, and then blood pressure was assessed two more times in the arm with highest reading. The average of the three reading was recorded.

5.4.2.4 Anthropometric measures

Obesity is an important risk factor associated with cardiovascular disease and disability in people with T2DM (see chapter two). Both overall obesity and central obesity were assessed in the current study, using BMI and WC, respectively. Both measures are considered anthropometric indicators of cardiovascular risk and have been associated with diabetes-related complications (Gholap et al., 2011; Misra and Shrivastava, 2013; Patel et al., 2017).

BMI was calculated as body weight in kilograms divided by height in meters squared. Body weight was measured using a manual balance scale (SECA, Model: 761 7019129, GMBH & CO). Participants were instructed to take jackets, shoes and heavy external clothes off. The same equipment was used throughout the study. Vertical height was measured (in cm) using a portable stadiometer (Invicta Plastics Ltd, Leicester, UK). Participants were instructed to stand erect with shoes off. The maximum distance from the floor to the vertex of the head was recorded (Singh and Mehta, 2009). The vertex was defined as the highest point on the skull when the head is held in the Frankfort plane (Singh and Mehta, 2009). Height was only measured at baseline. WC was measured (in cm) between the iliac crest and lower ribs using a standard tape measure. Participants were asked to stand up straight and relax their abdominal muscles. The tape was positioned horizontally, irrespective of whether the umbilicus was above or below the tape (Gayoso-Diz et al., 2013).

5.4.2.5 Functional mobility

As discussed in chapter 2, functional mobility is a relative treatment target in people with T2DM (Mesquita et al., 2016). While many functional mobility tests have been used in the literature to assess functional mobility in people with T2DM, a recent systematic review showed that none of these tests had been validated for use in people with T2DM (Dixon et al., 2017). Previous work examining functional mobility in people with T2DM tended to cite tests that have been validated for use with other populations such as elderly people or people with other chronic health conditions (Hansen et al., 2013; Dixon et al., 2017).

The six-minute walking test is widely used in studies targeting people with T2DM (Hansen et al., 2013). The test also showed excellent test-retest reliability in people with T2DM (Alfonso-Rosa et al., 2014). However, this test requires a 33-metre straight corridor to perform (Enright, 2003). Therefore, it was considered infeasible in this study as some assessment venues did not have a suitable corridor to conduct such a test.

In this study, functional mobility was assessed using The Timed Up and Go test (TUG) and Ten Meter Walking Test (10MWT). TUG is a widely used functional mobility test that was originally validated for use with elderly people (Podsiadlo and Richardson, 1991). The test evaluates different important mobility functions including sit to stand transfer, turning and walking. The TUG test scores also correlate with balance, lower limbs muscle strength, walking speed and fall risk (Ng and Hui-Chan, 2005).

The TUG test showed excellent test-retest reliability in people with T2DM (Alfonso-Rosa et al., 2014). TUG test measures the time that is required to stand up from a standard chair (height approximately 45cm), walk away for three metres and return to sit on the chair again.

In this study, participants were asked to do the TUG test three times and the average time was calculated recorded. The Minimal Detectable Change (MDC) for the TUG test in people with T2DM is a change > 0.85 seconds. MDC is a value that reflects a true change that is not due to measurement errors (de Vet and Terwee, 2010).

Ten Meter Walking Test (10MWT) is another functional mobility test used in this study (Wolf et al., 1999). The tests measures walking speed in metres per second over a 10-metre walkway. This test was found to be valid and reliable in elderly people (Wolf et al., 1999; Steffen et al., 2002). However, it remains to be examined for validity in people with T2DM. To accomplish the 10MWT, a 10-metre straight walk path was marked with tape on the floor. Participants were instructed to walk 10 metres at their preferred walking speed, using walking aids if required (Amatachaya et al., 2019). The time was measured for the intermediate 6 metres which was also marked with tape (Wolf et al., 1999; Amatachaya et al., 2019). The test was performed three times using a stopwatch and the average time was calculated. To convert to walking speed (m/s) this time was divided by the intermediate distance walked (6m).

5.4.2.6 Muscle strength

Muscles weakness is a predictor for physical disability in people with T2DM and therefore is considered a relative treatment target (Savaş et al., 2007; Taekema et al., 2010). People with T2DM have lower muscle strength compared with healthy people (Leenders et al., 2013).Hand-held dynamometry is considered the gold standard for measuring muscle strength (Hansen et al., 2013). This test involves a procedure in which the participant exerts an isometric force to resist a dynamometer held by the examiner. However, due to the cost of the Hand-held dynamometry and the high level of skill required many researchers found it infeasible (Hansen et al., 2013; Bohannon, 2019). To minimise cost and for practicality, it was suggested using handgrip strength as an indicator of general muscle strength (Verdijk et al., 2009; Bohannon, 2019). In this study therefore, handgrip strength was used.

Handgrip strength in this study was measured using the most widely used handgrip dynamometer with established test-retest, inter-rater and intra-rater reliability (JAMAR TM Hydraulic Hand Dynamometer, Jackson, MI 49203, USA) (Roberts et al., 2011). Participants were asked to squeeze a dynamometer using their dominant hand while they were in a sitting position with hips and knees at 90º, with feet on the floor, shoulder adducted in neutral position, and elbow in approximately 90º flexion, with the forearm and wrist in neutral position (Bohannon, 2019). The test was repeated three times with the dominant hand and the highest reading recorded. The handgrip strength test showed excellent test-retest reliability in people with T2DM and the MDC is 4 kg (Alfonso-Rosa et al., 2014).

5.4.2.7 Quality of life

As discussed in chapter two, T2DM negatively affects quality of life. Therefore, quality of life is a relative target in T2DM management. There are several tools that have been used in research to assess quality of life in people with T2DM. However, the paucity of well translated tools limited the choices in this study.

The World Health Organization Quality of Life Scale Brief (WHO-QOL BREF) was the most appropriate tool for this study due to two main reasons (Skevington et al., 2004). First, the tool has been found to be valid and reliable in cross cultural and chronic diseases including diabetes (Khan et al., 2003). The tool also was translated into 19 languages including Urdu which is the main language in South Asia (Khan et al., 2003). The WHO-QOL BREF is the short version of the WHOQOL-100, recommended when burden on respondent needs to be minimised. The questionnaire contains 26 questions addressing four domains namely physical health (7 questions), psychological health (6questions), social relationships (3 questions), and environment (8 questions) (World Health Organisation, 2004). Every question is rated on a 1-5 point Likert scale where 1 indicates very low and 5 indicate very high QoL. To determine domains scores, the mean score of the questions within each domain was calculated. The mean score of every domain was then multiplied by 4 resulting in a mean score per domain that is between 4-20, with higher scores indicate better quality of life (World Health Organisation, 2004). This instrument does not calculate a total score, rather, it assesses QOL based on the scores of the four individual domains (Skevington et al., 2004).

5.4.2.8 Dietary intake and Medications

Medications and diet confound the effect of exercise, therefore, it was essential to monitor these variables (Colberg et al., 2010). Participants were asked about their medications; dosage and frequency of use at baseline and to report any changes at subsequent assessments.

To monitor diet, the average daily intake of calories over the past 12 weeks was estimated at baseline and at subsequent assessments. The Scottish Collaborative Group food frequency questionnaire was used to estimate the average daily intake of calories (Hollis et al., 2017). The questionnaire has been designed and validated as a research tool that estimates the intake of energy and the macro and micro nutrients within the past 2-3 months in adults in the UK (Hollis et al., 2017). This questionnaire includes 170 food items commonly consumed in the UK into 19 sections (Hollis et al., 2017). Participants were asked to complete the questionnaire by estimating the amount of each food they had consumed within the past 2-3 months and how often they had eaten it. The questionnaire took approximately 20-30 minutes to be complete (Hollis et al., 2017). Data from each question, excluding participants personal information, was then entered by the CI in an online data entry system that belongs to the Scottish Collaborative Group Food Frequency Questionnaire https://w3.abdn.ac.uk/hsru/ffqv66/ using a username and private password. The system then generated the results which were sent to the CI via email by the manager of the Scottish Collaborative Group food frequency questionnaire.

5.4.3 Acceptability of and barriers to the arm intervention that was received

5.4.3.1 Qualitative interviews

To explore the acceptability of and barriers to the intervention, a sub-sample of participants from the intervention group (6-10 participants) were invited to take part in audio-recorded face to face interviews at the end of the intervention. Purposive sampling was used to ensure the sample consisted of people with different adherence rates to the programme. The interview took place after the final assessment, but within the same appointment and lasted for approximately 30 minutes. If necessary, translation services could be arranged for those with limited English.

At the beginning of each interview, the Chief Investigator explained the aim of the interview. Participants were asked not to use their names during the discussions and, even if they did, they were assured that their names would not be used in the transcript. A topic guide was developed based on the literature and previous experience (Table 5.4). This topic guide was piloted with PhD students at the Nursing and Healthcare School, University of Glasgow to estimate time and improve clarity.

Table 5.4 The interviews topic guide

Topic	**Questions**
Section 1:	Greeting. As we mentioned to you, at your 12 weeks appointment, we would invite some of you to take part in audio-recorded face to face interviews to explore your opinion about the internet-based exercise programme research study that you have been taking part in. This should take no more than 30 minutes. I would also like to record our conversation, is that ok?
Section 2	What are your thoughts about exercise? Prompt Before participating in this study did you take part in any exercise? If so what? If not, why? Why do you exercise? Do you enjoy exercising? Of the reasons given what reason is most important? Do you think it is important to exercise with your condition? If so what do you think the benefits are? If no why? Have you noticed any changes or benefits from taking part in this exercise programme? What are these changes/benefits?
Section 3:	Before taking part in the study, did you follow exercises on the internet or mobile apps? What are your thoughts about following an exercise programme over the internet? What do you think about web-based physio? What is good or not good about the platform? How does this internet-based exercise programme compare to exercise programmes you have followed in the past? How do you access the platform? Did you use a computer, laptop, tablet or phone? Have you faced any difficulty when using the platform? what about the language used? Texts? Videos? Other features such as the communication with the researcher? the colours? advice section? Diary?
Section 3:	Do you do your exercise three times a week as you advised in this study? Did you log on to the platform each time you did your exercise programme? If not why? Were there times when it was difficult to do your exercise as advised? If so what circumstances made it difficult?
Section 4:	And now that the official period of the exercise programme is finished, do you have any plans to continue with your web-based exercise programme? Why? Why not? Any changes you would advise us to make to the way the study worked or the intervention? That’s the end of my questions for you. Thank you for taking the time to answer my questions today. Do you have anything else that you would like to report back to us or any questions for me?

5.5 Protocol amendment

Pilot studies are exploratory in nature. Therefore, protocol amendment is recommended to overcome limitations (Eldridge et al., 2016). During the first two weeks of the recruitment period, it was noticed that the inclusion criteria were unrealistically limited to those participants with a BMI of 21−29.9 kg/m^2, while the majority of interested participants had BMI higher than 30 kg/m^2. Therefore, to include obese people who need exercise the most, the upper BMI limit was increased to 35 kg/m2. In addition, it was noticed that the initial protocol had only a female assessor to collect blood samples. However, it was expected that some male participants would prefer a same-gender researcher, for religious and cultural reasons. As such, the Chief Investigator, was added as a second person who could collect blood samples. The female blinded assessor still did collect all other clinical outcome measures. Ethical approval was obtained for these changes on 31 October 2017 from the West of Scotland REC 3, Amendment number: AM01 (substantial – change to inclusion criterion), 11.10.2017 (REC Ref AM01).

5.6 Data Analysis

5.6.1 Quantitative data analysis

All analysis was performed using SPSS version 25 (SPSS v.25.0 IBM Corp., Armonk, NY, USA). The normality assumption of data was assessed using the Shapiro-Wilk test which is appropriate for studies with small sample sizes (Laerd, 2018). Descriptive statistics (e.g. mean and standard deviation (SD), median with range or number with percentage) were used to summarise the feasibility outcomes as well as participant demographic and clinical characteristics at baseline.

Post intervention assessment (week=12) was the primary end point and the difference between both groups (intervention and control) at this point was considered the main comparison. As such, to explore the likely effect of the intervention, change scores from baseline to post intervention (week 12) were calculated for each outcome variable. Change scores were then compared between groups using an independent t test for normally distributed data. For non-normally distributed data, a Mann-Whitney U test was used to compare groups. Detailed statistics including appropriate description to the central tendency and p value are presented. For all statistical analysis significance level was set at 0.05.

The magnitude of the difference between groups, effect size statistics, were also calculated using d and r for parametric and non-parametric data respectively (Fritz et al., 2012). The results of effect sizes were interpreted based on Cohen's criteria (1988) as weak ($d<0.5$; $r<0.3$), moderate ($0.5<d<0.8$; $0.3<r<0.5$) or strong ($d>0.8$; $r>0.5$).

$$d = (Mean\ A - Mean\ B) \div \text{SD pooled}$$

$$\text{r} = \text{z value from Mann Whitney U test } \div \text{total number of observations}$$

All analysis in this study was conducted using the intention to treat (ITT) analysis principle, in which participants were included in the analysis as part of the group to which they were originally assigned, regardless of whether the participants had adhered to the intervention given (Gupta, 2011; Alshurafa et al., 2012; Del Re et al., 2013). This approach minimises selection bias resulting from excluding people with negative results, due to lack of adherence or other deviation from the protocol (Alshurafa et al., 2012; Del Re et al., 2013). It also provides a real estimation of the treatment effect as it reflects the reality of non-compliance that tends to occur in real clinical settings (Alshurafa et al., 2012; Del Re et al., 2013).

True ITT analysis requires a complete data set without loss of follow-up, which is difficult to achieve in clinical trials (Del Re et al., 2013). Literature in statistical analysis for clinical trials argues that even in the presence of missing data, ITT analysis can be claimed as long as researchers attempted to follow up all participants (Del Re et al., 2013). However, there is no agreement on a specific way to deal with missing data and different approaches can be used (Del Re et al., 2013). These approaches include data imputation methods and methods that ignore missing data such as complete case analysis and available case analysis (Del Re et al., 2013). The decision to choose one approach over another is usually based on an assumption about the patterns and types of the missing data (e.g. missing completely at random, missing at random or missing not at random) (Alshurafa et al., 2012; White et al., 2012) However, these assumptions are not testable. In this study, it was assumed that data was missed at random and complete case analysis was used as a primary analysis (i.e. excluding only participants who were lost to follow up). This approach is considered to be unbiased when data is missing at random (White et al., 2012). A secondary analysis that accounts for all randomised participants were also undertaken as a sensitive analysis to determine the impact of the departure from the assumption (last observed carried forward). No comparison between groups was conducted at follow up (i.e. two months after the completion of the intervention) due to the high rate of missing values (e.g. up to 76% for the primary clinical outcome measure).

5.6.2 Qualitative data analysis

There are different approaches for analysing qualitative data including deductive and inductive. Deductive approaches usually start with identifying themes using a pre-determined theory or a framework, while inductive approach tends to generate themes from the raw data without trying to fit it into a pre-existing framework or theory (Nowell et al., 2017). In this analysis, an inductive approach using content-thematic analysis as described by Burnard was used (Burnard, 1991).

Firstly, each audio-recorded interview was transcribed verbatim and the names of participants were replaced with pseudonyms. The researcher then familiarised himself with the raw data by listening to the recordings and reading the transcripts several times. Secondly, open coding with short notes in the margin of each transcript was undertaken to provide a summary statement for each element discussed. Thirdly, the written phrases in the margin of each transcript were collected on a clean piece of paper and duplications were removed. Fourthly, similar codes were grouped together, and a shorter list of themes/categories was generated. Grouping similar codes was based on the research questions, analytical and theoretical ideas developed during the research, and each category/theme was allocated a specific colour. Finally, the transcripts were read again and data that fitted under a particular theme/category was marked with the corresponding colour. The coloured themes were then saved as a Microsoft Word file. All these steps were undertaken by the Chief Investigator. To enhance rigour and reduce the element bias, every step was reviewed and discussed by the supervisor (Rhian) at all stages.

5.7 Data management

Consideration was given to data protection, and the Data Protection Act 1988 was followed throughout. All names were replaced with participant identification codes, whether in electronic format or on paper. Raw data were kept at the University of Glasgow in a safe place to which only the research team had access. Anonymised electronic data was stored on a password protected computer at the University of Glasgow. The platform used in this study to deliver the exercise is password protected, only the direct research team had access to participants' data. Representatives of the study Sponsor, NHS GG&C, could also gain access to participants' information for audit purposes. Participants' personal data was destroyed on completion of the study. Finally, upon completion of the study, the anonymous data was saved on a storage device and stored in a locked room in The University of Glasgow for 10 years.

5.7.1 Safety and risk assessment

Any exercise intervention has potential risks including musculoskeletal injuries, hypoglycaemia, hyperglycaemia, dehydration and angina. To minimise the associated risks, people with medical conditions that would affect adherence or contraindicate exercise were excluded. In addition, exercise guidelines for prescribing exercise for people with T2DM were followed (Colberg et al., 2016). Blood tests did not require a participant to be fasted, so participants were advised not to fast or alter their medication unless instructed to do so by their doctor.

Chapter 6 – Results- the feasibility and the likely effect

This chapter presents the results related to the first and second objectives of this study (i.e. the feasibility and the likely effect of a 12-week web-based exercise intervention in South Asians with T2DM. The findings related to the experience of participants in the intervention group will be presented in the following chapter (Chapter 7).

6.1 Feasibility outcomes

6.1.1 Recruitment

The CONSORT flow chart for the trial is shown in Figure 6.1. The study recruited 33 participants between August 2017 and April 2018, with an overall recruitment rate of approximately 4 participants every month. To increase recruitment, inclusion criteria were relaxed to include obese people with body mass index (BMI) ≤ 35 kg/m^2 (as mentioned in section 5.4.4).

A total of 110 people showed interest in taking part in the study, 80 (73%) people responded to faith centres leaders/posters, 27 (25%) people responded to REACH community health project, and only 3 (2%) people reposed to NHS staff/posters. Potential participants who expressed interest in taking part were screened for inclusion by the Chief Investigator and 77 people (70%) were excluded. The two main reasons for exclusion were; not from a South Asian background (n=23) and/or did not have type 2 diabetes (T2DM) (n=26). Other reasons for exclusion included the following: planned to travel abroad during the study duration (n=4), aged >65 (n=6), BMI > 35 kg/m^2 (n=5), unable to arrange an appointment time for assessment (n=6), engaged in formal exercise (n=1), recent coronary angioplasty and stent insertion (n=3), unstable angina (n=1), pregnant (n=1), and taking part in another study aiming to improve glycaemic control (n=1).

Thirty-three participants met the inclusion and exclusion criteria and provided informed consent to take part in the study. These participants were then randomised into intervention and control groups. No issue was identified during randomisation. Seventeen participants were allocated to the intervention group which consisted of a personalised web-based exercise programme for 12 weeks, while 16 participants were allocated to the control group which consisted of usual care.

Table 6. 1 and Table 6.2 summarise the baseline demographic and clinical characteristics for all participants and per group. Overall, the sample involved 14 (42%) male and 19 (58%) female. The majority of participants were married (n=30, 91%), completed at least secondary education (n=31, 94%), fluent in both English and Urdu (n=28, 85%). Most participants were originally from Pakistan (n=28, 85%), three participants were from India (9%) and two participants were from Sri Lanka (6%). The mean age of the total sample was 54 ± 7 years and the average length of diagnosis with T2DM was 10.8 ±7.3 years.

All participants were on glucose lowering medications and the majority had at least one of the following comorbidities: either osteoarthritis or gout (n=19), history of myocardial infarction (n=3) and history of stroke (n=2). The average blood glucose levels over the prior eight to twelve weeks (HbA1c) were 8.1 ± 2.1% and 8.8 ± 2.3% in the intervention and control groups respectively. These values were greater than the targeted levels for people with T2DM (i.e. <6.5%), indicating poor glycaemic control. It also appeared that the sample as whole had reduced physical capacity as the mean value of Timed Up and Go test was 10.65s ± 2.5 which was higher than the average values for healthy South Asians of similar age (i.e. 8.46 ± 1.25 s) (Khant et al., 2018). Despite this, the systolic and diastolic blood pressure for both groups were, in the main, within the recommended levels for people with T2DM (<140/90 mm Hg) (Solini and Grossman, 2016). Compared to the control group, participants in the intervention group had more female participants (i.e. n=8 vs n=11), lower HbA1c (mean= 8.1 vs mean= 8.8) lower calorie intake (i.e. median= 2024 vs median= 2784), lower TUG (i.e. mean=10.23 vs 11.1), and lower WC with similar Body mass index (i.e. mean= 105.2 vs mean= 107.6). The reason for having lower WC with similar BMI might have been due to the intervention group having more female participants.

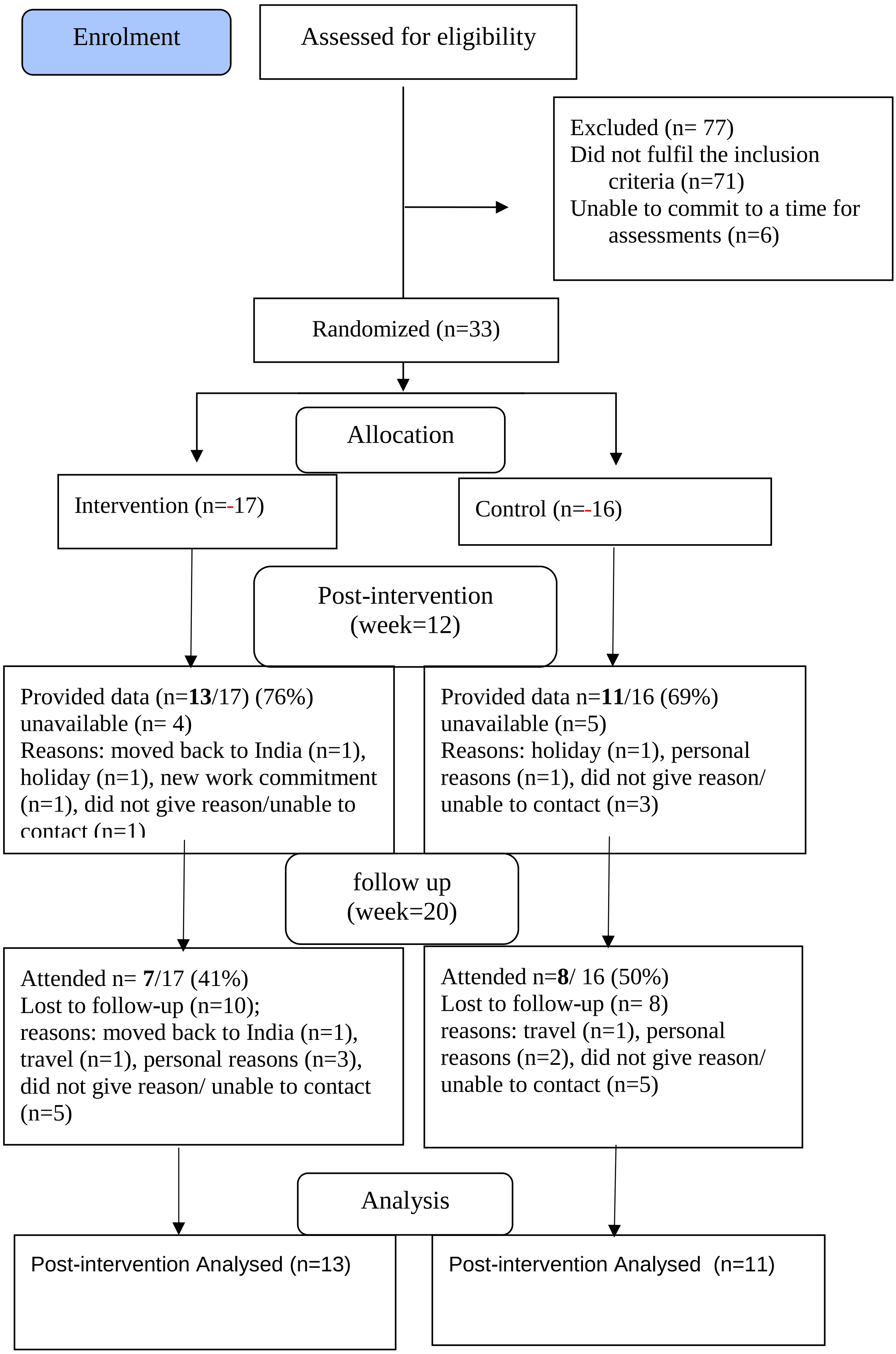


Figure 6.1 CONSORT diagram for flow of participants through the study

Table 6.1 Demographic characteristics for all randomised participants and for each group

Variable	**Total n=33**	**Intervention n=17**	**Control n=16**
Male, n (%)	14 (42%)	6 (35%)	8 (50%)
Female, n (%)	19 (58%)	11(65%)	8 (50%)
Age in years, mean (SD)	53.8 ± 7.4	53.1 ± 7.6	55.2 ± 7.6
T2DM duration in years, mean (SD)	10.8 ± 7.3	10.3 ± 7.2	11.5 ± 7.4
History of myocardial infarction, n (%)	3 (9%)	1 (6%)	2 (13%)
History of stroke, n (%)	2 (6%)	1 (6%)	1 (6%)
*Osteoarthritis or Gout, n (%)	19 (58%)	10 (59%)	9 (56%)
Anti-glycaemic medications, n (%)	33 (100%)	17 (100%)	16 (100%)
Cholesterol medications, n (%)	19 (56%)	10 (59%)	9 (56%)
Hypertension medications, n (%)	20 (60%)	8 (47%)	12 (75)
Originally from Pakistan, n (%)	28 (85%)	13 (76%)	15 (94%)
Originally from India, n (%)	3 (9%)	2 (12%)	1 (6%)
Originally from Sri Lanka, n (%)	2 (6%)	2 (12%)	0 (0)
Married, n (%)	30 (91%)	16 (94%)	14 (88%)
Other marital status, n (%)	3 (9%)	1 (6%)	2 (13%)
Educational levels, n (%) Secondary or lower College, University, or postgraduate	 12 (36%) 21 (64%)	 7 (41%) 10 (59%)	 5 (31%) 11 (69%)
Fluent in both English and Urdu	28 (85%)	15 (88%)	13 (81)
Fluent in either English or Urdu	5 (15%)	2 (12%)	3 (19%)

*osteoarthritis or gout were grouped together to reflect orthopaedic complications

Table 6.2 Baseline characteristics for all randomised participants and for each group

Variable	**Total** **n=33**	**Intervention** **n=17**	**Control** **n=16**
HbA1c % ^	8.4 ± 2.1	8.1 ± 1.9	8.8 ± 2.3
Total-C (mmol/l) ^	3.92 ± 0.9	3.84 ± 0.9	4 ± 1
LDL (mmol/l) ^	1.8 ± 0.6	1.83 ± 0.6	1.61 ± 1.4
HDL (mmol/l) ^	1.01 ± (0.3)	0.97 ± 0.2	1.06 ± 0.3
Triglyceride(mmol/l) ^	2.14 ± (1)	2.34 ± 1	1.92 ± 1
SBP (mmHg)	138.3 ± 15.6	140.3 ± 15.4	138.3 ± 13.3
DBP (mmHg)	81.5 ± 9.7	84.3 10.1	78.4 ± 8.5
BMI (kg/m^2)	29.7 ± 3.7	30 ± 2.9	29.5 ± (4.6)
WC (cm)	106.5 ±(10.2)	105.2 ± (7.8)	107.6 (12.4)
TUG (s)	10.65 ± 3.5	10.23 ± 1.8	11.1 ± 4.7
10MWT (m/s)	1.2 ± 0.3	1.17 ± 0.2	1.19 ± 0.4
Handgrip strength (Kg)	25.4 ± 10.6	25.2 ± 11.3	25.7 ± 10.2
QOL-Physical health	13 ± 3	13 ± 3	13 ± 3
QOL-Psychological	13± 3	14 ± 3	13 ± 4
QOL-Social	14 ± 3	14± 3	14 ± 4
QOL- Environment	14 ± 2	14 ± 2	14 ± 3
Daily intake of calories (kcal)*	2380 (1678-3098.)	2024 (1647 to 2742)	2784 (1878 to 3656

All data are mean ± standard deviation, unless stated otherwise

Total-C-: total cholesterol, LDL: low-density lipoproteins, HDL: high-density lipoproteins; SBP: systolic blood pressure; DBP: diastolic blood pressure; BMI: body mass index; WC: waist circumference, TUG: The Timed Up and Go test; 10MWT: Ten metre walking speed test; QOL-Physical health: Quality of life physical health domain; QOL-Psychological: Quality of life psychological domain; QOL-Social: Quality of life social domain; QOL- Environment: Quality of life environmental domain

*: Data are median (interquartile range)

^ HbA1c and blood lipids results were available from 27 participants at baseline (control=13, intervention=14).

6.1.2 Attrition rates and missing values

Out of the 33 randomised participants, 24 participants (73%) completed the post-intervention assessment (12 weeks). In the intervention group, four out of 17 participants (24%) did not complete assessments due to: relocated to India (n=1), not able to attend due to new work commitments (n=1), on holiday (n=1) or could not be contacted (n=1). In the control group, five out of 16 (31%) were not available: due to being on holiday (n=1), personal reasons (n=2) or they could not be contacted (n=2).

Table 6.3 and 6.4 present baseline demographic and clinical characteristics of completers and non-completers at post intervention assessment (week=12). Country of origin and functional mobility levels were notable differences between completers and non-completers. In terms of country of origin, all participants from India (n=3) did not complete the study. However, this did not reflect a systematic difference. Rather it reflects that these Indian participants were identified from faith centres that did not have suitable facilities for assessments and therefore were invited for assessment at Glasgow University which may have not been convenient for them. In addition, compared to completers, non-completers tended to have better baseline functional mobility scores at baseline as measured by the Timed up and Go test (completers= 11.1s ± 3.8, non-completers =9.4s ± 2). This again may have reflected the fact that people with better health are less likely to participate in health interventions (Groeneveld et al., 2009). As such, it was assumed that the data were missing at random in this study.

Only 15 participants (45%) completed the post-trial follow up assessment (week 20) (intervention=7 (41%); control=8 (50%)). Participants who had not attended the post-intervention assessment (12 weeks) did not attend the final assessment either, except one participant in the control group who returned to the study. An additional nine participants were unavailable at the final assessment (week 20), reasons included work commitments (n=2), personal reasons (n=1), or they could not be contacted (n=6).

Throughout the course of the study, blood samples were not taken on a total of 11 occasions (six at baseline, two at post intervention, three at follow-up). This resulted in a high number of missing values for HbA1c and blood lipids (up to 70% in the intervention group at follow-up, week=20). The reasons for not obtaining blood samples were as follows: unable to find a suitable vein (n=9), and lack of verbal consent (n=2). On two occasions, the drawn blood samples were not enough for blood lipid analysis. In addition, two participants in the control group preferred not to complete the ‘Timed Up and Go’ test at the post-intervention appointment as they felt that this test might trigger their knee pain.

Table 6.3 Demographic data for completers and non-completers at baseline

Variables	**Completer** **n=24**	**Non-completers** **n=9**
Intervention group, n (%)	13 (54%)	4 (44%)
Control group, n (%)	11 (46%)	5 (56%)
Male, n (%)	11 (46%)	3 (33%)
Female, n (%)	13 (54%)	6 (67%)
Age in years, mean ± SD	54 ± 8	54 ± 8
Diabetes duration in years, mean ± SD	11 ± 7	12 ± 7
History of myocardial infarction, n (%)	3 (13%)	0 (0%)
History of stroke, n (%)	1 (4%)	1 (11%)
Having osteoarthritis or gout, n (%)	14 (58%)	7 (
Originally from Pakistan, n (%)	22	6
Originally from India, n (%)	0 (0%)	3 (100%)
Originally from Sri Lanka, n (%)	2 (8%)	0 (0%)
Married, n (%)	21 (88%)	9 (100%)
Other marital status, n (%)	3 (13%)	0 (0%)
Educational levels, n (%) Secondary or lower College, University, or postgraduate	 9 (38%) 15 (63%)	 3 (33%) 6 (66%)
Fluent in both English and Urdu, n (%)	20 (83%)	8 (89%)
Fluent in either English or Urdu, n (%)	2 (8%)	3 (18%)

Table 6.4 Clinical outcomes for completers and non-completers at baseline

Variables	**completers** **N=24**	**Non-completers** **N=9**
HbA1c %	8.5 ± 2.3	8.2 ± 2.7
Total cholesterol (mmol/L)	3.9 ± 1	3.9 ± 0.8
LDL (mmol/L)	2 ± 0.7	1.9 ± 0.5
HDL (mmol/L)	1.1 ± 0.2	0.9 ± 0.2
Triglyceride (mmol/L)	1.94 ± 1	2.7 ± 1
SBP (mmHg)	140 ± 15	136 ± 12
DBP (mmHg)	82 ± 10	88 ± 10
BMI (kg/m^2)	29.8 ± 4	29.6± 3
WC (cm)	105 ± 16	109 ± 9
TUG (s)	11.1 ± 3.8	9.4 ± 2
10MWT (m/s)	1.1 ± 0.3	1.3 ± 0.2
Hand grip strength (kg)	25.4 ± 10	25.6 ± 13
QOL-Physical health	13± 3	13 ± 3
QOL-Psychological	13 ± 3	14 ± 3
QOL- Social relationships	14 ± 3	14 ± 3
QOL- Environment	14 ± 2	14 ± 3
daily intake of calories (kcal)*	2380 (1651 to 2813)	2299 (1827 to 3647)

All data are mean ± standard deviation, unless stated otherwise

Total-C-: total cholesterol, LDL: low-density lipoproteins, HDL: high-density lipoproteins; SBP: systolic blood pressure; DBP: diastolic blood pressure; BMI: body mass index; WC: waist circumference, TUG: The Timed Up and Go test; 10MWT: Ten metre walking speed test; QOL-Physical health: Quality of life physical health domain; QOL-Psychological: Quality of life psychological domain; QOL-Social: Quality of life social domain; QOL- Environment: Quality of life environmental domain

*: Data are median (interquartile range)

6.1.3 Platform usage and adherence

Out of the 17 participants allocated to the intervention group, 13 participants (76%) used the platform (logged in and reported at least one exercise session). Only four participants (24%) did not use the platform (i.e. had no diary entries and did not left any comments. Out of the 13 participants who completed the intervention, the percentage of adherents (i.e. completed two third of the prescribed sessions) was the highest in the first four weeks n=7 (54%). The percentage declined at week 5-8 to n=6 (46%), and further to n=4 (31%) during the last four weeks of the programme (week 9-12).

Adherence to the recommended dosage and duration of the exercise was not calculated in this study. All participants started the exercise programme with a very low duration of aerobic exercise and very low volume of resistance exercise (e.g. 5-10 minutes of aerobic exercise and one set of 8-15 repetition for resistance exercise). This was because participants were sedentary and new to exercise. In response to participants' comments or following a discussion over the phone which was undertaken every two weeks, the duration of the aerobic exercise and the volume of the resistance exercise were updated on the platform and increased by 5-10 minutes and 1 set of 8-10 repetitions respectively. Seven participants out of the 13 (54%), who attended the post intervention assessment, left on line comments and answered phone calls on a regular basis and therefore they reached the targeted duration of aerobic and the volume of resistance exercise within six weeks. The remaining six participants (46%) did not reach the targeted exercise dose due to not answering phone calls and/or leaving notes on a regular basis.

6.1.4 Adverse events

The intervention and the study protocol were well tolerated. No serious adverse events were recorded that could be attributed to the intervention or the study protocol in both groups. Only one participant in the intervention group indicated mild muscle soreness that resolved within a few days without seeking medical help.

Results- The likely effect findings

6.1.5 Overview

Table 6.3 presents the mean data from the assessed clinical outcomes and the number of participants with complete data at each assessment points.

In order to determine the likely effect of the intervention, differences between the groups at post-intervention (week=12) was considered the main point of comparison (section 6.2.2)

No comparison between groups were undertaken at follow up (week=20) (i.e. two months after the end of the intervention (at follow up, week=20), due to the high attrition rates and missing data (see section 6.2.3).

Table 6.5 Group means (SD) for the outcome measures at baseline, post intervention and follow up

Variables	**Intervention**			**Control**		
	n	**Mean ± SD**	**Cases with complete data, n (%)**	**n**	**Mean ± SD**	**Cases with complete data, n (%)**
HbA1c %						
Baseline	14	8.1 ± 1.9	-	13	8.8 (2.3)	-
Post intervention	11	7.5 ± 1.8	10 (59%)	11	8.4 ± 1.9	10 (63%)
Follow up	5	6.7 ± 0.9	4 (24%)	6	7.1 ± 0.8	6 (38%)
Total-C mmol/L^						
Baseline	14	3.84 ± 0.9	-	13	4 ± 1	-
Post intervention	10	3.73 ± 0.7	9 (53%)	10	4 ± 1.4	9 (56%)
Follow up	5	4.34 ± 0.8	4 (24%)	6	3.45 ± 1.5	5 (31%)
LDL mmol/L						
Baseline	14	1.83 ± 0.6	-	13	2.08 ± 0.7	-
Post intervention	10	1.93 ± 0.6	9 (53%)	10	2.1 ± 0.9	9 (56%)
Follow up	5	2.38 ± 0.8	4 (24%)	6	1.9 ± 1.2	5 (31%)
HDL mmol/L						
Baseline	14	0.97 ± 0.3	-	13	1.06 ± 0.3	-
Post intervention	10	0.98 ± 0.3	9 (53%)	10	0.98 ± 0.3	9 (56%)
Follow up	5	1.03 ± 0.3	4 (24%)	6	0.85 ± 0.3	5 (31%)
Triglyceride mmol/L						
Baseline	14	2.34 ± 1	-	13	1.92 ± 1	-
Post intervention	10	1.9 ± 0.8	9 (53%)	10	2.1 ± 1.3	9 (56%)
Follow up	5	2 ± 1.3	4 (24%)	6	1.68 ± 0.6	5 (31%)

Variables	Intervention			Control		
	n	**Mean ± SD**	**Cases with complete data, n (%)**	**n**	**Mean ± SD**	**Cases with complete data, n (%)**
SBP mmHg						
Baseline	17	140 ± 15	-	16	138 ± 13	-
Post intervention	13	137 ± 16	13 (77%)	11	140 ± 16	11 (69%)
Follow up	7	139 ± 15	7 (41%)	8	138 ± 19	7 (44%)
DBP mmHg						
Baseline	17	84.3 ± 10.1	-	16	78.4 ±8.5	-
Post intervention	13	81 ± 11	13 (77%)	11	81 ± 9	11 (69%)
Follow up	7	85 ± 7	7 (41%)	8	79 ± 10	7 (44%)
BMI (kg/m^2)						
Baseline	17	30 ± 2.9	-	16	29.5 ± 4.6	-
Post intervention	13	29.68 ± 3.6	13 (77%)	11	29.78 ± 6.3	11 (69%)
Follow up	7	28.7 ± 3.6	7 (41%)	8	29.5 ± 4.5	7 (44%)
WC (cm)						
Baseline	17	105.2 ± (7.8)	-	16	107.6+12	-
Post intervention	13	104.54 ± 8	13 (77%)	11	104.36 ± 14	11 (69%)
Follow up	7	102 ± 9	7 (41%)	8	105 ± 9	7 (44%)
TUG (s)						
Baseline	17	10.2 ± 1.8	-	16	11.1 ± 4.7	
Post intervention	13	9.77 ± 1.7	13 (77%)	9	12.52 ± (2.6)	
Follow up	7	10.32 ± 2.3	7 (41%)	8	11.45 ± 1.7	

Variables	Intervention			Control		
	n	**Mean ± SD**	**Cases with complete data, n (%)**	**n**	**Mean ± SD**	**Cases with complete data, n (%)**
10MWT (s/m)						
Baseline	17	1.17 ± (0.2)	-	16	1.19 ±0.4	-
Post intervention	13	1.21 ± 0.3	13 (77%)	11	1.13 ± 0.6	11 (69%)
Follow up	7	1.15 ± 0.2	7 (41%)	8	1.11 ± 0.2	7 (44%)
Handgrip (Kg)						
Baseline	17	25.2 ± 11.3	-	16	25.7 ±10.2	-
Post intervention	13	25.5 ± 11.9	13 (77%)	11	24.2 ± 8.8	11 (69%)
Follow up	7	26.8 ± 13.5	7 (41%)	8	27.2 ± 13.5	7 (44%)
QOL-Physical health						
Baseline	17	13 ± 3	-	16	13 ± 3	-
Post intervention	13	15 ± 3	13 (77%)	11	12 ± 3	11 (69%)
Follow up	7	16 ± 3	7 (41%)	8	13 ±2	7 (44%)
QOL-Physical health						
Baseline	17	13 ± 3	-	16	13 ± 3	-
Post intervention	13	15 ± 3	13 (77%)	11	12 ± 3	11 (69%)
Follow up	7	15 ± 3	7 (41%)	8	13 ± 3	7 (44%)
QOL-Psychological						
Baseline	17	14 ± 3	-	16	13 ± 4	-
Post intervention	13	14 ± 3	13 (77%)	11	12 ± 4	11 (69%)
Follow up	7	15 ± 3	7 (41%)	8	13 ± 4	7 (44%)

Variables	**Intervention**			**Control**		
	n	**Mean ± SD**	**Cases with complete data, n (%)**	**n**	**Mean ± SD**	**Cases with complete data, n (%)**
QOL-Social						
Baseline	17	14 ± 2	-	16	14 ± 4	-
Post intervention	13	13 ± 4	13 (77%)	11	12 ± 4	11 (69%)
Follow up	7	14 ± 3	7 (41%)	8	13 ± 4	7 (44%)
QOL- Environment						
Baseline	17	14 ± 2	-	16	14 ± 3	-
Post intervention	13	15 ± 2	13 (77%)	11	13 ± 3	11 (69%)
Follow up	7	16 ± 3	7 (41%)	8	13 ± 3	7 (44%)
intake of calories (kcal)*						
Baseline	17	2024 (1647 - 2742)	-	16	2784 (1878 to 3656	-
Post intervention	13	2163 (1646 –2743)	13 (77%)	11	2226 (1777 – 2544)	11 (69%)
Follow up	7	1766 (1502-2162)	7 (41%)	8	2768 (2189-3608)	7 (44%)

All data are mean ± standard deviation, unless stated otherwise

Total-C-: total cholesterol, **LDL:** low-density lipoproteins, **HDL:** high-density lipoproteins; **SBP**: systolic blood pressure; **DBP**: diastolic blood pressure; **BMI:** body mass index; **WC:** waist circumference, **TUG:** The Timed Up and Go test; **10MWT:** Ten metre walking speed test; **QOL-Physical health**: Quality of life physical health domain; **QOL-Psychological:** Quality of life psychological domain; **QOL-Social:** Quality of life social domain; **QOL- Environment:** Quality of life environmental domain

*: Data are median (interquartile range)

6.1.6 Trends and changes at the end of the interventions (week=12)

Table 6.4 summarises the difference in changes between the groups from baseline to post intervention. Since this study was underpowered, this section will focus on trends and effect sizes, rather than merely inferential statistical outputs.

6.1.6.1 Glycaemic control

Glycaemic control, as measured using HbA1c, was the primary clinical outcome in this study. Out of the 24 participants who completed post intervention assessment, 20 participants (i.e. intervention=10, control=10) had glycaemic control results. In the intervention group, there was a trend in change as seven participants (70%) decreased their HbA1c (range 0.1% to 2.4%). Whereas, only three participants in the control group decreased their HbA1c. However, the observed trend in the intervention group was unlikely to be clinically important as only two participants achieved a clinically important improvement in HbA1c which was defined as any reduction of 0.5% or more (Little et al., 2011). Statistically this difference between groups was not significant (p= 0.92) and the effect size for the difference between group was also small (d= 0.046) (Table 6.4**)**.

Table 6.6 Baseline characteristics and post intervention results for participants who completed the primary end point and included in the primary data analysis

Outcomes		**Intervention group**				**Control group**			**Differences between groups**	
	n	**Baseline**	**Post intervention**	**▲ (post - baseline)**	**n**	**Baseline**	**Post intervention**	**▲ (post- baseline)**	**P value**	**Effect size**
HbA1c %	10	7.83 ± 2	7.61 ± 1.9	-0.22 ± 0.9	10	8.78 ± 2.7	8.62 ± 2	-0.16 ± 1.6	0.918 [Ť]	d= 0.047
Total-C mmol/L^	9	4 ± 1	3.52 ± 0.4	-0.47 ± 0.9	9	3.84 ± 1	4.17 ± 1.4	0.34 ± 1.9	0.185 [Ū]	r= -0.312
LDL mmol/L	9	1.96 ± 0.7	1.78 ± 0.4	-0.18 ± 0.5	9	2.03± 0.8	2.2 ± 0.9	0.18 ± 0.7	0.310 [Ū]	r=-0.239
HDL mmol/L	9	1.02 ± 0.3	1.02 ± 0.2	-.00 ± 0.2	9	1.04 ± 0.2	1.03 ± 0.3	-.01 ± 0.3	0.427 [Ū]	r = -0.187
Triglyceride mmol/L	9	2.30 ± 1.2	1.77 ± 0.8	-0.53 ± 1.1	9	1.68 ±0.66	2.1 ± 1.4	0.43 ± 1.6	0.157 [Ť]	d=0.71
SBP mmHg	13	139 ± 17	137 ± 16	-2 ± 12	11	142± 14	140 ± 16	2 ± 9	0.663 [Ū]	r=0.071
DBP mmHg	13	83.5 ± 10.5	81.1 ± 11	-2.4 ± 9	11	80 ± 8.7	81 ± 9	1 ± 8	0.282 [Ť]	d=0.46
BMI (kg/m^2)	13	29.96 ± 2.9	29.68 ± 3.6	-0.27 ± 0.8	11	29.68 ±5.1	29.78 ± 6.3	0.1 ± 1.7	0.480 [Ť]	d=0.279
WC (cm)	13	103.4 ± 7.6	104.5 ± 8	1.2 ± 4.3	11	107.6 ± 13	104.4 ± 14	-3.2 ± 3.5	0.014 [Ť]	d=1.105
TUG (s)	13	10.1 ± 1.9	9.8 ± 1.7	-0.3 ± 1.1	9	10.1 ± 1.9	12.5 ± (2.6)	2.4 ± 2	0.001 [Ť]	d=1.66
10MWT s/m	13	1.16 ± 0.2	1.21 ± 0.3	0.05± 0.2	11	1.12 ± 0.5	1.13 ± 0.6	0.01± 0.4	0.417 [Ū]	r=-0.166
Handgrip Kg	13	25.2 ± 11.2	25.5 ± 9	0.3 ± 4	11	25.6 ± 10	24.2 ± 8.8	-1.4 ± 2.4	0.293 [Ť]	d=0.5
QOL-Physical health	13	14 ± 3	15 ± 3	1 ± 2	11	13 ± 3	12 ± 3	-1 ± 2	0.004 [Ū]	r= 0.518
QOL-Psychological	13	14 ± 3	14 ± 3	0 ± 1	11	13 ± 4	12 ± 4	-1 ± 2	0.736 [Ū]	r=0.129

Outcomes		Intervention group				Control group			Differences between groups	
	n	Baseline	Post intervention	▲ (post - baseline)	n	Baseline	Post intervention	▲ (post- baseline)	P value	Effect size
QOL-Social	13	14 ± 3	13 ± 4	-1 ± 3	11	14 ± 4	12 ± 4	-2 ± 2	0.370 Ū	r =0.171
QOL- Environment	13	15 ± 2	15 ± 2	0 ± 2	11	14 ± 3	13 ± 3	-1 ± 1	0.144 Ū	r = -0.373
Average Daily intake of calories (kcal)*	13	2163 (1646 to 2743)	2163 (1646 – 2743)	35 (-111– 117)	11	2784 (1709 -3656)	2226 (1777 – 2544)	45 (-408 – 212)	0.974 Ū	r=0.007

All data are mean ± standard deviation, unless stated otherwise
▲ change from baseline to post intervention (post-baseline)
LDL: low-density lipoproteins, HDL: high-density lipoproteins; SBP: systolic blood pressure; DBP: diastolic blood pressure; BMI: body mass index; WC: waist circumference, TUG: The Timed Up and Go test; 10MWT: Ten metre walking speed test; QOL: quality of life. QOL-Physical health: Quality of life physical health; QOL-Psychological: Quality of life psychological domain; QOL-Social: Quality of life social domain; QOL- Environment: Quality of life environmental domain
*: Data are median (interquartile range)
^ HbA1c% results were available for from 20 participants (intervention=10, control=10)
blood lipid results were available from 18 participants (intervention=9, control=9)
Ť: Result from independent t test between intervention and control groups
Ū: Result from Mann–Whitney U test between intervention and control groups due to non-normal distribution.

6.1.6.2 Blood lipid profile

Out of the 24 participants who completed post intervention assessment, 18 participants (i.e. intervention=9, control=9) had blood lipids results. In the intervention group, there was a trend toward a decrease in total cholesterol level as six participants out of nine (67%) displayed a decrease (range 0.04 to 1.95 mmol/L), while there was no notable trend in total cholesterol in the control group. Although the difference between groups did not reach a statistically significant level (p= 0.185), the effect size was moderate in favour of the intervention group (r= 0.312), (Table 6.4).

Similarly, there was a trend toward a decrease in triglyceride levels in the intervention group as six participants showed a decrease (range 0.22 to 2.59 mmol/l), while there was no notable trend in the control group. The difference between the groups did not reach a statistically significant level (p= 0.157). However, the calculated effect size was moderate in favour of the intervention group (d= 0.7) (Table 6.4).

Despite the improvements in total cholesterol and triglyceride, there were no noticeable trends in low-density lipoprotein (LDL) or high-density lipoprotein (HDL) levels in either the intervention or the control group. The difference between groups were also not statistically significant for low-density lipoprotein (p= 0.301), and for high-density lipoprotein (p= 0.427). Similarly, the effect sizes were small for LDL (r=0.24) and HDL (r= 0.187) (Table 6.4).

6.1.6.3 Blood Pressure

At the end of the intervention there were no notable changes observed in either group in terms of their systolic and diastolic blood pressure. The difference between the groups in systolic blood pressure was not statistically significant (p= 0.663) with a small effect size (r= 0.071). Similarly, the difference between the groups was not statistically significant in diastolic blood pressure (p= 0.282) with a small effect size (d= 0.46) (Table 6.4**)**.

6.1.6.4 Anthropometry

Two anthropometry measures were used in this study, namely, waist circumference (WC) and Body Mass Index (BMI). The BMI of both groups remained stable throughout the intervention period and the difference between groups was not statistically significant (*p*=0.608) with a small effect size (*d*=0.279) (Table 6.4**).** However, surprisingly, participants in the control group demonstrated a trend toward a decrease in WC by a mean of 3.18 cm ± 3.5, while this was not the case in the intervention group. In the intervention group seven participants remained stable, two participants decreased their WC, and four participants deteriorated. This observed reduction in WC in the control group was statistically significant compared to the intervention group (*p*= 0.014) with a large effect size (*d*=1.1.05) (Table 6.4**)**.

6.1.6.5 Functional mobility

Two measures related to function mobility were assessed in this study: the Timed Up and Go (TUG), and the 10-Meter Walking Test (10MWT). For the TUG, participants in the intervention group showed a trend towards improvement, with a decrease of mean of 0.3s ± 1.1. Five participants (39%) in the intervention group exceeded the minimal detectable change for the TUG test for people with T2DM (i.e. MDC= 0.85s), which reflects a true change that is not due to measurement error. In contrast, all participants in the control group, except one, deteriorated by a mean of 2.4s ± 2 (Table 6.4**).** An independent t-test revealed that the differences between the two groups were statistically significant in favour of the intervention group (*p*= 0.001) with a large effect size (*d*= 1.66) (Table 6.4**)**. In comparison, there was no noticeable trend in changes in the 10MWT in either the intervention or the control group and no statistically significant difference between the two groups (*p*=0.465). The effect size was also small (*r*=-0.166) (Table 6.4**)**.

6.1.6.6 Muscle strength

To examine the impact of the intervention on muscle power, handgrip strength was used as an indicator of general muscle strength. Overall, there was a trend toward a decrease in muscle strength in the control group by a mean of 1.4 kg ± 2.4, compared to the intervention group which remained relatively stable (e.g. mean change of 0.26 ± 4 kg). Although, the difference between groups did not reach statistically significant levels (*p*= 0.293), the effect size was moderate in favour of the intervention group (*d*= 0.5) (Table 6.4).

6.1.6.7 Quality of life

Quality of life was estimated using the WHOQOL-BREF scale which assesses QOL based on four individual domains: physical health, psychological, social relationships, and environment (Skevington et al., 2004). Consistent with the improvement in physical function mobility presented above, the change in the physical health domain of the WHOQOL-BREF between the groups was also statistically significant in favour of the intervention group (p=0.011), with a large effect size (r=0.518). The scores increased by a mean of 1 ± 2 in the intervention group, compared to a decrease by 1 ± 2 in the control group. No other statistically significant differences between the two groups or trends were observed for any of the other WHOQOL-BREF domains (Table 6.4**)**. However, a moderate effect size in favour of the intervention was found in the environmental domain (r= 0.373) (Table 6.4**)**.

6.1.6.8 Changes in diet and medication during the intervention period

There were no major changes in medications during the study period in either group. One participant in the control group increased the dose of their anti-hypertensive medication. However, adherence to the medications was not recorded. There was also no significant difference between groups in total dietary intake between baseline and post intervention as shown in Table 6.4.

6.1.7 Changes after the completion of the intervention (follow up week=20)

There were high rates of attrition at the follow up assessment, 59% in the intervention group and 50% in the control group. As already highlighted there was also a high number of missing data in terms of HbA1c and blood lipids. For these variables, only five participants (24%) in the intervention group had complete data for analysis from which change scores could be calculated. The baseline characteristics of these participants were not comparable to those who only completed the post-intervention assessment. For example, at baseline, HbA1c for the four participants in the intervention group was 6.4%, indicating good glycaemic control; whereas HbA1c for the original sample was 7.8% indicating poor glycaemic control. As such, it was considered that the available data at five months was less likely to represent the original sample and too small for a meaningful analysis. As such, no further analysis was conducted. However, the mean ± standard deviation from participants who have complete data are presented in Table 6.5.

Table 6.7 Available data from participants who completed baseline, post intervention and follow up assessment (week=20)

Variable	**Intervention**				**Control**			
	n	Baseline	Post	Follow up	n	Baseline	Post	follow
HbA1c %	4	6.4 ± 1.4	6.7 ± 1	6.6 ± 1.1	6	7.87 ± 1.1	7.97 ± 1.6	7.13 ± 0.9
Total-C mmol/L^	4	3.88 ± 0.9	3.57 ± 0.6	4.16 ± 0.8	5	4.09 ± 1.3	3.86± 1.4	3.8 ± 1.5
LDL mmol/L	4	2 ± 0.8	1.84 ± 0.5	2.22 ± 0.9	5	2.21 ± 1	2± 0.9	2.12 ± 1.3
HDL mmol/L	4	1.08 ± 0.2	1 ± 0.1	1.13 ± 0.2	5	1.08 ± 0.2	0.9 ± 0.1	0.96 ± 0.1
Triglyceride mmol/L	4	1.86 ± 0.7	1.53 ± 0.7	1.85 ± 1.4	5	1.7 ± 0.78	2.03 ± 1.3	1.51 ± 0.5
SBP mmHg	7	140 ± 14	140 ± 17	139 ± 15	7	146 ± 14	144 ± 18	140 ± 19
DBP mmHg	7	86 ± 10	85 ± 9	85 ± 7	7	83 ± 7	85 ± 8	80 ± 10
BMI (kg/m^2)	7	29.6 ± 3	28.9 ± 9	28.7 ± 4	7	29.8 ± 5	30.1 ± 6	29.5 ± 5
WC (cm)	7	101 ± 9	101 ± 8	102 ± 9	7	109 ± 11	106 ± 11	106 ± 10
TUG (s)	7	10 ± 1.9	9.9 ± 1.9	10.3 ± 2.3	7	9.7 ± 1.5	11.95 ±2.6	11.6 ± 1.8
10MWT (s/m)	7	1.1 ± 0.2	1.3 ± 0.3	1.2 ± 0.2	7	1.3 ± 0.3	1.4 ± 0.5	1.1 ± 0.2
Handgrip (Kg)	7	25 ± 11	25 ± 14	27 ± 13	7	29 ± 10	27 ± 11	28 ± 15
QOL-Physical health	7	15 ± 3	16 ± 3	16 ± 3	7	13 ± 3	12 ± 3	13 ± 3
QOL-Psychological	7	14 ± 4	15 ± 4	15 ± 3	7	14 ± 4	14 ± 3	14 ± 4
QOL-Social	7	14 ± 3	13 ± 6	14 ± 3	7	14 ± 4	12 ± 5	13 ± 4
QOL- Environment	7	15 ± 2	16 ± 3	16 ± 3	7	14 ± 3	14 ± 3	14 ± 3
Calories intake (kcal)*	6	1665 (1626-6971.00	1725 (1502-2162)	1766 (1448-1995)	5	2784 (2189-3608)	2544 (2229-3736)	2768 (1958-3281)

All data are mean ± standard deviation, unless stated otherwise
n= number of available participants; LDL: low-density lipoproteins, HDL: high-density lipoproteins; SBP: systolic blood pressure; DBP: diastolic blood pressure; BMI: body mass index; WC: waist circumference, TUG: The Timed Up and Go test; 10MWT: Ten metre walking speed test; QOL: quality of life. QOL-Physical health: Quality of life physical health; QOL-Psychological: Quality of life psychological domain; QOL-Social: Quality of life social domain; QOL- Environment: Quality of life environmental domain; *: Data are median (interquartile range). No statistically significant results were observed.

6.1.8 Secondary Analysis

Table 6.6 presents the results of a secondary analysis accounting for all randomised participants. Overall, the results did not differ from the primary analysis (complete-case analysis).

Table 6.8 A secondary analysis accounting for all randomised participants

Outcomes	**Intervention group**			**Control group**			**Differences between groups**
	Baseline	**Post intervention**	**▲ (post - baseline)**	**Baseline**	**Post intervention**	**▲ (post- baseline)**	**P value**
HbA1c %	8.1 ± 1.9	8 ± 1.9	-0.16 ± 0.8	8.8 ± 2.3	8.7 ± 1.7	-0.12 ± 1.4	0.936 Ť
Total-C mmol/L^	3.8 ± 0.9	3.5 ± 0.5	-0.3 ± 0.7	4 ± 1	4.2 ± 1.3	0.2 ± 1	0.245 Ū
LDL mmol/L	1.8 ± 0.6	1.7 ± 0.4	0.1 ± 0.4	2.1 ± 0.7	2.2 ± 0.8	0.1 ± 0.6	0.299 Ū
HDL mmol/L	1 ± 0.3	1 ± 0.2	0 ± 0.2	1.1 ± 0.3	1.1 ± 0.4	0 ± 0.3	0.383 Ū
Triglyceride mmol/L	2.3 ± 1	2 ± 0.8	-0.3 ± 0.9	1.9 ± 1	2.2 ± 1.4	0.3 ± 1.3	0.153 Ť
SBP mmHg	140 ± 15	139 ± 15	-1 ± 10	138 ± 13	137 ± 14	1 ± 8	0.985 Ū
DBP mmHg	84 ± 10	83 ± 10	2 ± 7	78 ± 9	79 ± 9	1 ± 7	0.919 Ť
BMI (kg/m^2)	30 ± 2.9	29.8 ± 3.4	-0.2 ± 0.7	29.5±4.5	29.5 ±5.5	0 ± 1	0.462 Ť
WC (cm)	105 ± 8	106 ± 8	1 ± 4	108 ± 12	106 ± 13	-2 ±3	0.018 Ť
TUG (s)	10.23 ± 1.8	10.02 ± 1.6	-0.21 ± 1	11.09±4.7	12.5 ± 4.8	1.36 ± 1.9	0.006 Ť
10MWT s/m	1.16 ± 0.17	1.21 ± 0.25	0.04 ± 0.18	1.19 ± 0.4	1.19 ±	0 ± 0.29	0.488 Ū
Handgrip Kg	25 ± 11	25 ± 10	0 ± 3	26 ± 10	24 ± 12	2 ± 5	0.123 Ť
QOL-Physical health	13 ± 3	14 ± 3	1 ± 2	13 ± 3	12 ± 3	-1 ± 2	0.012 Ū
QOL-Psychological	14 ± 3	14 ± 3	0 ± 1	13 ± 4	13 ± 4	0 ± 2	0.763 Ū

Outcomes	Intervention group			Control group			Differences between groups
	Baseline	**Post intervention**	**▲ (post - baseline)**	**Baseline**	**Post intervention**	**▲ (post- baseline)**	**P value**
QOL-Social	14 ± 3	13 ± 4	1 ± 2	14 ± 4	13 ± 4	-1 ± 2	0.488 Ū
QOL- Environment	14 ± 2	14 ± 3	0 ± 1	14 ± 1	14 ± 3	0 ± 1	0.260 Ū
Average Daily intake of calories (kcal)*	2023 (1647-2741)	2015 (1685-2721)	0 (-60 to 56)	2714 (1866 to 3559)	2231 (1878 to 3098)	0 (-240 to 166)	0.800 Ū

All data are mean ± standard deviation, unless stated otherwise
n= number of available participants; LDL: low-density lipoproteins, HDL: high-density lipoproteins; SBP: systolic blood pressure; DBP: diastolic blood pressure; BMI: body mass index; WC: waist circumference, TUG: The Timed Up and Go test; 10MWT: Ten metre walking speed test; QOL: quality of life. QOL-Physical health: Quality of life physical health; QOL-Psychological: Quality of life psychological domain; QOL-Social: Quality of life social domain; QOL- Environment: Quality of life environmental domain; *: Data are median (interquartile range). No statistically significant results were observed.

6.1.9 Summary of the clinical outcomes results

Thirty-three participants met the inclusion criteria and were randomised to either the intervention (n=17) or the control group (n=16). Twenty-four out of 33 participants completed the post intervention assessment and were included in the analysis. No adverse events were reported from this study. Approximately 76% of participants used the platform and accessed the intervention. The adherence to the intervention ranged from 57% in the first four weeks to 31% in the last four weeks.

Compared to the control group, participants in the intervention group showed better trends in changes with moderate to large effect sizes in the following outcomes: total cholesterol levels, triglyceride levels, handgrip strength, the Timed up and Go, and the physical health sub-domain of the WHO Quality of Life-BREF. However, the difference between groups in terms of the TUG was mostly explained by a deterioration in the control group. The difference between groups in terms of triglyceride may have been due to using non-fasting blood samples. Surprisingly, participants in the control group demonstrated a significant trend toward a decrease in WC as compared to the intervention group.

Chapter 7 – Qualitative findings

This chapter will present the views and opinions of those individuals who participated in the web-based exercise intervention in order to determine how the intervention was received by participants.

7.1 Selection of participants

At the end of the intervention, a sub-sample of the participants from the intervention group (7 participants) were invited to take part in audio-recorded 30-minutes face to face interviews. Purposeful selection of participants was undertaken to ensure that the sample consisted of male and female with different adherence rates to the intervention. Out of the seven participants who were invited, five participants agreed to be interviewed. Two participants preferred not to take part due to the lack of time. The characteristics, for all interviewed participants are presented in Table 7.1.

All interviews were carried out in English, by the Chief Investigator. At the beginning of each interview, the Chief Investigator explained the aim of the interview and participants gave additional verbal consent to take part in these interviews. Participants were assured that their names would not be used in the transcript. The interviews procedure is described in detail in Chapter 5.

Table 7 1 Demographic characteristics

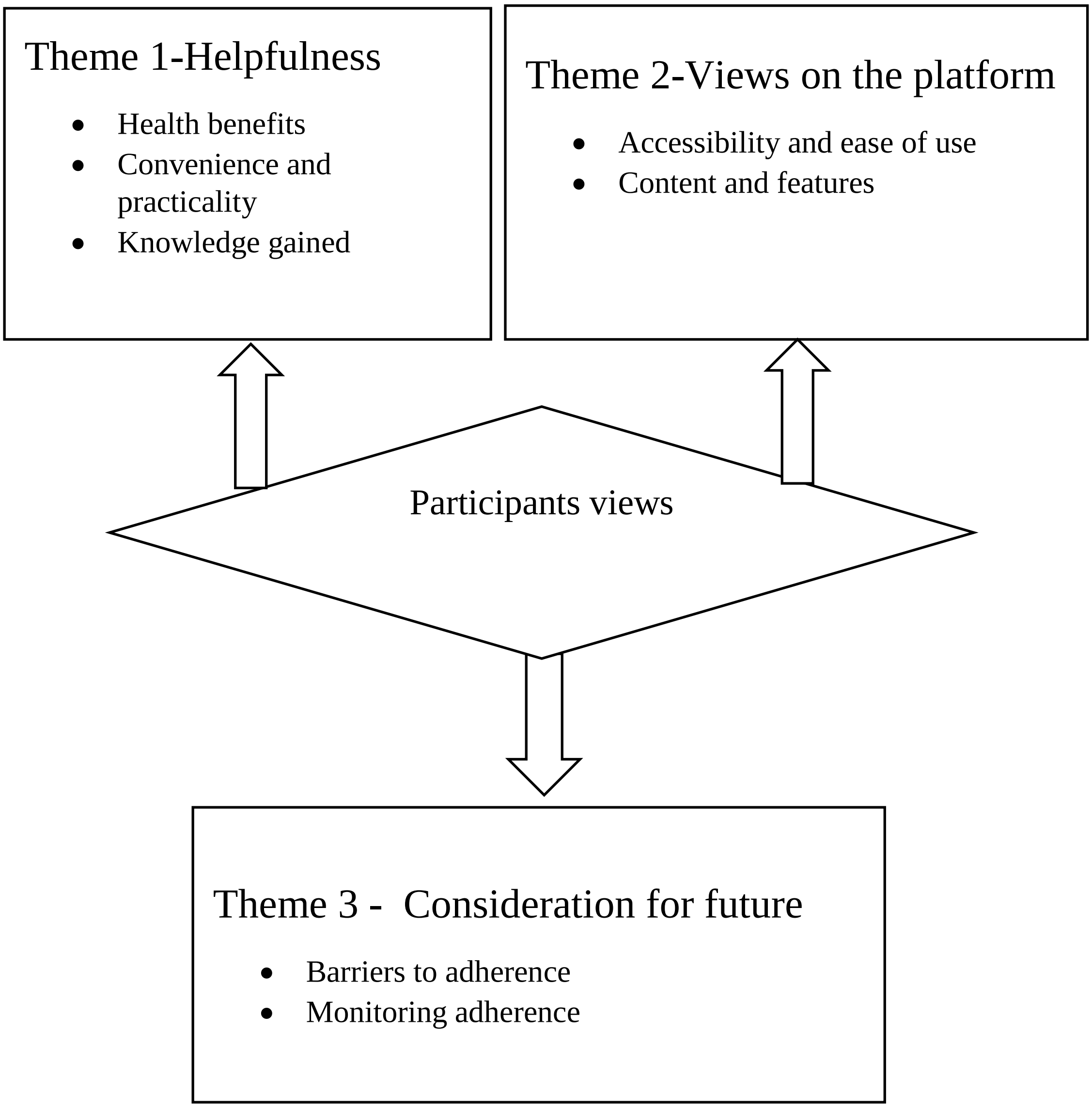
Variables	**P 1**	**P 2**	**P 3**	**P 4**	**P 5**
Age (years)	61	46	61	44	42
Gender	Male	Male	Female	Female	Female
Diabetes duration (years)	4	0.5	18	10	21
Comorbidities	Gout	Cholesterol	MI, OA	No	No
Education level	University	University	Postgraduate	Secondary	University
Origin	Pakistan	Pakistan	Pakistan	Pakistan	Pakistan
Place of birth	Pakistan	Pakistan	Pakistan	UK	Pakistan
Languages	E & U	E & U	E & U	E & U	E & U
Adherent	Yes	Yes	No	No	Yes

P: Participant; MI: history of myocardial infarction; OA: osteoarthritis; U: Urdu; E: English

7.2 Themes Identified

The analysis of the interviews identified three main themes and seven subthemes as summarised in Figure 7.1. These themes and subthemes are presented below and supported by illustrative verbatim quotations. Participant numbers, age, and gender are provided in parenthesis. The views within each theme did not vary depending on the characteristics of the participants, unless stated otherwise.

Figure 7.1 Identified themes



7.2.1 Theme one: Perceived Helpfulness

Perceived helpfulness was a theme that emerged from the analysis of the interviews. This consisted of three sub-themes: health benefits, convenience and practicality, and the knowledge gained. The following sections discuss each sub-theme of helpfulness with example quotations.

7.2.1.1 Health benefits

All participants commented subjectively on improvements in their health, which they attributed to the intervention. The improvement in physical function was the most frequent benefit mentioned by participants. Four participants felt that the intervention helped them to be more active in their lives.

> *"I feel more energetic and more willing to do work. Whereas before I used to be lazy and no energy in the body to do much work"* P1 (61 years old, male)

> *Well it kept my muscles in kind of a better shape. So, when I'm getting up off the sofa, no pain and no bones creaking [laughing]. So, definitely even my breathing has... well, it has not been that great in winter time [The time when she started the exercise] but I can see myself kind of I 've been a little bit more with the energy and the get up and go…It's improved the stamina. You know just the get up and go."* P3 (61 years old, female)

> *"you just feel a lot healthier and not like when your sugar is a high you feel so tired and you cannot do anything but exercise does make you feel better"* P5 (42 years old, female)

Other improvements such as better glycaemic control, better sleep, and losing weight were also reported; however, these improvements were not consistent among participants. For example, three participants commented on improvement in their glycaemic control, one participant reported improvement in their sleep quality and one participant mentioned weight reduction.

> *"I've noticed that it's been very very much under control [blood sugar levels]. Even if I miss my medicine sometimes, it seems to be under control."* P1 (61 years old, male)

> *"I feel I got better night sleep and I wake up earlier as well and less hungry"* P5 (42 years old, female)

> *"Lots of people said to me that I've lost weight…because there are some dresses that used to be like tight on me and they are not [as] tight now than they used to be like before. Even the nurse, when I had my check up, she said I'd lost weight which is a good thing"* P4 (44 years old, female)

7.2.1.2 Convenience and practicality

The convenience and practicality of the intervention was another sub-theme. Participants reported that in contrast to traditional exercise interventions, this intervention was convenient and practical as it fitted more easily into their personal lifestyle. For example, participants were happy that the intervention could be done at home, as it entailed less travelling time and did not require paying expensive gym fees.

> *"Its easier because you don't… it takes less time.. it's like if you go to the gym, you have to prepare in advance. And you know, half an hour travelling to get to the gym, then half an hour to get back. Whereas in the home you just get in with it."* P5 (42 years old, female)

> *"It's good, I think it is good. It gives you some ideas how you can do the exercise at home, not going to gym and paying lots of money in gym. You can do the exercises in your home it's very cheaper"* P2 (46 years old, male)

> *"So, that was easy. You don't have to go to make a special place or a special gym to do this"* P4 (44 years old, female)

Female participants in particular also felt that the intervention helped them to overcome the cultural barrier to exercise that is related to the lack of gender-specific exercise facilities. For example, one participant stated the following:

> *"Well mostly gyms like in Glasgow here, anyway, are mixed gender gyms. So, for us it's very difficult. I cannot say: right I'm going to gym now because I know it's not going to be just for ladies only. And if there are places for ladies only, it's usually a wee corner at the side and all the same. Sometimes, even if it is ladies only facility, some of the trainers are still men, and you think well it kind of defeats the purpose. And I think in Islamic countries as well it's always like harder for woman to just go and say right I'm going out for a walk. So in that sense they can fit it like they can do in the wee garden, back yard or even indoor in their bedrooms if they wanted to"* P3 (61 years old, female)

Another female participant, who used to attend female-only classes regularly, mentioned that even if there are female-specific exercises facilities, females tend not to attend on a regular basis and consequently these facilities often close. Therefore, she believed that this type of intervention was a solution.

> *"Sometimes only me and her [the trainer]. And because there were not enough ladies coming, the [ladies only centre] couldn't, you know, apply for more fund. Obviously, the more people have come, the more funding can come. So, they had to stop the exercises. So, I was thinking in these exercises that I can do in the house you know*" P4 (44 years old, female)

7.2.1.3 Knowledge gained throughout the intervention

Participants explained that the knowledge they gained throughout the intervention on exercise was perceived as helpful. Participants highlighted that the tailored exercise programmes helped them to know what exercises they should do, with the majority of participants (3/5) admitting that their knowledge was limited prior to the intervention. Participants explained that even if they were aware of exercise resources they were not able to determine whether these exercises were beneficial or could indeed make their condition worse. Consequently, the intervention provided them with a trusted source of exercise that they should do.

> *"I think if somebody gives you a full programme, what to do, then you tend to follow it more, whereas, before we never knew what to do, what exercise not to do, which one is beneficial for you. So this one [web-based physio] you know is beneficial for you because it has been started by a professional person. So, you tend to follow it more."* P1 (61year old, male)

> *"I think that support was really helpful, useful in any way, to get that kind of initial mental owning of, this is for me, and I should do this. You know this kind of thing. Whereas, if they are just there on the internet… you can google and get stuff… but they are just available for everybody, aren't they? so you don't know whether they are any good for you or"* P3 (61 year old, female)

> *Sometimes you think, oh I want to exercise but you don't know what to do. Whereas, if you got a set of exercise given to you it is easier, you can just get on with it"* P5 (42 years old, female)

In summary, participants identified the intervention as helpful, because it was practical, convenient, a trusted source of knowledge and beneficial in term of health and wellbeing.

7.2.2 Theme two- Web-based physiotherapy platform

Views on the mode of the delivery (web-based physiotherapy platform) was another theme that arose from the analysis, and within this theme there were two sub-themes. The first sub-theme explains the accessibility and usability of the platform, while the second sub-theme highlights the views on the content and features of the platform.

7.2.2.1 Accessibility and usability

Broadly, participants appeared to find the platform accessible and easy to use. They reported that they were able to access the platform, navigate the content, and follow the exercise programme from different locations at different times using various devices based on their personal preferences. For example, a participant who completed all exercise sessions reported that they were able to access the platform from a desktop, laptop and a smartphone, even when abroad.

> *I have used computer, have used laptop, and when I was away abroad I used my mobile phone, I accessed through my mobile phone so it's very easy to access to, through any of these devices … it's easy to navigate through the website .. it's easy to follow as well as the instructions, and everything is not difficult to follow"* P1 (61 years old, male)

Interestingly, even participants with low adherence rates stated that the platform was accessible and easy to use. For example, a female participant – with low adherence rate– reported that she was able to see her exercise programme and navigate the platform easily.

> *I think your website is nice. Very clear, how many time you should do, the way the people over the internet doing exercises, showing bit by bit what you should do. I think it's nice. I think it's easy"* P4 (44 years old, female)

7.2.2.2 Content and features

Participants gave positive feedback regarding the content and the key features of the platform. They liked the colours, layout, language used, and the clarity of the instructions. They also reported that the exercise videos were clear and helped them to remember the exercise programme. One participant mentioned that they logged on to the platform every time they intended to do their exercise programme.

> *"I prefer to refresh my memory every time, by logging in to the website. You can see the instructions every time and it is better to refresh your memory "*P1 (61year old, male)

> *"It's quite clear, I mean, the videos are ..quiet.. in well place, you can get access to them and you can go into your diary which is good so… it's fairly okay. I think generally the website is good because it lets you know what needs to be done .. how much you've done .. maybe as well"* P3 (61year old, female)

To further improve exercise videos, one participant suggested that adding more exercise videos with longer duration involving two models (trainer and lay person who is not familiar with the exercises). This suggestion was mainly to allow participants to compare the performance and to make sure they do the exercise correctly.

> *"I think it's a very good start and good direction to take it. The only thing I suppose you could do is, you know, have a person you know just a starter along with somebody who is showing you what to do. So they are following, you know, you are seeing somebody who is doing the exercise and somebody who knows what to do in the same videos and see what is the difference. It is just in terms of making it more colourful, catchier, but in term of the therapeutic it's ok I think it is great what you have is good enough"* P3 (61 year old female).

Participants also liked the availability of the online exercise diary that was embedded within the platform to monitor adherence and progress. To monitor adherence and progress, participants were asked to use an online exercise diary imbedded within the platform, by ticking a small box next to every exercise video that they successfully completed. They reported that it helped them to recognise how much they have done and encouraged them to meet their targeted level of exercise.

> *"It's actually pretty good because you can see where you have not been doing that supposed to be 150 [minutes] like this week I hardly got anything because my son was here from Canada."* P5 (42 years old female)

Despite this, two participants felt the exercise diary required further improvement, with one participant noting that it could give and inaccurate record. This was mainly due to the fact that the diary does not allow for corrections if participants ticks the exercise videos by mistake. While another participant felt that the process of recording every single exercise was impractical and time consuming.

> *"it's good you can go back and see what you were doing and how much you've done. it encourages you to do more exercise because you know how much you've done through the week…..The only thing is sometimes, it seems to put extra, if you've done the exercise once, it keeps saying you've done it twice "* P1 (61 year old male)

To improve the online exercise diary, it was suggested that it would be more practical if participants were asked to record the exercise session (e.g. one box to be ticked), rather than recording every single exercise video by ticking many boxes. Allowing for editing the exercise diary to correct mistakes was also indicated as an improvement in the functionality of the exercise diary.

> *"The only thing I suppose I found it a bit, you know, about that I struggled in terms of recording and how to go back after each video [recording diar]y. If the step could be, like you know, you've got a 15 minute initial workout and then the main whatever. And then [cooling] down, all altogether and then once you've completed just do a wee tick. That would make life a lot easier because"* P3 (61 year old female)

In conclusion to this theme, participants liked the platform and identified it as accessible and easy to use. However, to further improve the content two participants suggested improving the online exercise diary and one participant suggested adding longer exercise videos.

7.2.3 Theme three: Barriers and consideration related to adherence

Barriers and considerations related to adherence was the final theme that emerged from the data. Two sub-themes were identified under this theme: barriers to the intervention, and considerations related to monitoring the adherence.

7.2.3.1 Barriers to the intervention

Although participants believed that the intervention was convenient and practical, they admitted that there were a few barriers. The disturbance by the family members was the most frequent barrier, mentioned by three participants.

> *It's good to do it at home. So, you don't need to go to the gym. And it's easier to do it at home, but at the same time a lot of people disturb you as well when you are trying to get on with it"* P5 (42 year old, female)

To overcome this barrier, one participant preferred to do their programme in their office.

> *"it is especially difficult for me in house because in the office nobody dares to disturb me. So, I can do it, but other way it's difficult to do it because when I am in the house it's difficult to do, my granddaughter tends to disturb me"* P1 (61 years old, male)

Other barriers to participating in the intervention were not consistent among participants. For example, bad weather was a barrier mentioned by one participant who preferred the walking exercise. Feeling lazy was mentioned by one participant, and similarly the lack of time was mentioned by two participants who attributed this to their responsibilities as mothers.

> *"Because I have got busy life, five males I have to feed. So, I am the only female, so I have to …you know"* P4 (44 year old, female)

7.2.3.2 Consideration related to monitoring participants' adherence

Three participants gave responses that raised a concern about the suitability of the online exercise diary to monitor adherence and progress. Two participants indicated that although they did the exercises, they simply forgot to complete their exercise diaries, whereas the third participant perceived recording the diary to be time consuming. Indeed, two of these participants had significantly incomplete exercise diaries. These responses indicate that the exercise diary might not have been a good method to monitor exercise adherence and therefore further considerations are required in the future.

> *"I suppose I do have time as I've got my phone it gets internet in it I just need to put time on it, to fill in [the diary] I just forgot to"* P4 (44 year old female)

> *"I did find the recording of going to each video and then clicking on that to say yes I have done it.. I found it a bit tedious, so it was not as good like that.* P3 (61year old female)

7.3 Summary of qualitative finding

The participants found the intervention to be helpful due to the perceived health improvements, the knowledge about exercise that they gained, and the convenience of the intervention. The platform used to deliver the intervention was perceived to be accessible and easy to use. Participants gave positive feedback about the content of the platform. However, two participants raised a concern about the practicality of the online exercise diary and suggested further improvements to it. Disturbance by family members was the main barrier to doing the exercise intervention.

Chapter 8 – Discussion

This pilot study incorporated both quantitative and qualitative methods to determine the feasibility, the acceptability and the likely effect of a 12-week web-based exercise intervention in South Asians with T2DM. This chapter will discuss the findings in relation to the objectives of the study. Limitation and strength of the current study will be also discussed.

8.1 General findings

8.2 Feasibility

8.2.1 Recruitment

Overall, the finding of the current study suggests that recruitment strategies were feasible. However, further considerations are required to improve the efficacy of recruitment. In the current study a total of 33 participants were recruited over a period of 9 months with an overall recruitment rate of approximately four participants per month. Although the recruitment target was not achieved (i.e. 40 participants), the recruitment rate was comparable with other RCTs recruiting people from white European backgrounds (Walters et al., 2017). Extending the recruitment for additional 2-3 months would have allowed the study to include more participants and reach the target number of participants. However, due to time constraints, as this was a PhD project, it was difficult to extend the study duration. Therefore, future research should allow for a recruitment period of at least one year.

It was noted that the restricted inclusion criteria were a barrier to the recruitment. At the beginning of the recruitment period it was noticed that the majority of interested participants were obese, while the inclusion criteria were restricted to those of BMI of < 30 kg/m^2. Narrow inclusion criteria have been previously reported as a barrier to South Asian participation (Mukherjea et al., 2018). Therefore, to enhance recruitment in the current study, the inclusion criteria were amended to include those of BMI of up to 35 kg/m^2. As such, future studies targeting South Asians should also consider more relaxed inclusion criteria (i.e. no restriction on body mass index or age) as this may improve the recruitment further.

In this study, recruitment through NHS staff or posters at NHS sites were less successful, compared to the other two routes in which the community was involved (i.e. faith centres and REACH community Health Project). In the current study, only three people (2%) responded to NHS staff/posters, while 80 participants (73%) responded to faith centres leaders, and 27 (25%) responded to the REACH community health project. Another lifestyle interventional study targeting South Asians experienced similar challenges (Douglas et al., 2011), in which only 5% of potential participants were referred by NHS staff, while 82% of potential participants responded to other community-oriented routes. However, it should be noted that although recruitment through the community was considered a successful approach in the current study, it was not without challenges.

In the current study, ten local faith centres, attended mainly by South Asians, were approached by the Chief Investigator. All these centres showed interest in this study. Yet, the decisions to pass on information to their clients and the permission to use their facilities for screening and appointment purposes were influenced by relationship, consistency, and trust. Trust in a "student" project and fear of it being harmful were the main challenges faced when approaching faith centres. This was expected as mistrust in research has been previously reported as barriers to South Asian participation (Hussain-Gambles et al., 2004). Many faith centre leaders showed hesitation and expressed worries about the safety of the study when they knew that it was a PhD project and the Chief Investigator was a "student". As such, to assure faith centre leaders, all details about the study were explained. These details included: the study sponsor; the process of obtaining ethical approval; as well as the names and roles of the three PhD supervisors; and the name of the diabetes consultant involved in the project. It was previously reported that South Asians prefer a senior physician or academic to be involved in recruitment (Symonds et al., 2012). The supervisors also contacted some faith centre leaders and attended a social activity at one of the faith centres to further build the relationship and maintain trust. The development of trust and personal relationships is a strategy that has been recommended when targeting ethnic minority groups (Yancey et al., 2006; Quay et al., 2017) .

It was difficult to identify female participants through faith centres as males and females tend to gather separately, particularly in mosques. To solve this challenge, the principal supervisor (a female) tried to contact female group leaders, but this was also difficult due to not answering phone calls. Building a trustful relationship with female group leaders at early stages of this project would have facilitated recruitment further. In addition, faith centres, particularly mosques, tended to have limited rooms availability and therefore it was difficult to provide flexible appointment times for screening and assessment in several occasions. Furthermore, since people from different ethnic backgrounds tend to attend faith centres, this approach resulted in a large number of ineligible participants contacting the Chief Investigator. For example, in the current study, 80 interested individuals were identified through faith centre, the majority of which were non-south Asians or did not have T2DM. This made the recruitment through faith centres times consuming.

The REACH community health project (REACH) was another recruitment route used in the current study. The manager of REACH was a co-investigator in this study, and therefore no difficulties arose from this approach, in terms of identifying potential participants and using REACH facilities for screening and appointments.

8.2.2 Attrition rate and missing values

Attrition is a major concern in clinical trials as it negatively affects internal validity and the trial's statistical power (Karlson and Rapoff, 2008). In the current study, the attrition rate at post intervention assessment (week=12) was 27%. This percentage is acceptable as many researchers tend to adopt a cut-off attrition score of less than 30% to define acceptable rates in RCTs (Lyles et al., 2007; Amico, 2009). In addition, this percentage is comparable with other web-based physical activity trials. For example, Vandelanotte et al., (2007a) reviewed web-based physical activity trials and reported an average attrition rates of 27%. However, the attrition rate was high at follow up (55%) (i.e. eight weeks after the completion of the intervention).

The high attrition rate at follow up highlights the importance of employing strategies to improve participants retention in future larger studies with post intervention follow ups. Previous studies reported several factors that deter participants from remaining in clinical trials (Cassidy et al., 2001; Zweben et al., 2009). These factors included inconvenient appointments, greater travel, and travel cost. In the current study, efforts were made to minimise the impacts of these factors by providing late evening and weekend appointments (Cassidy et al., 2001; Zweben et al., 2009). In addition, all assessments took place at venues located in areas with high concentrations of South Asian residence. However, it should be considered that in the current study there were two factors that minimised the ability to provide flexible appointments in a number of occasions. These factors were: having only one assessor and the limited room availability in faith centres. In addition, participants in the current study had no exercise intervention at follow up (i.e. between post intervention and the final assessment), thus no motivation to continue participating in the study (Zweben et al., 2009). Therefore, strategies such as having more than one assessor, seeking permissions to use additional assessment venues and the use of routine health records might be useful in future studies (Llewellyn-Bennett et al., 2016).

In the current study, blood samples were also not taken on a number of occasions, which resulted in a high number of missing data for HbA1c and blood lipids (up to 76% in the intervention group at follow-up). The main reasons for not obtaining blood samples were lack of verbal consent and inability to identify a suitable vein. As such, it might be useful for future to consider additional phlebotomy training and practice before the start of the study. The high attrition rate and missing data also made it difficult to compare groups at follow-up. Having follow up data, would help to draw a clear conclusion regarding the longer-term effect of exercise.

8.2.3 Safety

The results of the current study indicate that the implementation of web-based exercise intervention is safe in South Asians with T2DM. No serious adverse events were recorded that could be attributed to the intervention or the study protocol in both groups. Only one participant in the intervention group indicated mild muscle soreness that resolved within few days without seeking medical help. This finding support the results of another recent study in that web-based exercise interventions are safe in people with T2DM (Akinci et al., 2018). However, it should be noted that the current intervention was personalised and graduated in nature where the dose of exercise was gradually increased every two weeks based on the participants' ability. In addition, people with medical conditions that contraindicate exercise were excluded in the current study. The platform also contained advice sections to minimise the risk of exercise related adverse events including hypoglycaemia and hyperglycaemia. For example, participants on insulin therapy were advised to check their blood sugar levels before, during and after exercise to make sure their blood glucose levels were within acceptable ranges.

8.2.4 The platform usage and adherence

In this study platform usage was satisfactory. Approximately 76% of participants logged in the platform and reported at least one exercise session. This figure is comparable with previous work in the field of web-based health interventions (Morrison et al., 2016; Akinci et al., 2018). For example, Akinci et al., (2018) examine the effect of a web-based exercise intervention in the management of T2DM in Turkish and reported that 28% of participants had never visited the platform.

Similarly, the adherence rates in the current study were satisfactory. During the first 4 weeks of the intervention the percentage of adherent participants was the highest (57%), this percentage declined to 46% at week 5-8 and further to 31% during the last four weeks of the intervention (week 9-12). This pattern of adherence is comparable to other studies exploring the efficacy of exercise programmes delivered using the internet in people with long-term conditions (Vandelanotte et al., 2007b; Akinci et al., 2018; Paul et al., 2018). However, it should be noted that the definition of adherence varies among studies. For example, Akinci et al., (2018) examined the impact of a web-based exercise intervention in people with T2DM and reported that 52% of participants were non-adherent, defined as failed to complete three session for three consecutive weeks. Paul et al., (2018) examined the impact of web-based exercise intervention in people with multiple sclerosis and reported that 63% of participants completed 75% or more of their programme during the first four weeks which reduced to 40% during the last four weeks.

However, the accuracy of recording adherence over the internet is questionable. Self-reported exercise adherence diaries in general have limited validity and reliability (Nicolson et al., 2018). In the current study, for example, two participants stated that although they did the exercise as advised, they did not complete their online diaries as they perceived this as too time consuming, or they simply forgot and did the exercise without logging into the platform.

8.3 Experience of participants

8.3.1 Acceptability

Overall, participants who were interviewed at the end of the intervention were satisfied with the intervention. According to the literature perceived ease of use and perceived benefits are two main factors that influence acceptability of technological innovations in health care (Gücin and Berk, 2015). In the current study, participants perceived the intervention as helpful and the platform used to deliver the intervention as easy to use. Participants expressed that the intervention was accessible, fitted easily into their personal lifestyle, provided them with a trusted source of exercise that they should do, and had the potential to improve their glycaemic control, sleep quality, capability for work and mobility. Female participants in particular felt that the intervention helped them to overcome the cultural barriers to exercise related to the lack of gender-specific exercise facilities. Participants also liked the content and features of the platform used to deliver the intervention and described it as easy to use. Participants stated that they easily navigated the platform using various devices. The exercise videos were clear and easy to follow. The online exercise diary helped them to monitor their progress. However, to further improve ease of use, participants suggested improvement to the online exercise diary by allowing for editing to correct mistakes and ticking one box to record adherence rather than ticking many boxes.

Several strategies were used in the current study in an effort to enhance the acceptability. These include using a user-centred design approach to make the platform accessible and culturally relevant (see chapter 3), tailored exercise programmes, graduated exercise progressions approach, phone calls every two weeks. All these strategies were found important in previous research (Zubala et al., 2017). Despite this, a number of people dropped out of the study. However, as no interviews were conducted with people who dropped out we are unable to confirm if acceptability of the intervention was one of the factors affecting completion of the study. As such, interviews with people who had been lost to follow-up would have provided more in-depth to explore the reasons.

It was indicated that prior to experiencing an intervention, people can form judgements about the acceptability of the intervention based on information provided about the intervention (Sekhon et al., 2017). These judgments affect acceptability and engagement with the intervention (Sekhon et al., 2017). It was also found that despite evidence that technology-based interventions are effective, many people still prefer face to face interventions (March et al., 2018). As such, assessment of anticipated acceptability prior to participation should be performed to ensure engagement and acceptability.

8.3.2 Barriers

Participants in the current study acknowledged that the intervention helped them to overcome the most common reported exercise barriers among people from South Asian communities. Participants perceived the intervention as practical as it requires less time and fitted easily in their daily routine. Female participants in particular felt that the intervention helped them to overcome the cultural barriers to exercise related to the lack of gender-specific exercise facilities. Whereas, South Asian participants in previous research reported the lack of gender-specific exercise classes, the expensive gym memberships, and the lack of time as barriers to exercise (Johnson, 2000; Farooqi et al., 2000; Lawton et al., 2006; Horne and Tierney, 2012; Galdas et al., 2012; Ruth et al., 2012; Vahabi et al., 2012; Horne et al., 2013; Singhal and Siddhu, 2014; Koshoedo et al., 2015; Cross-Bardell et al., 2015; Lisa et al., 2015; Sohal et al., 2015; Rajaraman et al., 2015).

Participants who were interviewed at the end of the study reported few barriers to the exercise. The disturbance from family members was the most reported barrier in the current study. However, some participants were able to overcome this barrier by doing their exercise programme at work. This reflected the flexibility of the web-based exercise intervention. Tiredness/fatigue was another barrier reported by one participant in this study. Tiredness is a common barrier to exercise and self-management activities among people with diabetes as well as other chronic health conditions (Thomas et al., 2004; Egan et al., 2013). Tiredness/fatigue is a multifactorial problem in people with T2DM caused by physiological, psychological and lifestyle factors (Fritschi and Quinn, 2010). Despite this, people with T2DM who experience fatigue/tiredness should be encouraged to undertake some exercise as it is likely to improve with exercise (Juvet et al., 2017). Poor weather condition was reported as a barrier in the current study by one participant who preferred walking. In this study, walking was a prescribed exercise based on participants' preference and ability. As such, to overcome this barrier, future study should consider prescribing additional home-based exercises and advise participants to perform these exercises when the weather is not suitable for outdoor activities.

8.4 The likely effect of a 12-week web-based exercise intervention

The results of the current study indicate that implementation of a 12-week personalised web-based exercise intervention is associated with favourable outcomes.

8.4.1 The effect on glycaemic control

Glycaemic control is the main treatment aim in people with T2DM since poor glycaemic control is strongly associated with both macro and micro complications (Shah et al., 2015). The present study did not yield a clinical important improvement in glycaemic control. However, this finding does not necessarily mean exercise is ineffective. Several randomised controlled trials (RCTs) examining the impact of exercise interventions on glycaemic control in South Asians reported significant improvement in favour of exercise intervention as compared to usual care (Shenoy et al., 2010; Hameed et al., 2012; Subramanian and Venkatesan, 2012; Seshadri et al., 2012; Subramanian et al., 2014; Paul and Mary, 2014; Dixit et al., 2014b; Hariharasudhan and Varunkumar, 2015; Natesan et al., 2015; Subramanian et al., 2016; Bashyal et al., 2016). For example, Subramanian & Venkatesan (2012) conducted a RCT of 60 South Asian participants who were equally allocated to either exercise intervention or control groups and reported significant improvement in glycaemic control as measured by HbA1c by a mean of 0.75% in favour of the exercise group. Hameed et al (2012) conducted a RCT of 48 South Asians with T2DM and reported a significant reduction in HbA1c by 0.6% in favour the intervention group. However, these studies tended to exclude people with complications and therefore prescribed exercise interventions at a higher dose than the current study (Hammed et al., 2012; Subramanian & Venkatesan, 2012).

In the current study, the majority of participants had other complications (i.e. orthopaedic complications n=19 (58%); history of stroke n= 3 (6%); history of myocardial infarction n= 3 (6%). At baseline, the sample as a whole had reduced physical capacity as the mean value of Timed Up and Go test was 10.65s ± 2.5 which was higher than the average values for healthy South Asians of similar age (i.e. 8.46 ± 1.25 s) (Khant et al., 2018). Therefore, participants were not able to start the exercise intervention at the recommended doses of exercise. As a result, the intervention in the current study was personalised and graduated in nature where the dose of exercise was gradually increased every two weeks based on the participants' ability. This approach is recommended by exercise prescription guidelines for people with T2DM as starting with a high duration of exercise might be a challenge for many people with T2DM and may also cause injuries (Marwick, Matthew D. Hordern, et al., 2009; Colberg et al., 2010). Therefore, the lack of improvement in glycaemic control in the current study may have been due to an insufficient exercise dose, because of the graduated and personalised approach utilised in the current intervention.

Participants in the current study began the exercise programme with a very low exercise dose (e.g. five to ten minutes of aerobic exercise, together with one set of 12 repetitions of a resistance exercise). The duration in this study was planned to increase by five to ten minutes, together with an increase of one set of eight to ten repetitions, every two weeks. Following this graduated approach, seven participants reached the target duration of aerobic exercise (30 minutes) and the target volume of resistance exercise (3-4 sets of 8-10 repetitions) after six weeks. The remaining six weeks might have not been sufficient to produce a change in HbA1c levels as this test measures the glycaemic control over a period of 12 weeks. Therefore, it may be that interventions utilising a graduated approach require approximately more than six months to allow for a sufficient progression in exercise duration and positive changes in glycaemic control.

To date, only one RCT involving South Asians with T2DM utilised a graduate exercise approach (Shakil Ur Rehman et al., 2017). In this study, Shakil Ur Rehman et al (2017) examined the effect of a graduated aerobic exercise intervention in which the duration increased by 10 minutes every four weeks for six months (reaching 50 minutes per session) and reported a significant impact on glycaemic control compared to the control group.

Inability to achieve the recommended level of exercise duration was previously reported in studies that did not use personalised approach among people with diabetes, and this also led to a lack of improvement in HbA1c (Marios et al., 2012; Narendran et al., 2017). For example, in the RCT conducted by Marios et al. (2012), 39 participants were randomly allocated either to intervention or control groups. Both groups were asked to complete 180 minutes per week of moderate exercise for six months. Unlike the control group, participants in the intervention group were followed by weekly phone calls and were asked to record their heart rate using a monitor. At the end of the study, it was found that participants in the intervention group completed a mean weekly volume of 138 minutes of moderate intensity exercise, while the control completed 58 minutes per week, measured using exercise diary.

Neither group showed any significant improvement in HbA1c, and the authors attributed this to insufficient dose of exercise.

8.4.2 The effect of the intervention on blood lipids

Blood lipid variables (total cholesterol, LDL, HDL and triglycerides) are independently associated with cardiovascular disease which is the leading cause of death in people with T2DM (Wong et al., 2016). In the current study, the intervention group displayed changes in the direction of benefits in total cholesterol and triglyceride with moderate effect sizes, compared to the control group. The lack of statistical significance could be attributed to the small sample size, as this study was likely underpowered to produce significant results. However, there were no obvious trends in changes in either HDL and LDL.

To date, only three other known RCTs have investigated the impact of exercise intervention on blood lipid levels in people with T2DM from South Asian backgrounds (Arora et al., 2009; Hameed et al., 2012; Shakil-Ur-Rehman et al., 2017b). All these studies reported a significant improvement in at least one blood lipid variable. However, the improved variables were inconsistent among studies. For example, Arora et al. (2009) carried out an RCT of 30 participants found an improvement in total cholesterol after 16 weeks of resistance exercise, but no change in either triglyceride or HDL levels. Hameed et al. (2012) conducted an RCT of 48 participants and found an improvement in HDL after eight weeks of resistance exercise, but no changes in other lipid variables. Shakil Ur Rehman et al (2017) carried out an RCT of 102 participants and found significant improvements in both HDL and LDL after 25 weeks of aerobic exercise as compared to usual care; however, the study did not measure either triglyceride levels or total cholesterol. The discrepant findings among these studies and the current study could be attributed to two main factors. First, while evidence from studies involving mainly white Europeans indicated that blood lipids variables tend to improve most in studies incorporating exercise programmes of high intensity and long duration (i.e. = 12 months), all studies of South Asian participants used relatively short exercise programmes with moderate intensity (Zou et al., 2016). Second, none of these studies included abnormal blood lipids profile as an inclusion criterion. Therefore, the impact might have been influenced by floor/ceiling effects (Fries et al., 2011). Further studies with longer duration and larger sample sizes are required to further investigate the impact of exercise on blood lipids in people with T2DM from South Asian communities.

8.4.3 The effect on blood pressure

In the current study, both groups maintained their blood pressure and no significant difference between groups detected in either systolic or diastolic blood pressure after the intervention. This finding is inconsistent with other studies targeting South Asians with T2DM that found the exercise intervention led to significant improvements in systolic and diastolic blood pressure, compared to usual care alone (Sridhar et al., 2010; Subramanian et al., 2016). However, it should be noted that hypertension was not an inclusion criterion in this study and the mean blood pressure of all participants in this study was within the recommend levels for T2DM patients (<140/90 mmHg (Solini and Grossman, 2016). Whereas, both other studies, where an improvement in blood pressure after exercise was observed included mainly people with T2DM and hypertension (Sridhar et al., 2010; Subramanian et al., 2016).

8.4.4 The effect on anthropometry

In the current study, there was no change in body mass index (BMI) or waist circumference in the intervention group. Despite this, at an individual level, two participants improved their BMI and one participant mentioned that she had noticed a reduction in her body weight. This finding is consistent with other studies examining the impact of exercise interventions in South Asians with T2DM (Arora et al., 2009; Shenoy et al., 2010; Hameed et al., 2012; Seshadri et al., 2012; Dixit et al., 2014b; Natesan et al., 2015). None of these trials reported significant improvements in BMI after the exercise intervention as compared to a control group. WC improved in only one study, but this study did not monitor participants diet (Hameed et al., 2012). It has been suggested that the beneficial effects of exercise on weight and body fat are most apparent when combined with diet interventions involving calorific restriction (Marwick et al., 2009). As such, interventions aiming to improve body weight in people with T2DM from South Asian communities should add a dietary component.

Unexpectedly, there was a significant improvement in WC in the control group. The reason for this might have been driven by an undetectable decrease in total dietary intake in the control group as the sample size in the current study was small to detect significant change in dietary intake. In addition, the study did not monitor physical activity levels which have the potential to, although evidence shows that control group improvement in physical activity is not uncommon (Waters et al., 2012).

8.4.5 The effect on functional mobility

Deterioration in functional mobility is a common clinical problem related to T2DM that directly reduces people's capability in their activities of daily living (Wray et al., 2005; Yavuzer et al., 2006; Atienzar et al., 2012; da Cruz Anjos et al., 2015). The results of the current study showed a significant improvement in favour of the intervention group with a large effect size on functional mobility as measured using the 'Timed Up and Go' test (TUG). This finding is in line with other studies examining the impact of exercise interventions on functional mobility in people with T2DM from South Asian backgrounds (Arora et al., 2009; Majeed et al., 2013). However, different exercise programmes were used in these studies. Majeed et al., (2013) reported significant improvements in functional mobility following a 6-week functional training exercise programme, while Arora et al. (2009) demonstrated that 16 weeks of either aerobic or resistance exercise induced significant improvements in functional mobility compared to the control group.

In the current study, participants in the control group increased the time to complete the TUG test by a mean of 2.3s ± 2, indicating a deterioration. This decrease in functional mobility in the control group might be explained by the present of other comorbidities. In the current study the majority of people in the control group had at least one of the following comorbidities: osteoarthritis, gout, history of stroke. Three participants who greatly contributed to the overall decrease within the group had multiple comorbidities. This deterioration may also reflect the fact that people with T2DM are at great risk of rapid decline in functional mobility (Wray et al., 2005; Leenders et al., 2013). For example, Wray et al., (2005) analysed data from 8001 middle-aged and older adults and found that the self-report of diabetes diagnosis at baseline significantly predicted limitations in functional mobility two years later in both middle-aged and older adults. The results of the current study also highlight the importance of the recommendation by the International Diabetes Federation that T2DM management should consider functional status (Colagiuri et al., 2013).

Participants in the intervention group decreased the time taken to complete the TUG by a mean of 0.3s ±1.1, indicating improvement, with five participants (39%) exceeded the minimal detectable change for people with T2DM (i.e. 0.85s) (Alfonso-Rosa et al., 2014). The observed change in the TUG test was also supported by the qualitative findings as participants who were interviewed at the end of the study reported that the intervention improved their functional mobility.

Despite the positive impact on the TUG, there was no change in the Ten-Meter Walking test. The lack of consistency between the two functional mobility measures used in this study did not indicate a lack of impact, rather these two measures assess functional mobility based on different activities. The TUG assesses a number of functional activities used in everyday life including rising from a chair, walking for three meters, turning a 180 degree and sitting down on a chair. These activities correlate with muscle strength, balance and walking speed. Whereas, the Ten-Metre walking test measures gait speed over a short distance by asking participants to walk in a straight line for ten metre at their comfortable speed. The use of a long walking speed test such as the Six-Minute Walking Test may provide better indication about functional mobility (Dalgas et al., 2012). However, this test was considered infeasible in the current study as some assessment venues did not have a suitable corridor to conduct such a test.

8.4.6 The effect on muscle strength

Muscle weakness is a common health problem associated with T2DM which can lead to deterioration in functional mobility and, ultimately, disability (Wong et al., 2013). The current study found a trend toward a decrease in handgrip strength in the control group by a mean of 1.4 kg ± 2.4, while the intervention group remained stable. Although the difference between groups did not reach a statistically significant level, the effect size was moderate. As such, the lack of statistically significant impact is likely due to the small sample size. However, while handgrip strength is widely used to predict overall muscle strength, lower extremity strength was found to be better associated with functional mobility in comparison to handgrip strength (Harris-Love et al., 2018). In addition, a systematic review examining the impact of exercise interventions in T2DM management noted improvement in lower limb strength but not in handgrip (McGinley et al., 2015). As such, if the study had measured lower limb strength in addition to handgrip strength it may have provided more insight and a clearer conclusion.

To date, only two other known RCTs have investigated the impact of exercise interventions on muscle strength in people with T2DM from South Asian backgrounds (Shenoy et al., 2009; Hameed et al., 2012). Both studies demonstrated significant improvement in muscle strength with exercise interventions. However, neither studies evaluated the impact on handgrip strength. Rather, Shenoy et al., (2009) demonstrated significant improvement in lower muscle strength (i.e. quadriceps) following 16 weeks of resistance as measured using isotonic/isometric dynamometer software, while Hameed et al., (2012) demonstrated a significant improvement in lower and/or upper limb strength using one-repetition maximum.

8.4.7 The effect on quality of life

People with T2DM tend to report a low quality of life. This study showed that the 12-week web-based exercise intervention led to a significant impact on the physical health domain of the WHOQOL-BREF. No statistically significant impacts were observed on other subscales. It may be that the positive impact on the physical health subscale reflected the improvement observed in functional mobility in the current study. Interestingly, the results of this study were in line with another RCT where exercise interventions led to significant improvement in quality of life subscales mainly related to functional mobility (Myers et al., 2013). Myers et al., (2013) examined the impact of 9 months of exercise on the quality of life in 173 people with T2DM (mainly white Europeans) using the Short Form-36 Health Survey questionnaire. The authors found that compared to a control group, exercise intervention significantly improved 3 of the 8 subscales, i.e. “physical health”, “general health” and “physical function”.

Studies investigating the impact of exercise intervention on South Asians with T2DM also reported positive results (Arora et al., 2009; Shenoy et al., 2010; Paul and Mary, 2014; Guglani et al., 2014; Dixit et al., 2014b). However, direct comparison with these studies is difficult due to using different tools to measure quality of life. For example, Dixit et al (2014) examined the impact of 8 weeks of exercise in 87 South Asians with T2DM and diabetic neuropathy and found that exercise significantly improved all domains of neuropathy quality of life, as compared to a control group. Subramanian. et al., (2014) reported significant impact on the total score using the 14 items scale measuring quality of life after 12 weeks of resistance exercise.

8.4.8 Change in medication and diet

Medications and diet confound the effect of exercise, therefore, these variables were monitored during the study period (Colberg et al., 2010). In the current study there were no major change in either total dietary intake and medications in either group. Therefore, the observed differences in changes between groups might have been independent from the changes in total energy intake or medications. However, it should be noted that the study was underpowered to detect difference in total energy intake. In addition, the adherence to medications was not monitor in the current study.

8.4.9 The long-term impact of exercise

In the current study it was difficult to explore the likely effect of the intervention at follow up assessment (i.e. two months after the completion of the intervention). This was mainly due to the high attrition rates and missing values. Therefore, future studies should focus on motivational strategies to maintain participants' engagement. This would allow for collecting long term data in order to draw a clear conclusion regrading the long term-effect of exercise interventions.

8.4.10 Sedentary behaviour as a further area of investigation

Sedentary behaviour refers to any activity that is performed during waking and requires very low energy expenditure such television watching and desk work (i.e. less than 1.5 metabolic equivalents of task (METs)) (Colberg et al., 2016). Prolonged sedentary behaviour has been associated with negative health consequences such poor metabolic health and cardiovascular disease (Patterson et al., 2018). On the other hand, interrupting sedentary behaviour with physical activity was found to be beneficially associated with better postprandial glucose levels and blood lipids (Healy et al., 2008). As such, it was recently recommended that people with T2DM should engage in regular physical activity and should be sedentary as little as possible. People with T2DM are recommended to break sedentary behaviour every 30 minutes with short bouts of light intensity activities such as walking, torso twisting and leg lifts (American Diabetes Association, 2018). However, despite the importance of sedentary behaviour, the current study focused on structured exercise only. Therefore, future studies should also focus on lifestyle interventions that aim to decrease sedentary behaviour as well as to increase physical activity.

8.5 Strengths and limitations

This study has several strengths. First, this study is the first web-based exercise intervention study targeting South Asians living in western countries. It is also one of the few studies examining the impact of web-based structured exercise in people with T2DM (Taylor 2008; Akinci et al. 2018). Second, the study incorporated both qualitative and quantitative methods to explore the acceptability and the likely effect of the intervention. Third, the assessor in the current study was blind to the allocation groups. Fourth, changes in medications and diet were monitored during the study, therefore the difference in change between group could be attributed to the exercise intervention

Despite this, the current study had a number of limitations which need to be considered. The sample size was small and therefore, the study was likely underpowered to detect significant differences. The high attrition rates and the missing values were also problematic, perhaps leading to further negative impact on the power of the study. Furthermore, neither the participants nor the therapist was blinded to the group allocation however, it is difficult to blind participants and therapists in exercise interventions.

Physical activity was not measured as an outcome in this study. Physical activity levels have the potential to confound the effect of the intervention. Previous work also shows that physical activity improvements in control group participants in lifestyle interventions are common (Waters et al., 2012). Therefore, future study should include physical activity as an outcome.

In this study non-fasting blood samples were used to determine blood lipids. Using non-fasting blood samples in this study was mainly to minimizes the risk of hypo-glycaemia and to simplify the procedure by enabling samples to be drawn at any time of day (Langsted and Nordestgaard, 2019). Several guidelines and organizations recommend non-fasting blood samples for blood lipids (Nordestgaard et al., 2009; NICE, 2014; Nordestgaard et al., 2016; Catapano et al., 2016). However, precise triglyceride results may still require fasting blood samples. As such, the improvement noticed in blood lipids, particularly triglyceride, should be interpreted with caution.

The majority of participants in the current study were originally from Pakistan, although an effort was made to recruit participants with different South Asian backgrounds. As such generalising the findings to other South Asians is limited. However, this was expected as the majority of South Asians living in Glasgow are originally from Pakistan (Walsh, 2017).

The number of people who were interviewed at the end of the study was guided by the number of people who attended post intervention assessment. Consequently, only five participants were interviewed. Therefore, data saturation may have not been reached. A larger sample size would have provided a better opportunity to discuss the topic further. In addition, only the views of those who attended the post-intervention assessment were obtained therefore findings cannot be generalised to those participants who dropped out.

The interviews were conducted by the chief investigator who was well known to participants. Therefore, participants might have felt that they should comment positively. However, all participants were informed that negative comments would help to improve the future work. They were also assured that the outcomes of the interviews would not affect the progress of the chief investigator.

Member checking, or respondent validation, is a technique used to enhance trustworthiness of qualitative findings in which qualitative results are sent back to participants to check for accuracy (Burnard et al., 2008). In this study, findings were not sent back to participants due to time constrains for both participants and the chief investigator. However, to enhance trustworthiness the analysis was verified and discussed with a supervisor (RNJ). All supervisors also commented on the final emerged themes.

8.6 Conclusion

This study indicates that a 12-week web-based exercise intervention was acceptable, feasible and has the potential for effectiveness in people with T2DM of South Asian descent. No adverse events were reported from this study. Seventy-six percent of participants used the platform and accessed the intervention. The adherence to the intervention was satisfactory (ranged from 57% during the first four weeks to 31% in the last four week). Participants identified the intervention as helpful primarily because it was convenient, practical, accessible, and had the potential to improve their health and wellbeing. Female participants felt that the intervention helped them to overcome the cultural barriers to exercise related to the lack of gender-specific exercise facilities. Participants liked the content and features of the platform and described it as easy to use. To further improve the ease of use, participants suggested adding further exercise videos with longer duration and allowing them to edit the exercise diary. Being disturbed by family members, while doing the exercise at home was the most reported barrier to this intervention. Participants in the intervention group demonstrated better outcomes with moderate to large effect sizes in the following outcomes total cholesterol, triglyceride, functional mobility, handgrip strength and the physical health sub-domain of the quality of life. Further studies with larger sample size are required to strength the findings. However, future studies should consider further strategies to improve the efficacy of recruitment strategies as well as to minimise the high attrition rates and missing data particularly at long-term follow up.

Chapter 9 – General discussion, conclusion and recommendations

9.1 Main studies summaries

The aims of this thesis were to explore the current literature about the impact of exercise interventions on South Asians with T2DM, to make an existing web-based exercise platform accessible and culturally relevant for people from South Asian communities and to examine the feasibility, acceptability and the likely effect of a 12-week, web-based exercise programme on several risk factors related to T2DM and its complication in South Asians with T2DM. These aims were formulated after an extensive literature review to address important gaps in the literature.

To meet the aims of this thesis, three studies were conducted. The first study in this thesis was a systematic review of 18 controlled clinical trials exploring the effect of exercise interventions in South Asians with T2DM. The outcome of the systematic review showed that all types of exercise were associated with improvement in at least one factor related to T2DM management in South Asians, which included glycaemic control, blood pressure, blood lipids, muscle strength, neuropathy progression, functional mobility and the quality of life. However, the evidence in this systematic review emerged from studies of poor methodological quality. In addition, due to the lack of studies comparing different exercise dose variables, it was difficult to determine the best exercise prescription for South Asians with T2DM. Therefore, this review highlighted that future studies of good methodological quality are required to further investigate the impact of different exercise dosage variables on T2DM management in South Asians and their long-term effect.

The second and third studies in this thesis focused on using technology as an alternative mode of exercise delivery to help South Asians with T2DM to overcome exercise barriers, such as lack of gender-specific classes and family commitment. The second study was conducted to modify an existing web-based exercise platform to be accessible and culturally relevant for people from South Asian communities. This study adopted a user-centred design approach in which two exploratory and two confirmatory focus groups were conducted. These focus groups enabled an understanding of South Asians' perceptions regarding using technology as a delivery method and highlighted what they found appropriate in a web-based exercise platform. Based on participants views the platform was modified to meet the views and the need of people from South Asian communities. Although this study focused on a specific platform, the findings included general views that can be beneficial for other researchers and clinicians.

The final study in this PhD thesis was a pilot RCT embedded with interviews to examine the feasibility, the acceptability and the likely effect of a 12-week, web-based exercise on glycaemic control, blood lipids profile, blood pressure, obesity, functional mobility, muscle strength and the quality of life of South Asians with T2DM. The findings of this study showed that a 12-week, web-based exercise intervention is acceptable and feasible for people of South Asian descent with T2DM and has the potential for effectiveness. However, further a powered randomised controlled study is required to confirm and expand the findings. Strategies to minimise attrition rates particularly after the end of the intervention (post intervention follow up) will be also needed.

9.2 Contribution to knowledge

Overall, the findings of this study expand on the available evidence in the understudied area of exercise interventions targeting ethnic minorities living in western countries. Each study in this PhD address important gaps in the literature. The systematic review presented in chapter three was most significant in that it was the first to assess the available literature for the efficacy of exercise in the management of T2DM in South Asians. This systematic review has been already published (Albalawi et al., 2017). The user-centred design study reported in chapter four was the first to involve people from South Asian communities to co-design a culturally relevant technology-based exercise platform. The findings of this study expand on the available evidence in the understudied area of using technology to deliver exercise interventions targeting ethnic minorities living in western countries. The pilot controlled, randomised study was the first to explore the acceptability and the likely effect of a web-based exercise intervention in South Asians with T2DM.

9.3 Cultural competence

The complexities of carrying out research with ethnic minority groups are well known (Douglas et al., 2011; Quay et al., 2017). Few researchers have shared their practical experience (Douglas et al., 2011). As such, one of the most important areas to learn from this project is regarding the strategies used to enhance South Asians' participation in this project. Lack of English language proficiency is a commonly cited barrier to South Asians' engagement in health research as well as access to healthcare (Jolly et al., 2005). For example, Jolly *et al.* (2005) observed that compared to other ethnic groups, a significant proportion of South Asians were excluded on the basis of language. To overcome language-related problems, previous work tends to provide linguistically matched staff, use interpreters and/or use native-language written materials (Conn et al., 2013). However, in this PhD project, it was impossible to provide interpreters or materials with all South Asian languages as South Asians speak many different languages. To minimise the impact of language, two strategies were used. First, at the early stage of this project, an interpreter from the REACH community health project, who was fluent in English and two main South Asian languages (i.e. Urdu and Punjabi), agreed to support those who had limited English throughout the project. Second, when the first study in this project started (see chapter five), participants were asked about their preferred language, and all participants agreed that Urdu was the most common. Consequently, the project materials were translated to this language, as well as being available in English as appropriate.

Lack of consideration to the target population's religions and sociocultural norms is a common barrier to South Asian participation (Hussain-Gambles et al., 2004). Throughout the project, careful considerations were given to different aspects of South Asians' religious beliefs and sociocultural norms. For example, all research activities involving participants, such as recruitment, screening and data collection were carried out at suitable times that did not conflict with their religious festivities such as Eid or Christmas. Research-related activities were also timed to occur before or after the holy month of Ramadan to avoid any inconvenience as the majority of Muslim South Asians tend to fast from dawn to sunset during the entire month.

The project also showed respect to sociocultural norms such as gender segregation and preference to same-gender researchers. Lack of gender-specific facilities was mentioned as a barrier to exercise (Johnson, 2000; Farooqi et al., 2000; Lawton et al., 2006; Horne and Tierney, 2012; Galdas et al., 2012; Ruth et al., 2012; Vahabi et al., 2012; Horne et al., 2013; Singhal and Siddhu, 2014; Koshoedo et al., 2015; Cross-Bardell et al., 2015; Lisa et al., 2015; Sohal et al., 2015; Rajaraman et al., 2015). Male and female South Asians tend to gather separately and prefer same-gender healthcare providers. As such, careful consideration was given to these aspects throughout this PhD project. For example, in research activities involving direct contact with participants (e.g. blood sampling), female and male research staff were available as appropriate. Similarly, when research activities required meeting with a group of participants (e.g. focus groups), male and female groups met separately, and the meetings were led by a gender-specific coordinator.

Lack of trust in research has also been reported as a barrier to South Asian participation (Quay et al., 2017). To overcome mistrust-related problems this PhD project collaborated with researchers with a South Asian background as well as with organisations providing health services to ethnic minority groups. These strategies were believed to enhance trust and facilitate positive social interaction (Kreuter and McClure, 2004). In terms of collaboration with organisations, a collaboration with the REACH community health project was sought at the early stage of this project. REACH is a third-sector organisation in Glasgow aiming to provide culturally sensitive healthcare for people from ethnic minorities. The collaboration involved using REACH facilities and resources. This collaboration established trust between the research team and participants and consequently facilitated recruitment.

In terms of collaboration with other researchers, this project also involved two researchers with a South Asian background. The first researcher was a consultant in diabetes and acted as a fourth supervisor. The second researcher was the manager of the REACH community health project. Although the role of these two researchers did not involve day-to-day support or contact with participants, they provided comments on the research proposals reflecting their experience in the field. The two researchers also facilitated initial contact with South Asian communities living in Glasgow on several occasions.

The potential costs associated with participation in research was also reported as a barrier to South Asian participation (Quay et al., 2017). Several strategies were employed to minimise the associated cost. First, the studies were conducted in specific locations with high concentrations of South Asian residence. This was mainly to minimise travel and other expenses that might occur. As such, this project sought permission to use several locations for data collection. These locations included local faith centres attended mainly by South Asians, the REACH community health project and the University of Glasgow. In this project, participants were paid £20 for every visit to compensate any expenses that might occur. In addition, participants could bring their children.

9.4 Recommendation for clinicians

- Exercise appears to be beneficial for South Asians with T2DM.

- Web-based exercise appears to be a safe, and acceptable method to facilitate the engagement of South Asians with T2DM in exercise intervention.

- When designing a web-based exercise intervention for people from South Asian communities the suitability of the language and the content of the intervention should be considered.

- Adding a dietary component to exercise interventions may enhance weight loss and promote greater reductions in body mass index and waist circumference.

9.5 Recommendation for future research

- Further studies with robust methodology are required to compare the effect of different exercise dose variables in the management of T2DM in South Asians.

- In keeping with stage three and four of the MRC framework, further powered studies with larger sample sizes are required to determine the effectiveness and cost effect of a web-based exercise intervention in South Asians with T2DM.

- User-centred design approach might be a useful method to customise existing technology-based exercise interventions to meet the need of people from ethnic minority groups.

- Future studies should establish the validity and reliability of functional mobility tests for use in people with T2DM. The minimal clinically important change should also be established for these measures in order to facilitate the interpretation of the results.

- Using faith centres for research appointments is a feasible strategy to enhance South Asian participation. However, some faith centres have limited room availability and therefore it may be difficult to provide flexible appointment times for assessment. In addition, this may negatively affect the choice of the outcome measures.

- It might be important to have several assessors in clinical trials targeting South Asians. This allows to provide flexible appointment, thus more recruitment rates and less attrition rates.

- Researchers aiming to recruit South Asians should use less restrictive inclusion/exclusion criteria in future studies to improve the recruitment.

- Strategies to minimise attrition rates particularly after the end of the intervention (post intervention follow up) will be also needed.

9.6 Conclusion

This thesis has provided preliminary data that exercise interventions are beneficial for South Asians with T2DM. Web-based exercise might be an acceptable and feasible approach to facilitate the engagement of South Asians with T2DM in exercise intervention. Web-based exercise interventions hold promising results for improving the health of this population. However, this thesis should be viewed as the groundwork to be built upon, and further research is required to strengthen, expand and confirm the findings.

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Appendices

Appendix 1 Consent form (A user-centred design)

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

Participant four-letter code for this study:

STUDY CONSENT FORM

Title of Project: **Is web-based physiotherapy culturally relevant and acceptable for the South Asian population?**

Name of Researchers:
Mr Hani Albalawi, Dr Elaine Coulter, Mr Shabir Banday, Dr Lorna Paul

Please initial boxes

1. I confirm that I have read and understand the participant information sheet (version 1, 29.03.2017) for the above study and have had the opportunity to ask questions. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason. ☐
3. I understand that I am participating in a controlled gender-specific focus group. ☐
4. I understand that the focus group discussions will be audio-recorded and transcribed. ☐
5. I agree to take part in the above study. ☐

Name of Participant	Date	Signature
Researcher	Date	Signature

*1 copy for participant; 1 copy for researcher.

Consent Form V1
03.03.2016

Appendix 2: Participants information sheet (user-centred study)

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

Participant Information Sheet

For the study entitled:

Is web-based physiotherapy culturally relevant and acceptable for the South Asian population?

We would like to invite you to participate in a research study. Before you decide whether or not to take part it is important for you to understand why the research is being undertaken and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information.

What is the aim of the study?

Being physically active is important for our physical and mental health. However many find it difficult to be physically active or exercise in the community. Our research group developed a website, www.webbasedphysio.com, to help people to exercise in their home. However this website may not be suitable for people from different ethnic groups. The aim of this study is make the web-based physio website suitable for south Asian people. We hope that you are able to share your opinions about exercise, using the internet, and our website.

Why have I been invited?

You have been invited to take part in this study because you are of south Asian ethnicity. We believe that only people of south Asian ethnicity will be able to help us make our website appropriate and acceptable for people of south Asian descent.

Do I have to take part?

Taking part in research is entirely voluntary; therefore it is up to you to decide. You should read this information leaflet and if you are interested in taking part you should phone the research team using the contact details at the end of this information leaflet.

What will happen to me if I want to take part?

If you decide to take part, we will contact you to arrange for you to participate in either a **male only** focus group or a **female only** focus group. The focus group will include 6-10 people who talk about their views and opinions on a particular topic. If you do not speak English, a translator who is fluent in Urdu, Punjabi and English will be present. The translator will ensure that everyone will be able to understand each other. The focus group will be informal and it is anticipated that it will last no longer than one hour.

What if there is a problem?
It is not likely that this study will cause concern or harm. However, if you have any concerns about any aspect of this study, you should speak to a member of the research team.

What will happen to the results of the research study?
It is intended that the results of the study will be published and written up as part of a PhD thesis. All data will be anonymised before this. Should you wish to know the results of the study then we will send you a summary of the main findings once the research is complete.

Who has reviewed this study?
The study has been reviewed and given a favourable opinion by the University of Glasgow, College of Medicine, Veterinary and Life Science Research Ethics Committee.

Contact details
If you are interested in participating, please contact:
Nargis Afzal
REACH Community Health Project
Govanhill Neighbourhood Centre
6 - 8 Daisy Street
Glasgow
0141 423 7095

If you have questions or concerns about the study, please contact:

Hani Albalawi (male)
PhD student
University of Glasgow
0141 330 6813
H.albalawi.1@research.gla.ac.uk

or

Dr Elaine Coulter (female)
Research Associate
University of Glasgow
0141 330 3249
Elaine.Coulter@glasgow.ac.uk

Thank you for taking the time to consider this study

Appendix 3: Topic guide (user-centred design study)

A. Questions Regarding Exercise

- **Do you take part in any form of exercise or physical activity? Why/ why not?**
- **What type of exercise do you like the most? What type of exercises do you not like? Why?**
- **What are the things that prevent you or your relatives from exercising?**
- **What are the things that motivate you or your relatives to exercise on a regular basis?**

B. Questions Regarding the General Opinion about the Use of the Internet as a Source for Medical Information

- **Have you ever used the Internet to get information about a disease, medication, treatment or exercise?**
- **If yes, can you describe this experience?**
- **If no, is there any reason that prevents you from doing so? where do you get your information from?**

C. Questions Regarding Current Web-based Physiotherapy

- **What is your general impression about this website?**
- **Do you think this website would help you to exercise if your health care provider has advised you to exercise** (Why/why not? Any suggestions for improvement?)
- **What is your impression about the language used? Colours? and videos?**

What language do you think is more understood?

- **Whom would you like to demonstrate and explain the exercise to you and what characteristics should he/she have?** (Why?)
- **What background would you like when performing exercises?** (Why?)
- **What features do you think should be added to the web?** (Why?)

- **Confirmatory focus groups: Questions Regarding the Modified Web-based Physiotherapy**

- **What is your impression about the modifications made in the following parts?** (Why/why not?)
- **What are the things that you would like improved more? Why?**
- **What other features would like to add to this website? (what/ why, why not)**
- **Are there any other topics you would like to discuss regarding this website?**

Appendix 4 Last study- A Participants information sheet Urdu

شرکت کرنے والے کی معلوماتی شیٹ

مطالعہ کے حقدارکیلئے :

ٹائپ 2 ذیابیطس کے شکار جنوبی ایشیائی باشندوں کے لئے ویب پر مبنی ورزش کے پروگرام

ہم ایک تحقیقی مطالعے میں حصہ لینے کے لئے آپ کو مدعو کرتے ہیں. اس سے پہلے کے آپ یہ فیصلہ کریں کہ اس مطالعے میں حصہ لینا چاہیے یا نہیں،یہ جاننا ضروری ہے کہ یہ ریسرچ کیوں کیا جا رہا ہے اور اس میں اور کیا کیا ہوگا. مندرجہ ذیل معلومات کو احتیاط سے پڑھیں اور اگر آپ چاہیں تو کسی اور سے مشورہ سکتے ہیں مزید یہ کہ اگر آپ کو سمجھ نہ اے تو معلومات کیلئے ہم سے پوچھ سکتے ہیں .

تحقیق کا مقصد کیا ہے؟

ٹائپ 2 ذیابیطس جو جنوب ایشیائی ممالک (پاکستان، بھارت، نیپال، بنگلہ دیش اور سری لنکا) سے تعلق رکھنے والے لوگوں میں عام ہے. تحقیق سے پتہ چلتا ہے کہ ورزش ٹائپ 2 ذیابیطس کے لوگوں کے لئے ضروری ہے.یہ صحت کو بہتر بنانے اور ذیابیطس مرض کے خطرے کو کم سے کم کرنے میں مدد دیتی ہے اور ذیابیطس مرض سے متعلق آنکھیں، دل، گردوں، اعصاب اور پیروں پر اثر انداز ہونے والی پیچیدگیوں میں بھی مدد دیتی ہے. تاہم، بہت سے لوگوں کو یہ مشکل لگتا ہے کیونکہ وقت کی کمی کی وجہ، کام، بچوں کی نگہداشت کی ذمہ داریاں یا مخصوص صنفی ورزش کے کلاسوں کی کمی انکے ورزش میں رکاوٹ بنتی ہے.

ہماری تحقیقی گروپ نے ایک ویب سائٹ تیار کی ہےجو لوگوں کو کہیں بھی اور کسی بھی وقت ورزش کرنے میں مدد دیگی. یہ ویب سائٹ جنوب ایشیائی باشندوں کی ثقافت کو مد نظر رکھ کر بنایی گئی ہے. اب ہم ٹائپ 2 ذیابیطس کے شکار جنوبی ایشیائی باشندوں کے لئے اس ویب سائٹ کا استعمال کرتے ہوئے ایک 12 ہفتے ورزش کے پروگرام کے فائدے بتاینگے.

www.webbasedphysio.com

مجھے کیوں مدعو کیا گیا ہے؟

ہم جنوبی ایشیاکے لوگ 25-65 سال کے درمیان عمر رکھنے والوں کو مدعو کرنا چاہتے ہیں جن کو 6 ماہ سے زیادہ ٹائپ 2 ذیابیطس ہو اور جنکی انٹرنیٹ تک رسائی حاصل ہو اور اس تحقیق میں حصہ لینے کیلئے انگریزی یا اردو زبان میں بات چیت کر سکتے ہوں.

آپ اس میں حصہ لینے کے اہل نہیں ہو سکتے اگر آپکو ڈاکٹر نے صرف نگرانی میں ورزش کرنے کو کہا ہے یا آپکو کسی طبّی وجہ سے ورزش کرنے سے منا کیا گیا ہے یا آپ بہت زیادہ موٹے ہیں .ہم 40 لوگوں کو بھرتی کرنے کا ارادہ رکھتے ہیں.

کیا مجھے حصہ لینا چاہیے ؟

نہیں ۔اس تحقیق میں حصہ لینا مکمل طور پر رضاکارانہ ہے. اسلئے یہ فیصلہ آپ پر منحصر ہے. آپ کو یہ معلوماتی لیفلیٹ پڑھنا چاہیے اور اگر آپ حصہ لینے میں دلچسپی رکھتے ہیں تو اس معلوماتی لیفلیٹ کے آخر میں رابطے کی تفصیلات پر تحقیقی ٹیم کو فون کریں.

اگر میں حصہ لوں تو کیا ہوگا ؟

مطالعہ کے آغاز سے پہلے آپکو ایک وقت اور مقام جو آپ کے لئے آسان ہو، محقق سے ملنے کیلئےمدعو کیا جاےگا. ملاقات کے دوران آپ کو کوئی بھی سوال کرنے کا موقع دیا جاےگا. آپ حصہ لینے کے اہل ہیں یا نہیں یہ معلوم کرنے کیلئے محقق آپ کے موجودہ اور ماضی کی طبی تاریخ کے بارے میں پوچھے گا اور آپ کا وزن اور

اونچائی کی پیمائش کرے گا۔ اگر آپ انگریزی نہیں بول سکتے، تو ہم انگریزی اور اردو کے مترجم کا بندوبست کرینگے ۔ اگر آپ اہل ہیں اور حصہ لینے میں دلچسپی رکھتے ہیں، تو ہم یا تو انگریزی یا اردو میں ایک منظوری فارم پرآپ سے دستخط لینگے۔ محققین آپکے جی پی سے رابطہ کر کے انھیں آپکی شرکت سے آگاہ کرینگے۔

اس کے بعد ہم آپ کو تشخیص دورے کے لئے کسی مناسب مقام پر شرکت کرنے کی دعوت دینگے (ٹیبل ملاحظہ کریں).اس تشخیص میں خون کے ٹیسٹ، سوالنامہ بھرنا اور کچھ جسمانی ٹیسٹ بھی شامل ہوں گے۔ جیسے ہی خون کا ٹیسٹ فراہم کرینگے اور آپ کو سوالنامہ بھرنے اور مختصر جسمانی ٹیسٹ انجام دینے کے لئے کہا جائے گا۔ سوالنامہ میں اپکے صنف، عمر، تعلیم کی سطح، پیدائش کا ملک، اصل ملک، زبانے جو آپ بول سکتے ہوں ، طبی تاریخ، ادویات جوآپ استعمال کرتے ہیں اور غذائی عادات کے بارے میں پوچھا جائے گا.جسمانی ٹیسٹ میں آپ کے قد، وزن، کمر فریم، بلڈ پریشر، پٹھوں کی طاقت اور ایک مختصر فاصلے کے دوران اپنے معمول کے چلنے کی رفتار اور ایک کرسی موقف ٹیسٹ بھی شامل ہوں گے.

اس دورے کے اختتام پر آپ کو تصادفی طور پر انٹروینشن گروپ یا کنٹرول گروپ میں شامل کیا جائے گا. تشخیص تقرری(appointments) کو مکمّل ہونے میں تقریباً 90 منٹس لگیں گے۔ آپ کو 12 ہفتے اور 20 ہفتے بعد پھر پیمایش کیلئے بلایا جاےگا تاکہ یہ دیکھ سکے کہ تحقیق کے آغاز میں جو پیمایش لی گی تھی اس میں کوئی تبدیلی تو نہیں آی .

اگر میں کنٹرول گروپ میں ہوں تو کیا ہوگا ؟

اگرآپکو تصادفی طور پر کنٹرول گروپ میں شامل کر دیا جاتا ہے تو، آپکو اپنے معمول ادویات اور طرز زندگی کو جاری رکھنے کے لئے کہا جائے گا.آپکو انگریزی یا اردو(آپ کی ترجیح کے مطابق) میں ایک معلوماتی لیفلیٹ دیا جاےگا۔ اگر آپ مشق کے لئے ویب سائٹ استعمال کرنا چاہتے ہیں تو، ہم آپ کے تشخیص پر مبنی ذاتی مشق پروگرام تیار کریں گے اور آپ کو مطالعہ کے اختتام تک رسائی فراہم کریں گے.

اگر میں انٹروینشن گروپ میں ہوں تو کیا ہوگا ؟

اگرآپکو تصادفی طور پر انٹروینشن گروپ میں شامل کر دیا جاتا ہے تو آپ کو ایک ذاتی ورزش کے پروگرام کیلئے کہا جاےگا جو 12 ہفتوں پر مشتمل ہوگا آپکو فی ہفتہ میں تین بار ایسا کرنے کے لئے کہا جائے گا۔ ہر ورزشی اجلاس (session) 45 منٹ کا ہوگا.آپ محقق (ہانی) سے مختصر جسمانی تشخیص کیلئے ملیں گے تاکہ ورزشی پروگرام کی مشکلات کا پتا لگا سکیں اور ورزشی اہداف پر تبادلہ خیال کر سکیں . یہ پروگرام آپ کے مقاصد، ضروریات اور جسمانی صلاحیت کی بنیاد پر آپ کے لئے ڈیزائن کیا گیا ہے۔ آپ کو آپ کی ورزش کے پروگرام کو مکمل کرنے کی ویب سائٹ کے لئے منفرد لاگ ان کی تفصیلات دی جائے گی.

ویب سائٹ ایک ہوم پیج ،آپکے شخصی ورزش پیجزاور ایک مشق ڈائری اور ایک مشورہ / معلومات کے حصے پر مشتمل ہوگا .اس ویب سائٹ کا ہر ورزش پیج جن چیزوں پر مشتمل ہوتا ہے وہ ہیں ، ورزش کا مظاہرہ، ٹائمر،ٹیکسٹ اور آڈیو ورزش کی وضاحت. ٹیکسٹ اور آڈیو ورزش بیان آپ کی ترجیح کے مطابق انگریزی یا اردو میں ہو سکتا ہے۔ محقق ہر دو ہفتے بعد آپ سے فون پے رابطہ کریگا یہ جاننے کیلئے کہ آپ کیسے جا رہے ہیں اور ہر 6 ہفتے بعد محقق آپ سے براہراست ملےگا تاکہ آپکے مقاصد اور پیشرفت کا جایزہ لیا جا سکے .

جو انٹروینشن گروپ میں شمولیت رکھتے ہیں انھیں براہراست انٹرویو کیلئے مدعو کیا جا سکتا ہے . ہم انٹروینشن گروپ کے 6-10 شرکاء کو انکی راے جاننے کیلئے مدعو کریں گے۔ اگر آپ انگریزی نہیں بول سکتے تو ہم ایک مترجم کا بندوبست کر سکتے ہیں۔ تمام انٹرویوز ایک ہی وقت ایک ہی ملاقات میں منعقد کیے جاینگے اور آڈیو ریکارڈ اور تحریری ریکارڈ کیے جاینگے تاکہ ہمارے پاس ریکارڈ موجود ہو . تاہم، آپ کا نام درج نہیں کیا جائے گا۔ انٹرویو تقریباً 20 منٹ کا ہو گا.

کیا اس تحقیق میں میرا حصہ لینا خفیہ رکھا جائے گا؟

جی ہاں، مطالعہ کے دوران آپ سے جمع تمام معلومات انتہائی خفیہ رکھا جائے گا، تمام ناموں کو مطالعہ نمبر سے تبدیل کر دیا جاےگا اور تمام آڈیو ریکارڈنگ کو حذف کر دیا جاےگا . مطالعہ sponsor کے نمائندے،

NHS GREATER GLASGOW AND CLYDE آپکے مطالعہ معلومات کا جایزہ لینگے یہ یقینی بنانے کیلئے کہ تمام مطالعہ صحیح فراہم کیا گیا ہے .

حصہ لینے کے ممکنہ فوائد کیا ہیں؟

امید ہے یہ معلوماتی پروگرام آپکی صحت کو بہتر بنانے میں مدد کریگا آپ کے خون میں شوگر کنٹرول، پٹھوں کی طاقت، فعال نقل و حرکت اور زندگی کے معیار کو بہتر بنانے میں مدد کرے گا. تاہم، اس بات کی ضمانت نہیں دی جا سکتی. اس کے علاوہ، انٹروینشن ، رکاوٹیں اور سہولیات فراہم کرنے کے بارے میں آپ کی رائے مستقبل میں دوسرے لوگوں کو ورزش کرنے کے لئے انٹروینشن کو بہتر بنانے میں ہماری مدد کریگی .

حصہ لینے کے ممکنہ نقصانات یا خطرات کیا ہیں؟

ورزش، چوٹ یا پٹھوں میں درد کا باعس بن سکتا ہے، تاہم ہم پوری کوشش کرینگے کہ آپ کی مشق آہستہ آہستہ شروع کرینگے اور پھر اسکو بڑھایینگے . ٹائپ 2 ذیابیطس کے لوگوں میں، ورزش بلڈ شوگر (ہائپو گلیسیمیا) میں کمی کا باعس بن سکتا ہے. تاہم، جو انسولین استعمال نہیں کرتے ان لوگوں میں یہ کم ہوتا ہے اور ہم بلڈ شوگر کی سطح کو کم کرنے کے علاج کے لئے مشورہ فراہم کرینگے.

کیا اس مطالعہ میں حصہ لینے کے اخراجات یا ادائیگیاں ہونگی ؟

تعین کے دوران ناشتہ فراہم کیا جائے گاہر تشخیص یا انٹرویو میں شرکت کے £20 آپکے سفر اور دوسرے اخراجات کیلئے دیے جاینگے .

اگر میں مطالعہ سے دستبردار ہونا چاہوں تو کیا ہوگا؟

اگر آپ حصہ لینے کا فیصلہ کرتے ہیں تو آپ کبھی بھی کسی بھی وقت بغیر وجہ بتائے اپنا فیصلہ واپس لے سکتے ہیں . آپ کے فیصلے سے قبل جمع ہر اعداد و شمار کو پھر بھی استعمال کیا جائے گا

اگر کوئی مسئلہ ہو تو ؟

اس بات کا کوئی امکان نہیں ہے کہ یہ تحقیق کسی تشویش یا نقصان کا سبب بنے. تاہم، اگر آپ کو اس تحقیق کے کسی بھی پہلو کے بارے میں کوئی خدشات ہیں تو، آپ کو تحقیقی ٹیم کے کسی رکن سے بات کرنی چاہئے اور اگر آپ کسی غیر جانبدار سے بات کرنا چاہتے ہیں تو EVAN CAMPBELL سے رابطہ کر سکتے ہیں

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معمول این ایچ ایس(NHS) شکایات کا طریقہ کار بھی آپ کو دستیاب ہو جائے گا

تحقیقی مطالعے کے نتائج کے ساتھ کیا کیا جاۓگا؟

ارادہ یہ ہے کہ اس تحقیق کے نتائج کو شائع کیا جاۓگا اور ایک پی ایچ ڈی مقالہ کے حصہ کے طور پر لکھا جائے گا .تاہم ایسی کوئی معلومات نہیں دی جاۓگی جس سے آپکی شناخت ہو. آپکی ذاتی معلومات، آڈیو ریکارڈنگ اور خون کے نمونوں کو تحقیق پورا ہونے سے پہلے ہی حذف کر دیا جاۓگا،صرف گمنام معلومات University of Glasgow میں محفوظ کی جاینگیں. اگرآپ تحقیق کے نتائج جاننا چاہتے ہیں تو ہم تحقیق مکمل ہونے کے بعد بنیادی نتائج کا خلاصہ آپکو بھیج دیں گے .

اس تحقیق کا جائزہ کار کون ہے ؟

مطالعہ کی منظوری اور جائزہ ویسٹ آف اسکاٹ لینڈ ریسرچ ایتھکس کمیٹی نے لیا ہے .

اگر آپ حصہ لینے میں دلچسپی رکھتے ہیں یا مطالعہ کے بارے میں سوال ہو تو، برائے مہربانی رابطہ کریں:

Hani Albalawi (male)

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ٹیبل 1. تجویز کی گی جگہیں ملاقات اور تشخیص کے لئے

ٹیبل 1. تجویز کی گی جگہیں ملاقات اور تشخیص کے لئے

Venue	Address
University of Glasgow	Wolfson Skills Lab, Wolfson Building, University of Glasgow, G12 8ll
MAB Scotland Centre (Mosque)	10 Grovepark Place Glasgow, United Kingdom, G20 7NG
Al-farouq education and community centre	32-38 Dixion ave, Glasgow, G42 8EJ
Glasgow central mosque	1 Mosque Ave, Glasgow G5 9TA
Baitur Rahman mosque	8 Haugh Rd, Glasgow G3 8TR
Gurdwara Singh Sabha	138 Berkeley St, Glasgow G3 7HY
Alfurgan mosque	19 Carrington St, Glasgow G4 9AJ
'REACH Community Health Project'	6 Daisy St, Glasgow G42 8JL
Tamil Church Glasgow - EMMANUEL CHRISTIAN MINISTRIES	348 Cathedral St, Glasgow G1 2BX
Masjid Madressa Al Arabia Al Islamia (mosque)	425 Paisley Rd W, Glasgow G51 1PZ
Bearsden Muslim association community,	Speirs Rd, Bearsden, Glasgow G61 2LX
Bishopbriggs Mosque and Community Centre	, 160a Auchinairn Rd, Bishopbriggs, Glasgow G64 1NQ
Masjid-E-Khazra (mosque)	G42 7AF
Glasgow Gurdwara	37 Albert Dr, Glasgow G41 2PE
Masjid Noor (mosque),	Pollokshield, Glasgow G41 2TA

اس تحقیق کے بارے میں غور کرنے کے لئےاور وقت نکالنے کے لئے آپ کا شکریہ

Appendix 4 B: Last study- PIS English version

Participant Information Sheet
For the study entitled:
Web-based Exercise programme for south Asian with type 2 diabetes

We would like to invite you to participate in a research study. Before you decide whether or not to take part it is important for you to understand why the research is being undertaken and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information.

What is the aim of the study?

Type 2 diabetes is common among people who originate from south Asian countries (Pakistan, India, Nepal, Bangladesh and Sri Lanka). Studies show that exercise is important for people with type 2 diabetes. It helps to improve health and minimise the risk of complications that can impact a wide variety of parts of the body including eyes, heart, kidneys, nerves and feet. However, many people find it difficult to exercise due to lack of time, work, childcare responsibilities or lack of gender specific exercise classes.

Our research group has developed a website, www.webbasedphysio.com, to help people to exercise anywhere and at any time to improve their health. This website has been tailored to be culturally relevant to people of south Asian backgrounds. Now we would like to investigate the benefit of a 12 week exercise programme using this website for people of south Asian backgrounds with type 2 diabetes.

Why have I been invited?

We would like to invite people of south Asian backgrounds, aged between 25-65 years, with type 2 diabetes for more than 6 months. To take part you must have access to the internet and be able to understand either English or Urdu. You may not be eligible to take part if you have been ever told by your doctor that you should only perform exercise under supervision, you know any medical reason that prevents you from doing exercise or you are very obese.

Do I have to take part?

No, taking part in research is entirely voluntary; therefore it is up to you to decide. You should read this information leaflet and if you are interested in taking part you should phone the research team on the contact details at the end of this information leaflet.

What will happen to me if I take part?

You will be invited to meet the researcher to discuss your participation before the beginning of the study at a time and location that is convenient to you. During the meeting you will have the opportunity to ask any questions you might have. The researcher will ask you about your current and past medical history and measure your weight and height to see if you are eligible to take part. If you don't speak English, we can arrange for a translator who is fluent in English and Urdu. If you are eligible and happy to take part, we will ask you to sign a consent form either in English or Urdu. We will ask your permission to let your GP know you are taking part. We will then invite you to attend an assessment visit at a location that is suitable for you (see Table 1).

The assessment will include blood tests, completing some questionnaires and physical tests. The blood tests are to measure your blood lipids and blood sugar levels. We will only take a small amount from a vein in your arm (approximately one tablespoon). No fasting is required for this test. After blood sampling you will be asked to fill in questionnaires and perform short physical tests. The questionnaires will be about your gender, age, education level, country of birth and origin, origin, languages you are fluent in, medical history, current medications and dietary habits. The physical tests will include your height, weight, waist circumference, blood pressure, muscle strength, your normal walking speed over a short distance and a chair stand test. At the end you will be randomly assigned to either the intervention group or control group. Assessment appointments will take approximately 90 minutes to complete. Everyone will be asked to return after 12 weeks and 20 weeks to repeat the measurements taken at the beginning to see if there has been a change from the measurements taken at the beginning of the study.

What happens if I'm in the control group?

If you are randomised to the control group, you will be asked to continue your normal medications and lifestyle. You will also receive an information leaflet, in English or Urdu, depending on your preference. "If you wish to access the intervention, we will develop a personalised exercise programme based on your assessment and provide you with access to the website at the end of the study.

What happens if I'm in the intervention group?

If you are randomised to the intervention group you will be asked to do a personalised exercise programme 3 times per week for 12 weeks. Each exercise session will take about 45 minutes. You will meet the researcher (Hani) for a brief physical assessment to decide on the level of difficulty of your exercise programme and to discuss your exercise goals. A personalised exercise programme will then be deigned for you. You will be given unique login details to the website to complete your exercise programme.

The website will consist of your personalised exercise programme, an exercise diary and an advice section. Each exercise page consists of a video demonstrating the exercise, text and audio description of the exercise and a timer. The text and the audio description can be either in English or Urdu. The researcher will contact you by phone every two weeks to see how you are getting on and you will meet the researcher after six weeks to discuss your goals and progress.

People who are assigned to the intervention group may also be invited to take part in a face to face interview. We will invite 6-10 participants to ask them about their opinion about the intervention. If you do not speak English, we can arrange for a translator. All interviews will be conducted at the same appointment as your study assessments (week 12) and will be audio recorded and transcribed, so that we have a record of what was said. However, you name will not be recorded. The interview will last approximately 20 minutes.

Will my taking part in this study be kept confidential?

Yes, all information collected from you during the study will be kept strictly confidential, your name will not be used as we will replace all names with a study number and delete all audio-recordings. Representatives of the study Sponsor, NHS Greater Glasgow & Clyde, may need to look at your study information to make sure that the study is being conducted correctly

What are the possible benefits of taking part?

We hope that this web-based exercise programme will help you to improve your health by improving your blood sugar control, blood lipids, muscle strength, functional mobility and quality of life. However, this cannot be guaranteed. In addition, your opinion about the intervention, barriers and facilitators might help us to improve the intervention for other people in the future to exercise.

What are the possible disadvantages or risks of taking part?

Exercise can be associated with injury or muscle soreness, however we will ensure that your exercise programme is started gently and gradually progressed. In people with type 2 diabetes exercise might also be associated with a drop in the blood sugar (hypoglycaemia). However, this is rare in people who do not use insulin and we will provide advice on how to avoid hypoglycaemia.

What about expenses or payments involved with taking part in the study?

Refreshments will be provided during the assessments. We will also give you £20 for each assessment or appointment you attend. This is to compensate your travel or other expenses you may have incurred.

What will happen if I want to withdraw from the study?

If you decide to take part you are still free to withdraw at any time and without giving a reason. Any data collected prior to your withdrawing from the study will still be used.

What if there is a problem?

It is not likely that this study will cause concern or harm. However, if you have any concerns about any aspect of this study, you should speak to a member of the

It is not likely that this study will cause concern or harm. However, if you have any concerns about any aspect of this study, you should speak to a member of the research team. If you would like to talk to someone independent about the study you may contact Evan Campbell (male) (Tel: 0141 330 7154, Email: Evan.Campbell@glasgow.ac.uk) or Fatima Saleh (female) (Tel: 0141 330 3754, Email: f.al-dhabbari.1@research.gla.ac.uk). The usual NHS complaints procedure will also be available to you.

What will happen to the results of the research study?

It is intended that the results of the study will be published and written up as part of a PhD thesis. However no information will be presented that could identify you. Your personal data, audio-recordings and blood samples will be destroyed upon completion of the study. Only anonymous data will be stored securely at The University of Glasgow. Should you wish to know the results of the study then we will send you a summary of the main findings once the study is complete.

Who has reviewed this study?

The study has been reviewed and approved by the West of Scotland Research Ethics Committee.

If you are interested in participating or have questions about the study, please contact:

Hani Albalawi (male)

PhD student and Chief investigator

University of Glasgow
0141 330 6813
H.albalawi.1@research.gla.ac.uk

Professor Lorna Paul (female)
PhD supervisor and co-investigator
0141 331 8108

lorna.paul@gcu.ac.uk

Dr. Elaine Coulter (female)
PhD supervisor and co-investigator
ECoulter@qmu.ac.uk
0131 474 0000

Table 1. Suggested venues for meeting and assessment

Venue	Address
University of Glasgow	Wolfson Skills Lab, Wolfson Building, University of Glasgow, G12 8LL
MAB Scotland Centre (Mosque)	10 Grovepark Place Glasgow, G20 7NG
Al-farouq Education and Community Centre	32-38 Dixon Ave, Glasgow, G42 8EJ
Glasgow Central Mosque	1 Mosque Ave, Glasgow G5 9TA
Baitur Rahman Mosque	8 Haugh Rd, Glasgow G3 8TR
Gurdwara Singh Sabha	138 Berkeley St, Glasgow G3 7HY
Alfurgan Mosque	19 Carrington St, Glasgow G4 9AJ
'REACH Community Health Project'	6 Daisy St, Glasgow G42 8JL
Tamil Church Glasgow - EMMANUEL CHRISTIAN MINISTRIES	348 Cathedral St, Glasgow G1 2BX
Masjid Madressa Al Arabia Al Islamia (mosque)	425 Paisley Rd W, Glasgow G51 1PZ
Bearsden Muslim association community,	Speirs Rd, Bearsden, Glasgow G61 2LX
Bishopbriggs Mosque and Community Centre	, 160a Auchinairn Rd, Bishopbriggs, Glasgow G64 1NQ
Masjid-E-Khazra (mosque)	G42 7AF
Glasgow Gurdwara	37 Albert Dr, Glasgow G41 2PE
Masjid Noor (mosque),	Pollokshield, Glasgow G41 2TA

Thank you for taking the time to consider this study

Appendix 5: Last study-Posters (English and Urdu version)- Intervention study

NHS
Greater Glasgow and Clyde

University of Glasgow

<u>Web-based Exercise for South Asians with Type 2 diabetes</u>

Exercise helps people with type 2 diabetes to improve health and minimise the risk of diabetes related complications. At the University of Glasgow we are recruiting people to take part in a study that compares the effect of a 12 week exercise programme delivered via the internet with usual care for people with type 2 diabetes.

- Are you aged between 25 and 65 years old and from a South Asian background?
- Do you have type 2 diabetes?
- Do you have access to the internet?

If you are answered yes to these questions, you are interested in taking part or would like more information please contact

Hani Albalawi

0141 330 6813

H.albalawi.1@research.gla.ac.uk

ٹائپ 2 ذیابیطس کے شکار جنوبی ایشیائی باشندوں کے لئے ویب پر مبنی ورزش کے پروگرام

ورزش، ٹائپ 2 ذیابیطس کے افراد کے صحت کو بہتر بنانے اور ذیابیطس مرض کے خطرے کو کم سے کم کرنے میں مدد دیتی ہے اور ذیابیطس مرض سے متعلق آنکھیں، دل، گردوں، اعصاب اور پیروں پر اثر انداز ہونے والی پیچیدگیوں میں بھی مدد دیتی ہے. گلاسگو یونیورسٹی میں ہم ٹائپ 2 ذیابیطس کے شکار افراد کے لئے عمومی تدابیرکے ساتھ ساتھ انٹرنیٹ کے ذریعے 12 ہفتے ورزش کے پروگرام کے اثرات کے موازنے کیلئے لوگوں کو بھرتی کر رہے ہیں

کیا آپ کی عمر 25 اور56 کے درمیان ہے اورکیا آپ جنوبی ایشیا سے تعلق رکھتے ہیں؟

کیا آپ کو ٹائپ 2 ذیابیطس ہے؟

کیا آپ کو انٹرنیٹ تک رسائی حاصل ہے؟

اگر آپ ان سوالات کے ہاں میں جواب دیتے ہیں یا آپ کو حصہ لینے میں دلچسپی ہے تو مزید معلومات کیلئے رابطہ کریں

ہانی

0141 330 6813

H.albalawi.1@research.gla.ac.uk

Appendix 6- final study consent forms (English and Urdu versions)

اس تحقیق کے شرکا کا چار عددی کوڈ:

مطالعہ منظوری فارم
پروجیکٹ کا عنوان: ٹائپ 2 ذیابیطس کے شکار جنوبی ایشیائی باشندوں کے لئے ویب پر مبنی ورزش کے پروگرام: کنٹرول شدہ بے ترتیب مطالعہ

عام لوگوں کیلئے عنوان - **ٹائپ 2 ذیابیطس والے جنوبی ایشیائی باشندوں کے لئے ویب پر مبنی ورزش**

محققین کے نام :
Mr Hani Albalawi, Dr Elaine Coulter, Dr Rhian Noble-Jones, Dr Aleksandra Dybus
Dr Nazim Ghouri, Mr Shabir Banday, Professor Lorna Paul.

براہ مہربانی خانے پر کریں

(1) میں تصدیق کرتا ہوں کہ میں نے معلوماتی شیٹ 3 ورژن مورخہ 10.01.18 مندرجہ بالا مطالعہ کے لئے پڑھ اور سمجھ لی ہے اور مجھے سوالات کرنے کا موقع بھی ملا . ☐

(2) مجھے سمجھ ہے کہ میری شرکت رضاکارانہ ہے اور یہ کہ میں کسی بھی وقت بغیر وجہ بتائے اپنا فیصلہ واپس لے سکتا ہوں ☐

(3) مجھے سمجھ ہے کہ مجھے دو گروہوں میں سے ایک کیلئے مختص کیا جاےگا (12 ہفتے انٹرنیٹ کی بنیاد پر ورزش کے پروگرام یا معمول کی دیکھ بھال). ☐

(4) مجھے یہ بھی سمجھ ہے کہ شاید مجھے روبروانٹرویومیں حصّہ لینے کیلئے بلایا جائےجسے آڈیو ریکارڈ (صرف آواز کی ریکارڈنگ) کیا جاےگا . ☐

(5) میرے نام کے ذکر کے بغیر میری تحقیق سے کوٹیشن اور رپورٹوں کے استعمال کے لئے اجازت اور منظوری دے ☐

(6) میں اجازت دیتا ہوں کہ محققین میرے جی پی سے رابطہ کر کے انہیں میری شرکت سے آگاہ کر سکتے ہیں ☐

.(7) میں اپنے خون کا نمونہ مطالعہ کے اختتام تک گلاسگو یونیورسٹی میں ذخیرہ کیے جانے کی اجازت دیتا ہوں . ☐

(8) میں مندرجہ بالا مطالعہ میں حصہ لینے کے لئے اتفاق کرتا ہوں ☐

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شرکا کا نام	تاریخ	دستخط
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محقق	تاریخ	دستخط

Participant four-digit code for this study:

STUDY CONSENT FORM

Title of Project:
Lay title: Web-based exercise for South Asians with Type 2 diabetes

Name of Researchers:
Mr Hani Albalawi, Dr Elaine Coulter, Dr Rhian Noble-Jones, Dr Aleksandra Dybus, Dr Nazim Ghouri, Mr Shabir Banday, Professor Lorna Paul.

Please initial boxes

1. I confirm that I have read and understand the participant information Sheet v3 dated 10.01.18 for the above study and have had the opportunity to ask questions.
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.
3. I understand that I will be randomised to one of two groups (a 12 week internet based exercise programme or usual care).
4. I understand that I might be also invited to take part in a face to face interview which will be audio-recorded.
5. I agree to the use of anonymised quotes in reports and publications.
6. I give permission for the researchers to contact my GP to inform them of my participation.
7. I give permission for my blood sample to be stored at The University of Glasgow until the end of the study.
8. I agree to take part in the above study.

Name of Participant	Date	Signature
Researcher	Date	Signature

*1 copy for participant; 1 copy for researcher.

Appendix 7: Advice section English and Urdu

ADVICE PAGE English

WHAT IS TYPE 2 DIABETES?

Diabetes is a condition which occurs when your body cannot use blood glucose properly. Our bodies use glucose in the blood for energy. Blood glucose levels go up when we eat any food or drink that contains carbohydrate such as chapatti, rice, bread, potatoes, pasta, biscuits, sweets, fizzy drinks and fruit juice. When you have diabetes, your blood glucose levels stay up because your body cannot use glucose properly for the energy it needs. If this is not corrected, it can lead to complications that can make you go blind, have a heart attack or stroke, or even have an amputation.

WHO TYPICALLY GETS TYPE 2 DIABETES?

Type 2 diabetes usually appears in people over the age of 40, though in South Asian people, who are at greater risk, it often appears from the age of 25. It is also increasingly becoming more common in children, adolescents and young people of all ethnicities. Type 2 diabetes accounts for between 85 and 95 per cent of all people with diabetes and is treated with a healthy diet and increased physical activity. In addition to this, medication and/or insulin are often required.

In Type 2 diabetes there is not enough insulin (or the insulin isn't working properly), so the cells are only partially unlocked and glucose builds up in the blood.

HOW CAN I HELP MYSELF?

- Attend all your appointments.
- Take your medication as prescribed.
- Check your feet every day for any loss of sensation and changes in colour or shape.
- Try to sit less.
- Change your eating habits.
- Get your winter flu jab.
- Get help to lose any excess weight.

- If you smoke – stop.
- Do more exercise, such as start walking more, and build that up over time.

MYTH: PEOPLE WITH DIABETES CAN'T PLAY SPORT

People with diabetes are encouraged to exercise as part of a healthy lifestyle. Keeping active can help reduce the risk of complications associated with diabetes, such as heart disease. During physical activity, active muscles allow your body to use glucose more efficiently. This effect lasts for 1-2 days, so regular physical activity is important to better manage your blood glucose and your diabetes

However, there may be some considerations to take into account before taking up a new exercise regime.

GENERAL ADVICE

- Avoid doing exercise in extremely hot or cold temperatures.
- Warm up for 5 minutes before starting to exercise and cool down for 5 minutes after.
- Drink plenty of water before, during, and after activity to stay hydrated.
- Activities should be energizing but not overly difficult.
- Use the “talk test” to make sure you are not pushing yourself too hard. If you become short of breath and you can’t talk, then slow down.
- Take care of your feet by wearing shoes and clean socks that fit you well. You should also check inside your shoes before wearing them. Shoes with silica gel or air mid-soles are a good choice for weight-bearing activities like walking because they are built to reduce stress on your feet and joints. Socks that are made out of a material that reduces friction and pulls moisture away from your skin can also help protect your feet.
- Carefully inspect your feet before and after activity for blisters, redness, or other signs of irritation. Talk to your doctor if you have a foot injury or a non-healing blister, cut, or sore.
- Stop doing an activity if you feel any pain, shortness of breath, or light-headedness and Talk to your doctor about any unusual symptoms that you experience

How hard do you need to exercise?

1 - 10 Borg Rating of Perceived Exertion Scale	
0	Rest
1	Really Easy
2	Easy
3	Moderate
4	Sort of Hard
5	Hard
6	
7	Really Hard
8	
9	Really, Really, Hard
10	Maximal: Just like my hardest race

Moderate Intensity is recommended for people with type 2 diabetes. *Vigorous physical activity should only be started with the approval of your doctor or with the guidance of a qualified exercise professional (RPE >7). So while doing physical activity, we want you to rate your perception of exertion. You will rate your perception of how hard you are working using the "Borg" Rate of Perceived Exertion – RPE Scale.

Perceived exertion is how hard you feel your body is working. It is based on the physical sensations a person experiences during physical activity, including increased heart rate, increased respiration or breathing rate, increased sweating, and muscle fatigue.

During activity, use the Borg Scale to assign numbers to how you feel (see instructions below). Self-monitoring how hard your body is working can help you adjust the intensity of the activity by speeding up or slowing down your movements.

Through experience of monitoring how your body feels, it will become easier to know when to adjust your intensity. For example, a walker who wants to engage in moderate intensity activity would aim for a Borg Scale level of "moderate" (3). If he describes his muscle fatigue and breathing as "very light" (1 on the Borg Scale) he would want to increase his intensity. On the other hand, if he felt his exertion was "very hard" (7) on the Borg Scale) he would need to slow down his movements to achieve the Moderate (3) intensity range. The Borg Rating of Perceived Exertion is also the preferred method to assess intensity among those individuals who take medications that affect heart rate or pulse.

UNDERSTANDING YOUR BLOOD GLUCOSE REACTION

Exercise may affect your blood sugar levels both during and after exercise. Checking your blood glucose level frequently before and after exercise can help you to see the benefits of activity. You also can use the results of your blood glucose checks to see how your body to reacts to different activities. Understanding these patterns can help you also prevent your blood glucose from going too high or too low.

HYPOGLYCAEMIA (HYPO) AND EXERCISE:

Hypoglycaemia means 'low blood glucose levels' – less than 4 mmol/l*. People with type 2 diabetes are less likely to have issues with hypoglycaemia during or after exercise, unless they

- Are on insulin
- Exercise for a long time
- Exercise strenuously

Keep in mind that low blood glucose (hypoglycaemia) can occur during or long after exercise.

HYPOGLYCAEMIA (HYPO) *SYMPTOMS:*

Hypos can come on quickly and everyone has different symptoms, but common hypo symptoms are:

- **feeling shaky**
- **sweating**
- **hunger**

- **tiredness**
- **blurred vision**
- **lack of concentration**
- **headaches**
- **feeling tearful, stroppy or moody**
- **going pale.**

HOW TO AVOID HYPOGLYCAEMIA (HYPOS):

- If you are using insulin test your blood sugar levels before starting exercise
- If your blood sugar level is less than 5.5 mmols/l (100 mg/dl) prior to exercise, take a carbohydrate snack prior to beginning the exercise.
- If your blood sugar level is higher than 5.5 mmols/l (100 mg/dl) before exercise, it may not be necessary to take a carbohydrate snack before a light exercise session, but you may need extra carbohydrates during or following the exercise. Check your blood to see if your blood sugar dips below 4 mmols/l (70 mg/dl) following exercise.
- If you are with friends, make sure they know how to recognise and treat a hypo and, if you are exercising alone, let someone know where you are.

HOW TO TREAT HYPOGLYCAEMIA (HYPOS)

If you experience hypoglycaemia during or after exercise, treat it immediately. Use the same process as you would any other time of the day:

- Have at least 15-20 grams of fast-acting carbohydrate (sports drinks, regular soda, or glucose tabs are all good ideas).
- Wait 15-20 minutes and check your blood glucose again.
- If it is still low and your symptoms of hypoglycemia don't go away, repeat the treatment.
- After you feel better, be sure to eat regular meals and snacks as planned to keep your blood glucose level up.

If hypoglycemia regularly interferes with your exercise routine, talk to your healthcare provider about adjusting your treatment plan. Your provider may suggest eating a small snack before you exercise or they may make an adjustment to your medication(s).

AVOIDING HIGH BLOOD SUGAR LEVELS

If you use insulin, be careful when your blood sugar levels are above 13mmol/l as activity can raise it higher. If this happens, this is probably because you don’t have enough insulin. Think about giving yourself an extra dose of bolus insulin (correction dose) but please talk to your diabetes team about how to do this.

USEFUL LInKS

https://www.diabetes.org.uk/

ADVICE PAGE Urdu/

ذیابیطس کیا ہے؟

ذیابیطس ایک ایسا مرض ہے جس میں آپ کا جسم خون کے گلوکوز کو مناسب طرح سے استعمال نہیں کرسکتا ۔ ہمارا جسم خون میں گلوکوز کو توانائی کے لیے استعمال کرتا ہے۔ جب ہم کوئی ایسی غذا کھاتے یا پیتے ہیں جس میں کاربوہائیڈریٹ ہو، جیسے کہ چپاتی، چاول، بریڈ، آلو، پاستا، بسکٹس، مٹھائیاں، بلبلہ آور مشروبات اور پھلوں کا رس، تو خون میں گلوکوز کی سطحیں بڑھ جاتی ہیں۔

ذیابیطس میں، آپ کے خون میں گلوکوز کی سطح بڑھی ہوئی ہوتی ہیں کیونکہ آپ کا جسم اس توانائی کے لیے اس گلوکوز کو مناسب طور پر استعمال نہیں کرپاتا جس کی اسے ضرورت ہے۔ اگر اسے درست نہ کیا جائے تو، یہ پیچیدگیاں پیدا کرسکتا ہے جس کے سبب آپ نابینا ہوسکتے ہیں، آپ کو دل کا دورہ یا فالج ہوسکتا ہے، یا یہاں تک کہ عضو کاٹنے کی ضرورت پڑ سکتی ہے۔

عام طور پر کسے ٹائپ 2 ذیابیطس ہو سکتا ہے؟

ٹائپ 2 ذیابیطس عام طور پر 40 سال سے زاید عمر والے افراد میں نمودار ہوتا ہے تاہم جنوبی ایشیائی لوگوں میں چونکہ اس کا خطرہ زیادہ ہوتا ہے اس لئے ان میں اکثر 25 سال کی عمر میں ظاہر ہوتا ہے . اور اب یہ تیزی سے بچوں، نوعمروں اور سب سے زیادہ نوجوان لوگوں میں عام ہوتا جا رہا ہے . ذیابیطس کے جتنے مریض ہیں ان میں 85 سے 95 فی صد ٹائپ 2 ذیابیطس کے شکار ہیں، جس کا علاج صحتمند غذا کھانے سے اور جسمانی سرگرمی میں اضافے سے کیا جا سکتا ہے .

ٹائپ 2 ذیابیطس میں کافی مقدار میں انسولین نہیں ہوتا (یا انسولین مناسب طریقے سے کام نہیں کرتا)، لہٰذا خلیات(cells) صرف جزوی طور پر کھلے ہوتے ہیں اور گلوکوز خون میں بنتا ہے

میں خود اپنی مدد کس طرح کرسکتا ہوں؟

اپنی سبھی مقررہ تقرریوں (Appointments) پر جائیں۔
اپنی ادویات نسخے کے مطابق لیں۔
اپنے پیروں کو روز حساسیت کھونے اور رنگ یا شکل میں تبدیلی کیلئے چیک کریں .
روزانہ اپنے پیروں کی جانچ کریں۔
کم بیٹھنے کی کوشش کریں۔
اپنے کھانے کی عادات میں تبدیلی کریں۔
سردیوں کے موسم کے فلو کا ٹیکہ لیں۔
اضافی وزن کم کرنے کی کوشش کریں۔
اگر آپ سگریٹ نوشی کرتے ہوں تو، اسے بند کریں۔
زیادہ ورزش کریں، جیسے کہ زیادہ ٹہلنا ،اور وقت کے ساتھ ساتھ اس میں اضافہ کریں۔

متک(MYTH): ذیابیطس کے شکار، ورزش نہیں کر سکتے

ذیابیطس کے شکار لوگوں کو ایک صحت مند طرز زندگی کے حصے کے طور پر ورزش کرنی چاہیے . فعال(active) رہنے سے ذیابیطس سے منسلک پیچیدگیوں کا خطرہ کم ہو سکتا ہے ،جیسے کے دل کی بیماریاں .Steve Redgrave ، اولمپک گولڈ میڈلسٹ، ذیابیطس کے مریض ہونے کے باوجود کھیل کے میدان میں بڑی کامیابیاں حاصل کر چکے ہیں .تا ہم کوئی بھی نئی ورزش شروع کرنے سے پہلے اس کے خد و خال .پر غور کرنا ضروری ہے

عام مشورہ

• انتہائی گرم یا سرد درجہ حرارت میں ورزش کرنے سے اجتناب کریں.
• ورزش شروع کرنے سے پہلے 5 منٹ کے لئے وام اپ کریں اور ختم کرنے کے بعد 5 منٹ کیلئےٹھنڈے ہو جاییں.
• ورزش شروع کرنے سے پہلے ، درمیان اور بعد میں کافی مقدار میں پانی پیئں تاکہ ہاےدراٹڈ hydrated رہیں
• ورزش توانائی بخش ہونا چاہیے لیکن حد سے زیادہ مشکل نہیں ہونا چاہیے
اس بات کو یقینی بنانے کے لئے کہ آپ خود کو زیادہ تو نہیں تھکا رہے ، "ٹاک ٹیسٹ" کا استعمال کریں. اگر آپکی سانس پھول جائے یا آپکو بات کرنے میں مشکل ہو تو آرام سے کریں .
اپنے پیروں کی دیکھ بھال کیلئے ایسے جوتے اور موزے پہنیں جو آپ کےپیروں کی صحیح ناپ کے مطابق ہو.اپنے جوتے پہننے سے پہلے اندر دیکھ کر اچھی طرح تسلی کر لیں. سیلیکا جیل یا ہوادار وسط تلووں کے

بنے جوتے جو وزن برداشت کرنے والی سرگرمیوں ، جیسے چلنے پھرنے کیلئے بہت اچھے ہیں کیونکہ ان کو اس طرح بنایا جاتا ہے کہ وہ آپ کے پاؤں اور جوڑوں پر دباؤ کو کم کریں .وہ جرابے جو خاص ایسے مواد سےبنایئں جایئں جو رگڑ (فریکشن) کو کم کرتے ہیں اور آپ کی جلد سے نمی کو کینچھتے ہیں ، آپ کے پاؤں کی حفاظت میں مد د گار ثابت ہو سکتے ہیں

ہر سرگرمی سے پہلے اور بعد میں، چھالے،لالی اور دیگر علامات کیلئے اپنے پاؤں کا معائنہ کیا کریں .اگر پاؤں میں زخم ہو یا غیر شفا یابی چھالا یا کٹ ، تو اپنے ڈاکٹر سے رجوع کریں

- کسی بھی سرگرمی کے دوران اگر درد ،سانس کی کمی، یا ہلکا پن محسوس ہو تو اسے فورا روک دیں اور کسی بھی غیر معمولی علامات کے بارے میں اپنے ڈاکٹر سے بات کریں .

کتنا مشکل آپ ورزش کرنے کی ضرورت ہے؟

(بورگ ریٹنگ) سمجھی ریٹنگ پیمانے کے 1-10	
0	باقی
1	واقعی آسان
2	آسان
3	اعتدال پسند
4	چھانٹیں کے مشکل
5	
6	
7	واقعی مشکل
8	
9	واقعی بہت مشکل
10	زیادہ سے زیادہ: صرف میری سب سے مشکل ریس دیں

اعتدال پسند شدت ٹائپ 2 ذیابیطس کے ساتھ لوگوں کے لئے سفارش کی جاتی ہے. * جوردار جسمانی سرگرمی صرف اپنے ڈاکٹر کی منظوری کے ساتھ یا ایک تعلیم یافتہ مشق پیشہ ور (پری> 7) کی رہنمائی کے ساتھ شروع کیا جانا چاہئے. جسمانی سرگرمی کر رہے ہیں جبکہ تو، ہم آپ کو تبشرم کے آپ کے خیال کی درجہ اسکیل - تم آپ استعمال کر سمجھا تبشرم کے "بورگ" شرح کام کر رہے ہیں کہ RPE .بندی کرنا چاہتے ہیں .کس طرح مشکل کے آپ کے خیال کی درجہ بندی کریں گے

سمجھی تبشرم آپ کو آپ کے جسم کو کام کر رہا ہے کہ کس طرح مشکل محسوس کی ہے. یہ جسمانی احساس میں اضافہ ہوا دل کی شرح میں اضافہ، سانس یا سانس لینے کی شرح میں اضافہ ہوا پسینہ آ رہا، اور پٹھوں کی تھکاوٹ سمیت جسمانی سرگرمی کے دوران ایک شخص کے تجربات پر مبنی ہے.

سرگرمی کے دوران، آپ کو لگتا ہے کہ کس طرح کرنے کے لئے اعداد (مندرجہ ذیل ہدایات ملاحظہ کریں) تفویض کرنے بورگ اسکیل استعمال کرتے ہیں. خود نگرانی آپ کے جسم آپ کو تیز یا آپ کی نقل و حرکت کو سست کر سرگرمی کی شدت ایڈجسٹ مدد کر سکتے ہیں کام کر رہا ہے کتنا مشکل ہے.
آپ کے جسم کیسا لگتا نگرانی کے تجربے کے ذریعے، یہ آپ کی شدت ایڈجسٹ کرنے کے لئے جب آپ کو معلوم کرنے کے لئے آسان ہو جائے گا. مثال کے طور پر ایک ڈبلیو چاہتا ہے جو اعتدال پسند شدت سرگرمی میں مشغول کرنے کی "اعتدال پسند" ایک بورگ اسکیل سطح کے لئے مقصد کرے گا (3). وہ (بورگ پیمانے پر 1) "بہت روشنی" کے طور پر ان کے پٹھوں کی تھکاوٹ اور سانس لینے میں بیان کرتا ہے تو وہ اپنے شدت میں اضافہ کرنا چاہتے ہیں. دوسری طرف، انہوں نے محسوس کیا ہے تو اس کے تبشرم "بہت مشکل" (7) بورگ پیمانے پر) وہ اعتدال پسند (3) شدت رینج کے حصول کے لئے ان کی نقل و حرکت کو سست کرنے کی متاثر کرنے والے ادویات لے PULS ضرورت ہو گی تھی. سمجھی تبشرم کے بورگ بندی بھی دل کی شرح یا جو ان افراد کے درمیان شدت کا اندازہ کرنے کے ترجیحی طریقہ ہے.

اپنے خون میں گلوکوزکے ردعمل کو سمجھنا

ورزش آپکے خون میں شوگر کی سطح پر اثر انداز ہو سکتا ہے آیا ورزش کے دوران یا بعد میں .اپنی ہر سرگرمی کے فوائد جاننے کیلئے ہر ورزش سے پہلے اور بعد میں اپنے خون میں گلوکوز کی سطح کی جانچ کر لیا کریں .اور اپ اپنے خون میں گلوکوز کی سطح کی جانچ کے نتائج کو یہ دیکھنے کے لئے بھی استعمال کر سکتے ہیں کہ آپکا جسم کوئی بھی سرگرمی کرتےہوے کیسا رد عمل ظاہر کرتا ہے .اس طرز عمل سے آپ اپنے خون میں گلوکوز کو بہت زیادہ یا بہت کم ہونے سے روک سکتے ہیں .

ہائپو گالیسیمیا (ہائپو) اور ورزش:

ہائپو گالیسیمیا کا مطلب ہے 'خون میں گلوکوز کی کم سطح ' *4 mmol/ l سے کم' .ٹائپ 2 ذیابیطس کے شکار افراد میں ہائپو گالیسیمیا کے امکانات ورزش کے دوران یا بعد میں کم ہوتے ہیں اگر وہ :

- انسولین پر ہیں
- ایک طویل وقت کے لئے ورزش کرتے ہیں
- بہت مشکل ورزش کرتے ہیں

ذہن میں رکھیں کہ خون میں گلوکوز کی کمی (ہائپو گالیسیمیا) ورزش کے دوران یا بعد میں ہو سکتی ہے

ہائپو گالیسیمیا کے علامات:

ہائپو گالیسیمیا فوری طور پر آ سکتا ہے اور سب کو مختلف علامات ہو سکتے ہیں، لیکن عام ہائپو علامات درج ذیل ہیں:

، لرزاں لگنا•

پسینہ آنا •

بھوک لگنا•

تھکاوٹ •

دھند لی نظر•

ارتکاز(concentration) کی کمی •

سر درد •

رونا یا موڈی محسوس کرنا

رنگ کا ہلکا ہونا•.

ہائپو گالیسیمیا سے کیسے بچا جا سکتا ہے

اگر آپ انسولین استعمال کررہے ہیں ، ورزش شروع کرنے سے پہلے اپنے خون میں شوگر کی سطح کو ٹیسٹ کر لیں •

اگر ورزش سے پہلے آپکے خون میں شوگر کی سطح 5.5 mmols / l (100mg / dl) سے کم ہے. تو ورزش شروع کرنے سے پہلے کاربوہائڈریٹ سنیک لے لیں . •

اگر ورزش سے پہلے آپکے خون میں شوگر کی سطح 5.5 mmols / l (100mg / dl) سے زیادہ ہے تو ہلکی ورزش سے پہلے کاربوہائڈریٹ سنیک لینے کی ضرورت نہیں لیکن شاید آپکو ورزش کے دوران یا بعد میں کاربوہائیڈریٹس کی ضرورت پڑ سکتی ہے . یہ جاننے کے لئے کہ آپکے خون میں شوگر کی مقدار (4 mmols / l (70mg / dl سے کم ہے ،اپنا خون چیک کریں .

اگر آپ دوستوں کے ساتھ ہیں،تو انھیں یہ پتہ ہونا چاہیے کہ ہائپو کو کیسے پہچانے اور اس کا علاج کیسے کریں ،اگر آپ اکیلے ورزش کر رہے ہیں تو کسی جاننے والے کو بتایے کہ آپ کہاں ہیں .

ہائپو گالیسیمیا کا علاج کرنے کا طریقہ

اگر آپ کو ورزش کے دوران یا بعد میں ہائپو گالیسیمیا ہو جائے تو اس کا فورا علاج کریں اسی عمل کا استعمال کریں جو آپ باقی دنوں میں کرتے ہیں :

کم از کم 15-20 گرام ، تیزی سے اثر کرنے والا کاربوہائڈریٹ لیں (سپورٹس مشروبات، عام سوڈا، یا گلوکوز ٹیبلیٹس تمام کار آمد ہیں)

- 15-20 منٹ انتظار کریں اور دوبارہ اپنے خون میں گلوکوز چیک کریں
- اگر اب بھی کم ہے اور ہائپو گالیسیمیا کی علامات دور نہیں ہو رہیں تو یہی علاج پھر سے دہرائیں

بہتر محسوس کرنے کے بعد،خون میں گلوکوز کی سطح کو برقرار رکھنے کیلئے باقاعدگی سے کھانے اور سنیکس کھایئں.

اگر ہائپو گالیسیمیا باقاعدگی سے آپکے ورزش کے معمول میں مداخلت کریں ، تو علاج کی منصوبہ بندی کو ایڈجسٹ کرنے کے بارے میں اپنے ہیلتھ کیئر پرووائیڈر (Provider Healthcare) سے بات کریں

.پرووائیڈر آپ کو ورزش کرنے سے پہلے ایک چھوٹا سا ناشتا کھانے کا مشورہ دے سکتا ہے یا وہ آپ کی دوا (یا ادویات) میں ایڈجسٹمنٹ کر سکتا ہے

ہائی بلڈ شوگر کی سطح سے گریز

اگر آپ انسولین کا استعمال کرتے ہیں:

اگر آپکے خون میں شوگر کی مقدار 13 mmol /l سے زیادہ ہے ،توبہت احتیاط کریں کیونکہ کسی بھی سرگرمی(ورزش) سے اس میں اضافہ ہو سکتا ہے ، اگر ایسا ہوتا ہے تو اس کا مطلب ہے کہ آپکے بد ن میں انسولین کی کمی ہے اس صورت میں اضافی بولس (bolus) انسولین لینے کا سوچیں لیکن یہ جاننے کے لئے کہ اسکو کرنا کیسے ہے اپنی ذیابیطس کی ٹیم سے بات کریں .

مفید لنکس

https: //www.diabetes.org.uk/Other_languages/Urdu/