Mapping, Co-Creating, and Trialling Workplace Physical Activity Interventions: A Route Map for Developing Feasible Workplace Physical Activity Interventions for Employee Mental Health

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Abstract

Poor mental health, including depression and anxiety, is a world-leading cause of illness and disability worldwide. Higher levels of physical activity are strongly associated with better mental health, while PA interventions have been demonstrated to be as effective in treating and preventing severe depression as medication. Workplaces have been identified as important settings for potential interventions; however contextual factors play a role in the outcomes of each intervention. This PhD aimed to review the literature on workplace physical activity interventions for mental health, evaluate the mental health and physical activity behaviours in a small-to-medium Scottish enterprise (ACS Clothing Ltd) through a mapping process, then use the findings from both the review and mapping to codevelop an intervention for the whole workplace, and finally test the feasibility of this tailored intervention.

Study one (Chapter 3) reports a three-year workplace mapping process designed to characterise mental health, wellbeing, productivity, and physical activity patterns within a small-to-medium enterprise and to inform the development of a workplace physical activity intervention. Annual Wellbeing Evaluations (AWEs) were delivered across 2022-2024, combining physical health assessments, seven-day accelerometery, and validated surveys of wellbeing, depression/anxiety, stress, sleep, productivity, and work engagement. Linear models examined differences across years and job types (manual vs. desk-based), while compositional data analysis assessed how physical activity behaviours contributed to these patterns. Across 181 evaluations, most outcomes remained stable over time, except for a marked worsening of depression and anxiety in the third year, coinciding with organisational restructuring. Manual workers consistently exhibited poorer mental health, sleep, and engagement than desk-based workers. Physical activity compositions during work and across the full day meaningfully contributed to differences in depressive symptoms and job-type disparities. The AWEs, originally conceived as observational, evolved into an engagement tool as personalised feedback prompted behaviour change and organisational adjustments.

Study two (Chapter 4), was a systematic review of evidence on the effectiveness of workplace physical activity and exercise interventions for improving employee

mental health and wellbeing. Following PRISMA guidelines, searches to June 2024 identified 54 eligible studies (58 interventions) spanning randomised controlled trials, quasi-experimental designs, and pre-post studies. Validated mental health outcomes were extracted and synthesised using effect-direction plots due to methodological heterogeneity. Risk of bias was assessed using ROB-2, ROBINS-I, and NIH tools, with certainty of evidence evaluated through GRADE. Certainty of evidence was low for stress, mood/affect, and general wellbeing, and very low for anxiety, depression, and quality of life, primarily due to heterogeneity, methodological weaknesses, and inconsistent reporting. Mind–body activities such as yoga and Tai Chi, group-based delivery, and higher intervention dose were more frequently associated with favourable effects in some outcomes.

In study 3 (Chapter 5), potential interventions were developed through a co-creation process. Co-creation involves engaging end-users and stakeholders throughout the research process increasing the likelihood of intervention success and of sustaining an effect beyond the research project. This approach was delivered through workshops with managers and employees. These workshops involved feeding back the results from the review and mapping exercise and facilitating participants to create their own workable intervention solution. Participants' proposals were recorded using a participatory drawing exercise, where participants drew their ideas before discussing the practicalities, and discussion points were recorded via researcher note taking. Findings from these workshops were delivered to a project steering group consisting of a representative sub-set of employees and managers who, along with the research team, assisted with the final development of the intervention.

Study 4 (Chapter 6) tested two co-developed physical activity interventions (job rotation and walking meetings) designed to support employee mental wellbeing. The mixed-methods feasibility trial applied Framework Thematic Analysis of semi-structured interviews to explore feasibility, acceptability, and perceived impact, while linear mixed-effects models with compositional analysis of physical activity behaviours were used to assess potential effectiveness. Both interventions were acceptable within the respective target work groups, with 80% adherence for job rotation and 100% for walking meetings. For job rotation

participant reports indicated perceived benefits to workforce flexibility and self-efficacy, while acceptability was shaped by capacity for rotation, resistance to change, and organisational agility. Acceptability of the walking meetings was influenced by factors such as group size, physical and social environment, and leadership support. Job rotation had no detectable effect on wellbeing in this sample ($p = 0.703$), while walking meetings showed potential benefits ($p = 0.019$). The findings suggest both approaches are feasible but require further adaptation to workplace context to maximise uptake and impact.

Beyond generating new empirical insights, this PhD contributes a methodological model for integrating mapping, co-creation, and feasibility testing within live workplace systems, offering a replicable approach for future workplace health research.

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PRESENTATIONS

Tumblety, C., Cusack, M., Demou, E., Kelly, P., Ryde, G.C. (2023) Developing a Workplace-wide Physical Activity Intervention for Mental Health. *International Society of Behavioural Nutrition and Physical Activity Annual Meeting, Uppsala, Sweden, 14th-17th June 2023.*

Tumblety, C., Demou, E., Kelly, P., Trost, S., Ryde, G.C. (2024) Job Descriptions Can Be Misleading in Physically Active Jobs: An Evaluation Of Physical Activity Exposures in an Active Workplace. *10th International Society for Physical Activity and Health Congress, Paris, France, 28th – 31st October 2024.*

PUBLICATIONS

Tumblety, C., Demou, E. Rosaini, N. D., Lu, J., Ryde, G. C. (2026). A Systematic Review of Physical Activity and Exercise Interventions for Mental Health or Wellbeing in Workplace Settings. *In review – Occupational Medicine.*

ADDITIONAL PUBLICATIONS

Parra-Soto, S., **Tumblety, C.**, Ho, F. K., Pell, J. P., Celis-Morales, C. (2022) Associations Between Relative Grip Strength and the Risk of 15 Cancer Sites. *American Journal of Preventive Medicine*, 62, (2), e87-e95

Parra-Soto, S., **Tumblety, C.**, Araya, C., Rezende, L. F. M., Ho, F. K., Pell, J. P., Celis-Morales, C. (2023) Associations of Physical Activity with Breast Cancer Risk: Findings from the UK Biobank Prospective Cohort Study. *Journal of Physical Activity and Health,* 20(4), 272-278. https://doi.org/10.1123/jpah.2022-0437[1]

Durán-Agüero, S., Prada, G. E., Parra-Soto, S., **Tumblety, C.**, Celis-Morales, C., Moya-Osorio, J. L. (2025) Sociodemographics and Food Purchase Preferences Associated with Food Insecurity During the Covid-19 Pandemic in Chile. *Archivos Latinoamericanos de Nutrición,* 75, (4), 279-288. https://doi.org/10.37527/2025.75.4.005

[1] Shortlisted for Best Observational Study in the JPAH 2024 Article of the Year Awards.

Acknowledgement

> *"It must not be claimed that anyone can sense time by itself apart from the movement of things."* – Lucretius, De rerum natura.

I had a very different life before this PhD. When I applied for the Medical Research Scotland studentship led by Dr. Gemma Ryde, most of the world was still in COVID-19 lockdown, my first son, Harris, had just been born, and I was running a strength and conditioning business. A lot has changed since then. My wonderful girlfriend became my wonderful wife, we now have two sons (Travis joined us in 2023), and I haven't taught anyone how to do a clean and jerk in years. However, I have to admit writing this thesis has been similar to a lockdown at times. All these changes remind me how much time has passed and how much work has gone into this PhD. It has been a significant time in my life, and so I will not forget it or the people who were a part of it.

The first of those people I'd like to acknowledge is the previously mentioned Dr. Gemma Ryde, the person who made this research possible and my lead supervisor. There are times in a PhD where it feels like being stuck in a maze, but her enthusiasm was infectious and it kept me going at times when I didn't feel like I was moving forward. I can't thank her enough for how she has guided me through this PhD.

One of Dr. Ryde's greatest strengths is her ability to surround herself with brilliant people, and I benefitted from her knack for team building with two excellent supporting supervisors. First, Dr. Evangelia Demou was there from the day I interviewed for the PhD and was supportive from the start. She consistently encouraged me to go a little further and challenged me to think a little deeper, something I took as a compliment. Then along with my University of Glasgow supervisors, I was delighted to have Dr. Paul Kelly from the University of Edinburgh, as the kathegetes of the team. Together, my team of supervisors managed to balance out my blunders and reign in my rants. I have so much respect for all of them and will always appreciate how they've helped me throughout this PhD.

Thank you also to Professor Stewart Trost and Dr. Tom Stewart, who both patiently guided me through data processing and analysis that I couldn't even have comprehended four years ago.

I also know how extremely lucky I was to land at ACS Clothing and get to work with so many fantastic people. This research would not have been possible without their contributions. This thesis is about those people, and I sincerely hope the work can have some small impact for them, and others like them. Particular thanks go to Michael Cusack (my ACS supervisor) and Anthony Burns for allowing me the privilege of working at ACS, and to Radoslaw Lacki and Andy MacFarlane for their support.

Medical Research Scotland are a fantastic independent medical research charity, who are committed to supporting people at the early stages of their research careers. Beyond funding this research, they have also encouraged my development as a researcher, and I always enjoyed their annual events. I'd like to thank Dr. Alex Graham for always showing an interest in this work and for inviting me to speak at the charity's outreach events.

Special thanks and appreciation are reserved for my wife, Lauren, who has handled more than her fair share of tantrums and tears (some of them from our children) to support me along the way. Through long periods of isolation, she kept her humour and kept bringing me tea.

Thank you also to my sister, Heather, who I can hear cheering me on from the other side of the world.

Thank you to my father, Gordon. He made me stubborn and I needed that.

Finally, I'd like to acknowledge my mother, Karen Tumblety, who has always encouraged me to give my best and celebrated my successes, even when I couldn't. I told myself I returned to academia after ten years away because I wanted to be helpful, but mostly I think it was a way for me to cope with the helplessness I felt eight years ago. I'll keep going now, because of her.

Author's Declaration

I declare that, except where explicit reference is made to the contribution of others, the work presented in this thesis is entirely the result of my own. This thesis was carried out under the supervision of Dr Gemma C. Ryde, Dr. Evangelia Demou, and Dr. Paul Kelly. This research was supported by the PhD studentship of Medical Research Scotland (PHD-50209-2020). The contents of this thesis have not been submitted for any other degree at the University of Glasgow or any other institution.

Craig Tumblety

April, 2026

List of Abbreviations

ACS	ACS Clothing Ltd
AIC	Akaike Information Criterion
AWE	Annual Wellbeing Evaluations
BIC	Bayesian Information Criterion
BMI	Body Mass Index
BP	Blood Pressure
CHEW	Checklist of Health promoting environments at Worksites
CIE	Change-In-Estimate
CM	Centimetre
CoDA	Compositional Data Analysis
COM-B	Capability Opportunity Motivation - Behaviour
CT	Craig Tumblety (author of the thesis)
DALYS	Disability Adjusted Life Years
DASS-10	Depression, anxiety, and stress scale (10 items)
DIEM	Dynamic Integrated Evaluation Model
ECG	Electrocardiography
ELISA	Enzyme-Linked Immunosorbent Assay
EWAP	Employee Wellbeing Assessment Portal (www.ewap.co.uk)
GBD	Global Burden of Disease
GRADE	Grading of Recommendations, Assessment, Development and Evaluation
HR	Heart rate
HPQ	Health and Productivity Questionnaire
HWQ	Health at Work Questionnaire
Hz	Hertz
ICC	Intraclass Correlation Coefficient
ILR	Isometric log-ratio
JD-R	Job demands-resources
JR	Job Rotation
KG	Kilogram
LMM	Linear Mixed Model
LPA	Light-intensity physical activity
LTPA	Leisure time physical activity
METs	Metabolic equivalents
MG	Milligram — a unit of mass equal to 10^{-3} grams

MRC	Medical Research Council
MRS	Medical Research Scotland
MVPA	Moderate-to-vigorous intensity physical activity
NMOL	Nanomol - a unit of amount of substance equal to 10^{-9} moles.
OPA	Occupational physical activity
PA	Physical activity
PAR	Participatory Action Research
PDSA	Plan–Do–Study–Act
PG	Picogram
PSS	Perceived Stress Scale
PSQI	Pittsburgh Sleep Quality Index
REML	Restricted Maximum Likelihood
R^2	Coefficient of determination
SD	Standard deviation
SDT	Self-Determination Theory
SED	Sedentary behaviour
SE	Standard error
SEM	Social Ecological Model
SME	Small-to-medium enterprise
UWES	Utrecht Work Engagement Scale
VIF	variance inflation factors
VM	Vector Magnitude
VO2MAX	Maximal oxygen uptake
WEMWBS	Warwick-Edinburgh Mental Well-being Scale
WHO	World Health Organization
WHO-5	World Health Organization five item mental wellbeing index
WM	Walking Meeting

General Definitions

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

Physical activity type: The type of physical activity performed (i.e. walking, running, resistance exercise).

Intensity: A measure of physiological effort of the physical activity or exercise being performed. Generally classified into light, moderate, vigorous and very vigorous intensity physical activities. For aerobic exercise, intensity can be measured by heart rate (reserve or maximal), metabolic equivalents (METs), and maximal oxygen uptake (VO2max).

Moderate to vigorous intensity physical activity (MVPA): Commonly quantified by physical activity performed at an intensity that is above the resting level (1 MET) into the moderate (3-<6 METs) and vigorous level (>6 METs). MVPA is often used for assessing adherence to the aerobic physical activity guideline (≥150 minutes of MVPA per week). Example of activities include walking, running, and cycling (1).

Workplace: A place where people work, such as an office, university or factory.

Worksite: The specific area of land or building where people work. Some workplaces may have several buildings or areas of land that are spread out across different locations i.e. a university would be a workplace, but a specific university building would be a worksite.

Employees: In this thesis, the term will refer to anyone employed by the organisation/company, encompassing core staff and managers.

Managers: Are employees with supervisory responsibilities or oversight of departments or divisions within the organisation.

Core staff/staff: Any employee who is not a manager.

Manual workers: Sometimes called blue-collar workers, are employees whose jobs involve physical work, such as fabrication, assembly, material handling, maintenance, and similar activities.

Desk-based workers: Employees who work behind a desk or computer for most of the workday, using a laptop or desktop for communication and job tasks.

Mental Wellbeing: An individual's ability to develop their potential, work productively and creatively, build strong and positive relationships with others, and contribute to their community. Considered by the World Health Organization to be an interchangeable term with mental health (2), this definition of mental wellbeing is concerned exclusively with positive mental health states, and this approach will also be applied in the way that the terminology is used in this thesis.

Compositional Data Analysis (CoDA): CoDA, developed by John Aitchison (1986), is the statistical analysis of compositional data, vectors of positive components that represent parts of a whole and carry only relative information (3). These components typically sum to a constant (e.g., 1 or 100%), requiring special log-ratio methods rather than standard statistics.

Co-creation: Refers to the collaborative process in which stakeholders, such as employees, or communities, actively participate in creating or improving operations, services, or solutions (4).

Job rotation: A technique where employees move periodically and in a planned manner between a range of jobs or tasks within an organisation (5).

Chapter 1 Thesis Introduction and Outline

1.1 Thesis introduction

The World Health Organization (WHO) defines mental health as “a state of wellbeing that enables people to cope with the stresses of life, realise their abilities, learn well and work well, and contribute to their community” (6). Poor mental health and mental illness are highly prevalent globally and, in the UK, with significant personal, social, and economic consequences. In workplaces, mental health problems are a leading cause of sickness absence, presenteeism, reduced productivity, and job loss resulting in substantial costs for employers, society, and individuals (7–9).

Physical activity is most commonly defined as “any bodily movement produced by skeletal muscles that results in energy expenditure” (10,11). This definition, originating from Caspersen et al. (1985), is widely used in epidemiological research and informs global health policy, including WHO guidelines (10,12). Physical activity encompasses a broad range of activities, including occupational, sports, conditioning, household, and other daily movements. Higher levels of physical activity are robustly associated with improved mental health and reduced risk of mental disorders, with evidence supporting its effectiveness as a treatment for depression and other conditions (13–16). The workplace is a strategic setting for physical activity interventions, offering opportunities to reach large populations and address both individual and organisational determinants of health (17).

While the evidence base for workplace physical activity interventions to improve mental health contains promising findings, it remains limited and mixed, particularly regarding long-term effectiveness and applicability across diverse job types (8,18–23). Methodological limitations, contextual barriers, and the need for tailored and inclusive approaches are key challenges (24,25). There is a need for high-quality research that prioritises context-sensitive interventions, rigorous evaluation of mental health outcomes, and strategies to enhance engagement, equity, and sustainability across all workplace settings (21,26,27).

Context of this research project

This PhD project was sponsored by Medical Research Scotland (MRS), in collaboration with ACS Clothing Ltd (ACS). MRS is Scotland's largest independent medical research charity, whose focus is on supporting research that improves health in Scotland and globally in three ways: by improving the diagnosis, treatment or prevention of diseases; by understanding basic disease processes; and by the development of medical technologies. In this PhD project, MRS expectations were for an intervention to be developed which would improve and prevent mental ill-health within workplaces.

ACS had participated in previous workplace physical activity research with the lead supervisor of this PhD, Dr. Gemma Ryde. The company was therefore involved from study conception and acted as the external partner organisation in the project, which meant that they would partially fund the PhD studentship and provide their workplace as setting for this research, in exchange for benefitting from the processes and findings. The company launched in 1997 and has specialised in the cleaning, repairing, and renewal of rental clothing for over 20 years. However, as this project began in October 2021 the company had started to shift its business model towards circular fashion, which extends the life of existing textiles and diverts clothing from landfill by working with retail partners to create rental or resale options for their customers. This transition in the services that ACS were delivering, led to transitions in several functions within the business which included changes in employee tasks, seasonality of the business, and departmental and hierarchical structures, and will be evident in the reporting and discussion in this thesis.

In order to better observe and understand the contextual factors influencing the development and implementation of any interventions, I was placed as an embedded researcher with ACS. This involved being stationed at their worksite in North Lanarkshire, Scotland two days per week throughout the majority of this research and more regularly during data collection, implementation and testing periods. The perspectives and insights gained as an embedded researcher, as well as the possible influences on participants, will be part of the discussion within the relevant chapters that follow.

1.2 Outline of the Thesis

This PhD was originally planned to follow a traditional academic timeline, as shown in Figure 1-1:

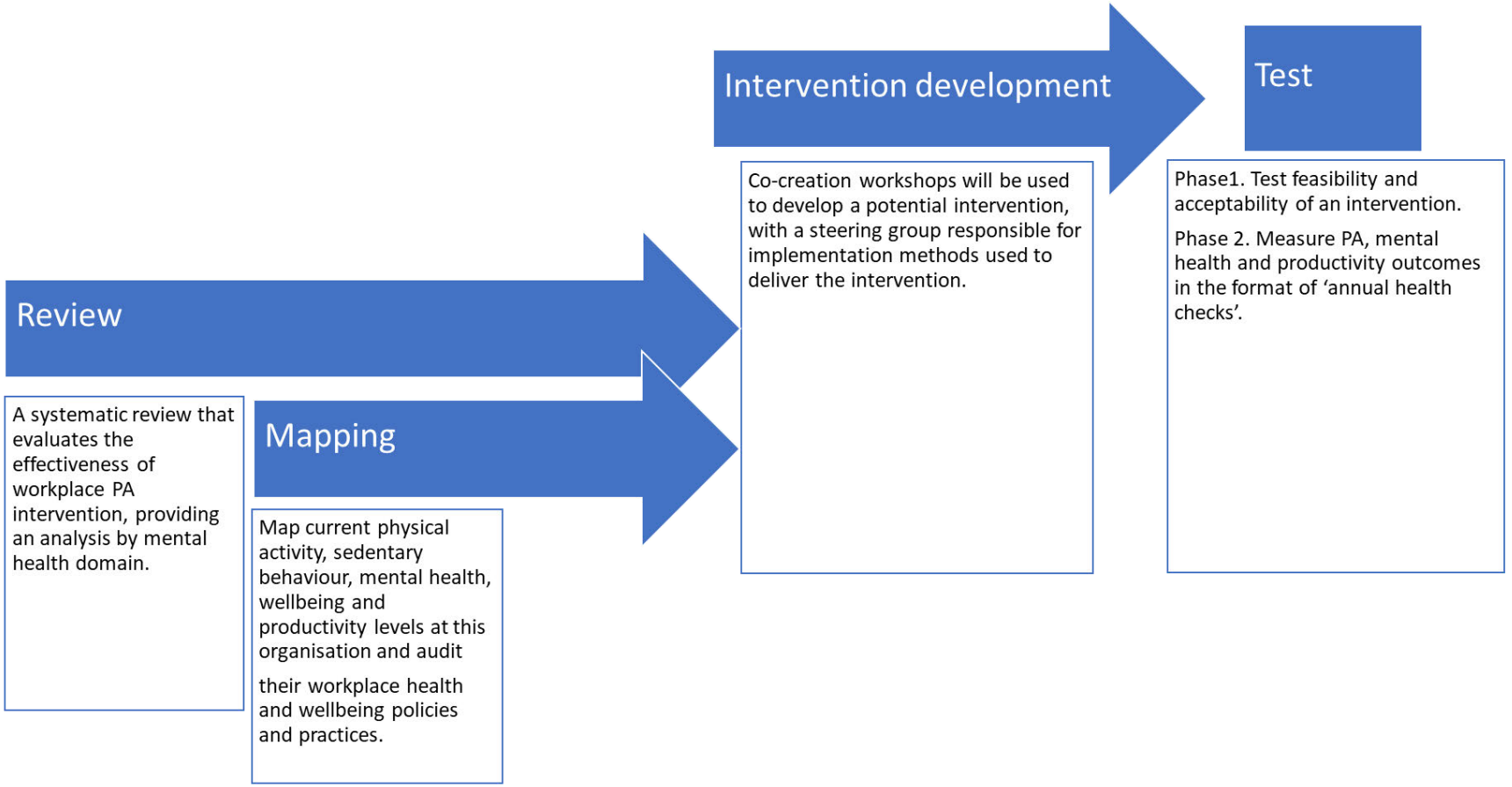

Figure 1-1 The original research plan for the PhD project

However, the research timeline was adapted to better meet expectations from and maintain engagement with ACS employees and management. As this research was carried out in a real workplace, which invested resources and finance into the project, there was urgency to see impacts from the start of the PhD. Therefore, the systematic review was delayed allowing the mapping and co-creation processes, which the workplace could actively participate in, to take precedence. Figure 1-2 shows how the project timeline unfolded in reality and will be reflected in how this thesis is presented.

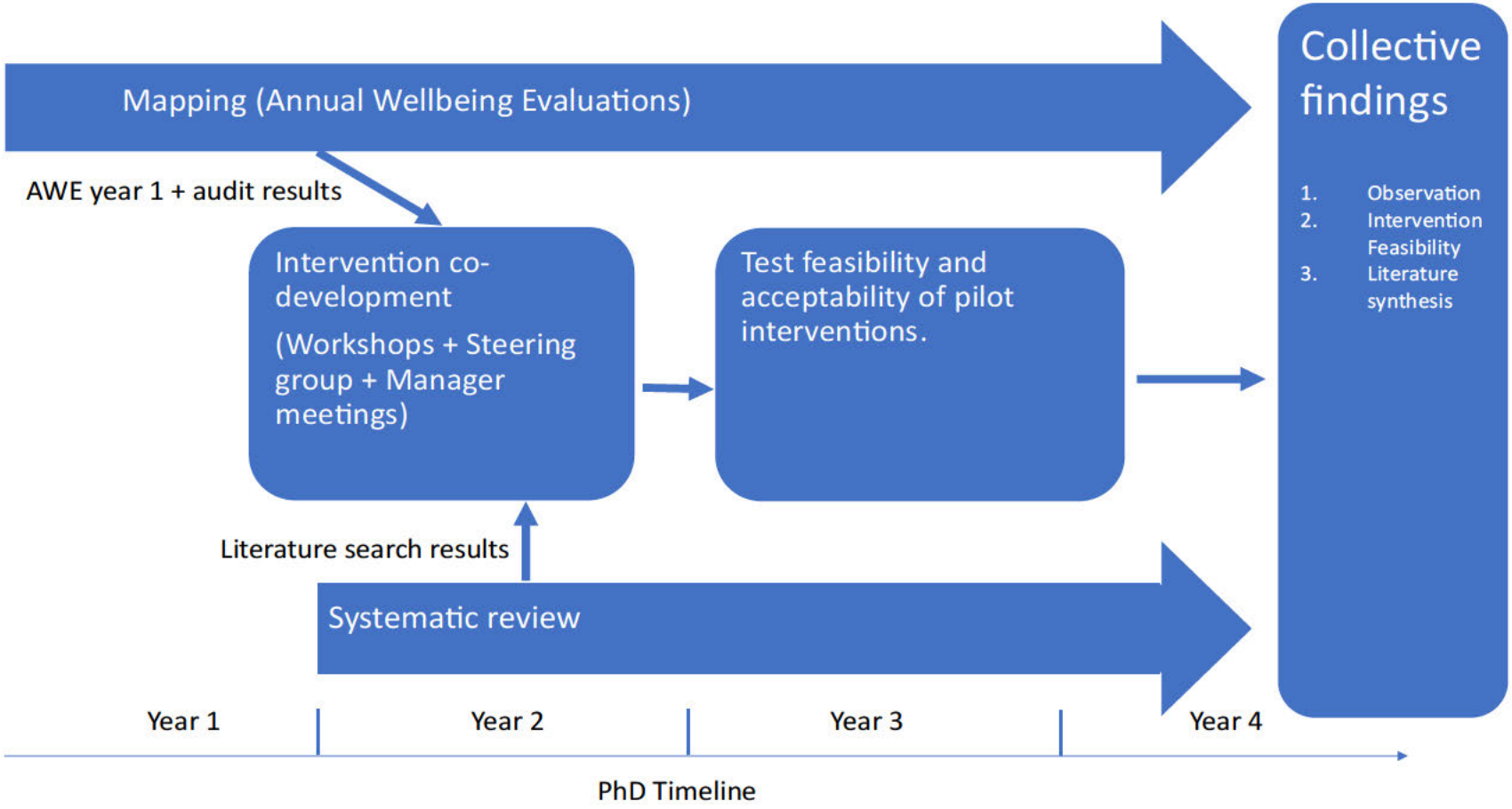

Figure 1-2. Final workflow of the PhD project

This PhD thesis will report and discuss the findings and evolution of the PhD project, including how the research was planned, how it was adapted and why, and what knowledge it contributes. The outline of this thesis is as follows:

Chapter 2 – Literature review

This chapter will:

- Provide empirical background from the available literature on the prevalence and impacts of mental ill-health broadly and in the workplace.
- Describe the evidence for associations between physical activity and mental health, and potential differences between physical activity at work and during leisure time.
- Evaluate the evidence for the feasibility and effectiveness of workplace interventions to increase physical activity and improve mental health.
- Identify challenges and facilitators reported in previous workplace physical activity interventions.
- Identify research aims based on the gaps in evidence.
- Discuss what disciplinary and methodological approaches were applied to meet these research aims and why.

Chapter 3 – The Evolution of the Annual Wellbeing Evaluations (AWEs): From Observational Data Collection to Intervention Tool

This chapter will:

- Describe the methods used to measure and evaluate physical activity, mental health, and productivity at ACS Ltd.
- Describe and justify the three significant pivots to the methods and approaches that were made following responses and reactions from ACS employees and management.
- Evaluate the physical activity, mental health, and productivity of ACS staff over three years and the differences between job types.

Chapter 4 – A Systematic Review of Workplace Physical Activity Interventions for Mental Health and Wellbeing

This chapter will:

- Systematically review the available literature on past workplace physical activity interventions.
- Evaluate the evidence for the effectiveness of workplace-based physical activity interventions to improve mental health.

Chapter 5 - Tailored Intervention Co-Development

This chapter will:

- Describe the process co-development of tailored interventions for ACS.
- Identify the physical activity interventions that were most highly ranked by ACS employees, that fit with the pre-defined criteria for the context of ACS and had the most supportive evidence from the literature.

Chapter 6 - Feasibility Trials

This chapter will:

- Assess the feasibility and acceptability of two workplace physical activity interventions tailored to job type.
- Assess the effectiveness of the two interventions to improve mental wellbeing.

Chapter 7 - Final Discussion

This chapter will:

- Summarise the key findings and novel contributions of this thesis.
- Discuss these findings in the context of previous research.
- Discuss the contextual learnings and the adaptations to the research.
- Provide recommendations for future research in this area

Chapter 2 Thesis Background Literature Review

This first chapter will provide an overview of the literature on mental health epidemiology, physical activity (PA) and its associations with mental health, current trends in PA, and current approaches to improve PA behaviour and in turn, mental health. Justifications will be provided here for why a workplace is a suitable setting for a PA intervention for mental health and what strategies have been successful in this setting previously. Finally, the challenges that have been previously identified in implementing PA interventions in workplaces will be discussed, providing a basis for the methodological decisions made throughout this PhD project.

2.1 The prevalence and burden of poor mental health

Mental health-related illnesses, particularly depression and anxiety, are among the leading contributors to non-fatal disease burden worldwide, affecting over one billion people globally, they for account 19% of all years lived with disability (28). Systematic analyses from the Global Burden of Disease (GBD) Study, which is a collaborative effort to aggregate data from registries, surveys, censuses, and epidemiological studies across 204 countries and territories, demonstrate that mental ill-health accounts for a substantial proportion of disability-adjusted life years (DALYs) across all regions, with approximately 332 million suffering from depression, which has been identified as the leading contributor to years of healthy life lost due to disability (29–32). Age-standardised rates remain persistently high over recent decades despite increased policy attention (33). Furthermore, the consequences extend beyond symptoms alone, contributing to long-term functional impairment, reduced quality of life, and elevated risk of comorbid physical conditions such as cardiovascular and musculoskeletal disorders (34–37). In Scotland, this pattern is mirrored in national burden-of-disease estimates, which show that mental ill-health accounted for an age-standardised DALY rate of 2,494 per 100,000 population in 2019, underscoring the substantial contribution to morbidity at the population level (38,39).

Beyond individual and population health, the economic and societal implications of the mental health burden are considerable. Across high-income countries,

including the UK, the majority of costs associated with common mental disorders arise not from healthcare utilisation but from productivity losses due to sickness absence, presenteeism (working with reduced productivity), and premature labour-market exit (40,41). Waddell and Burton's influential review in 2006 for the Department for Work and Pensions highlighted that common health problems, including depression and anxiety, account for approximately two-thirds of all sickness absence and long-term incapacity in the UK, underscoring their major role in work-related disability (42). More recently, the Health and Safety Executive found that 22.1 million working days lost between March 2024 and March 2025 were attributable to mental ill-health, with average 22.9 days lost per case of stress, depression or anxiety (43). Additionally, the Stevenson Farmer review found that 300,000 individuals with chronic mental health problems lose their jobs every year (44). These findings highlight the impact of mental health problems on workforce participation and productivity, despite improving detection and treatment (45).

2.2 Physical Activity and Mental Health

A definition of PA has been provided in Chapter 1, but the volume and intensity of PA play a role in its effects on health outcomes (46,47). Typically, PA is classified as light (LPA), moderate, or vigorous, with moderate-to-vigorous PA (MVPA) being the focus of most health guidelines (48–51). Whilst guidelines vary by country, despite using the same evidence base, the UK guidelines recommend that adults (age 19-64 years) should accumulate 150 minutes of moderate intensity PA or 75 minutes of vigorous intensity PA per week, and resistance exercise two or more times per week (48).

The health benefits of regular PA are extensive and well-documented. Engaging in sufficient PA reduces the risk of non-communicable diseases such as cardiovascular disease, type 2 diabetes, certain cancers, and obesity (10,51–54). Meta-analyses demonstrate a curvilinear dose–response relationship: the greatest health gains are observed when moving from inactivity to moderate activity, with diminishing returns at higher activity levels (52,55,56). For example, adults achieving at least 150 minutes per week of moderate-intensity activity have a 31% lower risk of all-cause mortality and a 29% lower risk of cardiovascular mortality compared to inactive individuals (57). Even lower doses confer

substantial benefit, supporting the public health message that “some activity is better than none” (48).

PA also confers mental health benefits. Systematic reviews and meta-analyses consistently show that regular PA is associated with reduced symptoms of depression and anxiety, improved psychological wellbeing, and enhanced cognitive function (16,58). One recent meta-analysis found an inverse curvilinear association between PA and risk of incident depression in 191,130 participants, with adults meeting PA recommendations at 25% lower risk (95% CI, 18%-32%) compared with those not reporting any PA (59). Additionally, PA and exercise have been shown to be at least as effective in treating depression as prescription medication (60,61) The magnitude of benefit varies by domain, intensity, and individual characteristics, but the overall direction is robust: PA is a protective factor for mental health across the lifespan (16,58).

The mechanisms by which PA influences mental health are multifactorial and complex, involving biological, psychological, and social pathways. Recent systematic reviews have identified at least 27 mediators, including psychological, social, biological and neurobiological mechanisms (16,62–66). Notably, while neurobiological mechanisms are often cited, recent evidence suggests that psychological and social pathways are more strongly supported in the literature (16,63). This has important implications for intervention design, highlighting the value of activities and environments that foster self-efficacy, social support, and positive affect.

Conversely, sedentary behaviour, which refers to any waking activity characterised by an energy expenditure of ≤1.5 metabolic equivalents (METs) while in a sitting, reclining, or lying posture, is independently associated with adverse health outcomes, including increased risk of all-cause and cardiovascular mortality, type 2 diabetes, and some cancers, even after adjusting for PA levels (67–70). A 2025 systematic review and dose-response meta-analysis (25 studies; n = 252,503) found that individuals with high sedentary behaviour had a 35% higher risk of depression compared with those with low sedentary behaviour (OR = 1.35, 95% CI 1.20–1.52) (71). Additionally, another recent systematic review and meta-analysis (12 studies; 40,314 workers) showed that occupational sedentary behaviour increased the risk of intermediate

and severe mental health issues by 34% (95% CI 18–49%) (72). However, several experimental studies have found that breaking up prolonged sitting produced significant improvements in affective well-being, including higher valence and energetic arousal, compared with uninterrupted sedentary periods (73–75).

2.3 Trends in Physical Activity Behaviour: Scotland, UK, and Global

Globally, physical inactivity is a major public health concern. The latest WHO estimates indicate that 31% of adults and 80% of adolescents do not meet recommended PA levels, with inactivity rates rising in high-income countries and among women and older adults (76). If current trends persist, the proportion of inactive adults is projected to reach 35% by 2030 (68,76). In Scotland, PA levels have remained broadly static over the past decade, with modest improvements. According to the 2024 Scottish Health Survey, 62% of adults met the guidelines for moderate or vigorous PA, a figure that has fluctuated between 62% and 69% since 2012 (77). However, significant inequalities persist, with 73% of adults in the least deprived areas meeting guidelines, versus 50% in the most deprived (77). Furthermore, inherent bias in the self-report methods of measuring PA, commonly used in epidemiology studies, likely mean that prevalence of those meeting guidelines is over estimated (78,79).

Measuring Physical Activity

Self-report methods (e.g., questionnaires, diaries, interviews) are widely used in large-scale surveillance due to their low cost and ability to capture context, type, and domain of activity (78). However, they are prone to recall bias, social desirability bias, and misclassification, often leading to overestimation of PA and underestimation of sedentary time (79,80). Device-based methods of measuring PA, such as accelerometers, pedometers, and heart rate monitors provide high-resolution data on movement intensity, frequency, and duration. They are less susceptible to bias and can capture light-intensity and intermittent activities that are difficult to recall in self-report measures (81). However, they are more expensive, require participant compliance, and may not accurately capture contextual information (82–85). Device-based prevalence estimates are typically lower than self-report, and methodological choices, such as device type,

placement, epoch length, and cut-points can substantially affect results (81,83,86,87). For example, a study comparing self-reported and accelerometer measured PA in office workers supplied with height-adjustable working desks, found that self-reported data yielded a significant under-estimation of standing time (13.3 vs. 17.9 %) and an overestimation of walking time (12.7 vs. 5.0 %) (88). There is a growing consensus that combining self-report and device-based measures provides a more comprehensive picture, capturing both the quantity and context of activity (88–90).

One aspect of measurement that is increasingly supported throughout the PA and health literature, is the recognition that accelerometer-derived time-use data are inherently compositional (91–96). This is because behaviours classified into activity families during the processing of raw data, such as sitting, standing, and walking activities or sedentary, LPA, and MVPA, will collectively sum to a fixed whole (e.g., 24 hours or a workday). Traditional Euclidean statistical approaches treat each behaviour as independent, ignoring their perfect co-dependency and risking biased estimates and spurious associations (92,94,95). Compositional Data Analysis (CoDA) provides a principled framework that accounts for this constrained structure by analysing the relative distribution of time-use components rather than their absolute durations (3,93,94). The development of the 24-hour Activity Cycle Framework, in 2016, by the Stanford Center on Longevity (97) highlighted a paradigm shift toward recognising the co-dependency of movement behaviours and demonstrates that CoDA better aligns with the theoretical and mathematical properties of accelerometer data than Euclidean models, which assume unconstrained and independent variables. CoDA approaches have rapidly increased in application in PA and sedentary behaviour research, offering advantages such as appropriate handling of multicollinearity, improved interpretability of substitution effects (e.g., reallocating time between behaviours), and statistically valid comparisons of behavioural compositions (93). This growing evidence base supports CoDA as a more robust analytical strategy for accelerometer-derived movement data compared with traditional Euclidean metrics.

2.4 Physical activity in the workplace

The workplace has been identified as a critical setting for PA interventions due to the large proportion of adults in employment (75% in the UK adults between September and November 2025 (98), the substantial amount of time adults spend at work (estimated as over half of their waking hours), and the limited opportunities for PA outside working hours (99,100). In Scotland, as in much of the UK, occupational PA has declined over recent decades, while sedentary time has increased (101). An analysis of historical time-use data showed the extent of this progressing decline in occupational PA in the UK, from 145.8 MET-hours per week in 1961 to 95.4 MET-hours per week in 2005, a difference of 35% that is projected to become 60% by 2030 (102). The shift from manual to service-based industries has reduced opportunities for incidental PA at work, particularly among lower socioeconomic groups (101). The Scottish Health Survey and Active Lives Survey document highlight high levels of sedentary behaviour among working adults, with significant inequalities by occupation, gender, and deprivation (77,103,104).

International and national guidelines, including those from the WHO and Scottish Government, emphasise the importance of creating active workplaces and reducing sedentary behaviour during work hours (101,105). Additionally, a recent umbrella review found that desk-based workers were the primary target for workplace PA intervention trials between 2000 and 2024, reflecting the global trend towards sedentary work environments (106). This focus on sedentary jobs, however, may come in part from a lack of distinction between the effects of occupational PA (OPA) and leisure-time PA (LTPA) on health outcomes. While both contribute to total energy expenditure, it has been suggested that their health impacts differ markedly, a phenomenon known as the physical activity paradox (107,108). LTPA, such as sport, exercise, and recreational walking is consistently associated with reduced risk of all-cause mortality, cardiovascular disease, cancer risk and improved mental health (15,34,109–111). In contrast, high levels of OPA such as manual labour and repetitive tasks are not consistently associated with similar benefits and may even be detrimental (107,112). Furthermore, illness related to OPA can have a detrimental effect on overall PA behaviour and other health outcomes. For example, pain from musculoskeletal disorders, for which Scotland has the

highest incidence of in the UK, can lead to worse sleep and mental health (113,114).

A 2018 meta-analysis of 17 prospective cohort studies (193,696 participants) found that men with high OPA had an 18% (HR 1.18, 95% CI 1.05–1.34) increased risk of all-cause mortality compared to those with low OPA, with no association found in women (115). Whereas, a later umbrella review, published in 2020, found that higher OPA was related to health benefits in multiple cancer outcomes (including colon and prostate), ischaemic stroke, coronary heart disease and some mental health outcomes (mental wellbeing and life satisfaction), whilst also being associated with unfavourable health outcomes for all-cause mortality in men, mental ill health (depression and anxiety), osteoarthritis, and sleep quality and duration, with the authors noting a lack of high-quality evidence at that time (116).

Several large cohort studies have since found that higher OPA was either not beneficial or associated with increased risk of morbidity and mortality, independent of LTPA and confounders. An epidemiological study, from Pearce et al (2021), of 460,901 UK Biobank participants (aged 40–69 years), followed for a median of 12.0 (IQR: 11.3–12.7) years, found no association between higher levels of OPA and all-cause, cardiovascular disease or cancer mortality (117). Incidentally, in the same year a study following 104,046 participants in the Copenhagen General Population Study found that those who reported high levels of LTPA had reduced risk of major adverse cardiovascular events and all-cause mortality (HR 0.77, 95% CI 0.69-0.86 and HR 0.59, 95% CI 0.54-0.64, respectively), while those who reported high levels of OPA had an increased risk of major adverse cardiovascular events and all-cause mortality (HR 1.15, 95% CI 1.04-1.28 and HR 1.13, 95% CI 1.01-1.27, respectively), with no evidence of interaction between the two domains on risk of either outcome (118). However, a more recent study of 404,249 adult Norwegians found that compared with those in sedentary jobs, individuals with physically active jobs had a lower risk of developing endometrial (walking-and-lifting - HR 0.86, 95% CI 0.76-0.97), colon (heavy labour - HR 0.82, 95% CI 0.74-0.91), breast (walking-and-lifting HR - 0.85, 95% CI 0.80-0.90; and heavy labour HR 0.77, 95% CI 0.67-0.89), rectum- (heavy labour - HR 0.87, 95% CI 0.76-0.99), and prostate (walking-and-lifting -

HR 0.94, 95% CI 0.90-0.99) cancers, but a higher risk of oesophageal cancer (walking-and-lifting - HR 1.33, 95% CI 1.05-1.67) and kidney cancer in women (walking-and-lifting - HR 1.49, 95% CI 1.18-1.88) (112). It is worth noting that all three of these cohort studies categorised OPA differently from each other, limiting the extent to which the findings can be generalised to specific job roles or tasks.

The difference in health outcomes between LTPA and OPA appears to extend beyond only physical health and may also exist in mental health. A 2025 meta-analysis of over 3.3 million participants found that LTPA (r=0.21, 95% CI 0.16 to 0.25) was positively associated with mental health, while work-related PA (r=0.13, 95% CI 0.07 to 0.20) was positively associated with mental ill-health (58).

Despite these findings, most PA guidelines do not differentiate between OPA and LTPA, potentially leading to misconceptions among employers and workers in physically demanding jobs. There is a growing call for domain-specific recommendations and further intervention research to clarify the health impacts of changes to PA specifically within workplace settings (119,120).

2.5 Past Approaches to Workplace Physical Activity Interventions

Workplace PA interventions can offer opportunities such as access to relatively large adult populations, integration of PA into daily routines, potential for organisational support, and the incentive of shared benefits for employers (e.g., reduced absenteeism, increased productivity) and employees (e.g., improved health, wellbeing) (121). Such interventions are increasingly implemented, as evidenced by a PubMed search for the title and abstract terms “workplace” and “physical activity” and “intervention”, limited to comparative studies, controlled trials, multicentre studies, observational studies and randomized control trials. As shown in Figure 2-1, this search found only 17 studies published between the years 1983-2008, but 24 articles were published in 2015 alone and no year since has had fewer than 11 articles.

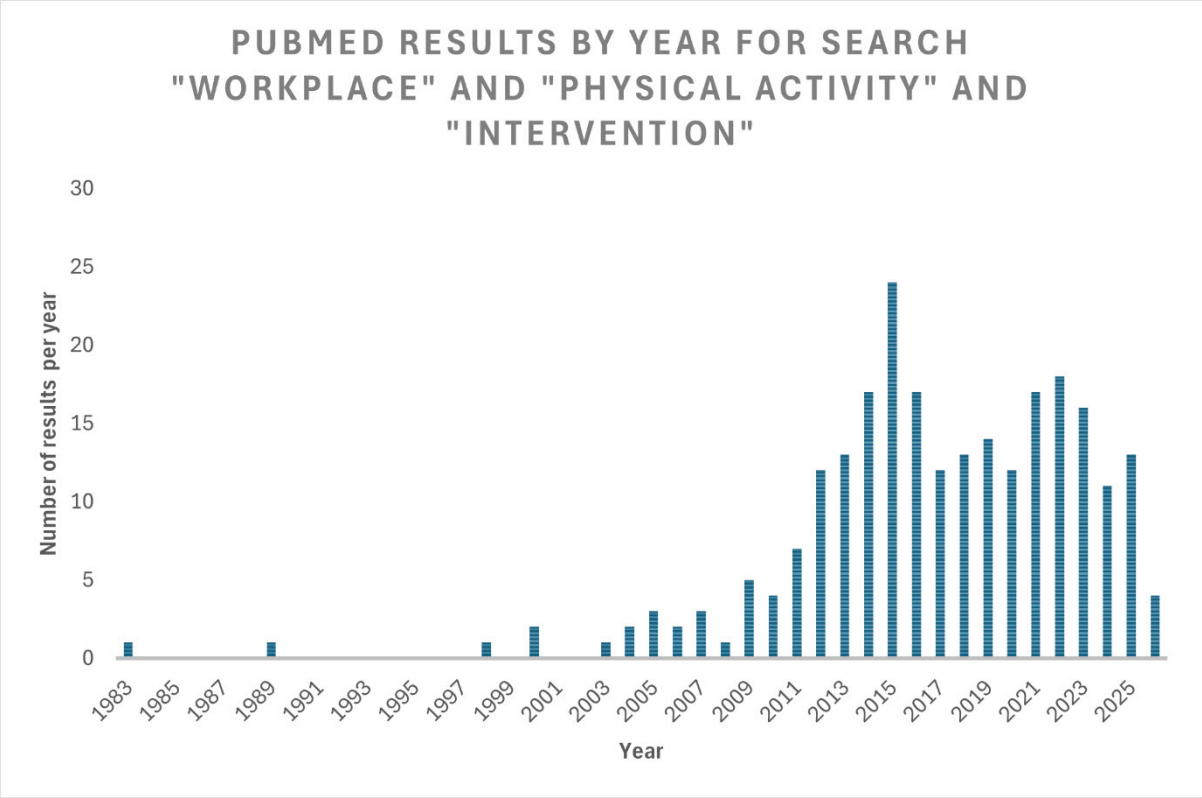

Figure 2-1. PubMed results by year showing a progressing increase in published articles on the topic on workplace physical activity interventions

Participation and effectiveness of workplace PA interventions vary by sector, job type, and organisational culture (27,122). Early meta-analytic evidence showed modest improvements in PA (effect size *d* = 0.21), quality of life (effect size d=0.23), job stress (effect size *d* = 0.33), and small improvements in mood (effect size d=0.13), but highlighted considerable heterogeneity in outcome measures, industry, and intervention strategy, as well as methodological limitations in most primary studies (123). More recently, Zhang et al. (2025), in a systematic review of PA-led workplace health promotion interventions, found some significant improvement in 81.3% of studies for PA outcomes, 80.0% for stress management, and 42.9% for anxiety and depressive symptoms (124). A meta-review of workplace interventions for common mental disorders (125) found consistent evidence of symptom reductions following PA intervention in moderate quality systematic reviews, whilst another looking more broadly at workplace health promotion interventions on physical and mental health outcomes found strong evidence for positive effects of such workplace initiatives on weight-related outcomes, musculoskeletal health, and mental health (126).

Workplace interventions promoting PA vary substantially in design and components. A recent scoping review found that of 134 interventions conducted during a paid break from work, 15 (11.2%) used aerobic exercise, 36 (26.9%) resistance exercise, 17 (12.7%) used stretching, and 66 (49.3%) used a combination of either aerobic, resistance and/or stretching; 48 (35.8%) provided group classes/sessions, 35 (26.1%) provided supervised sessions at work, 34 (25.4%) individual sessions at work, one intervention (0.7%) used individual sessions at home, and 16 (11.9%) used a combination of delivery methods (127). The authors reported that 85.1% of these interventions had positive effects on target outcomes, suggesting that a wide variety of intervention strategies can improve physical and mental health (127).

Comparative evidence is conflicting on whether theory-informed interventions are more effective than non-theory-informed designs. A review by Taylor et al (2012) found larger effect sizes for theory-informed interventions (effect size = 0.34, 95% CI 0.23–0.45; I^2=0%) than for non-theory informed interventions (effect size = 0.21, 95% CI 0.10–0.31; I^2=28%) (128). However, Lock et al. (2021) reported that workplace PA interventions using device-based measures showed positive overall effects for daily step counts (814.01 steps/day; 95% CI 446.36-1181.67; p <0.01; i2 = 88%) and measured VO_2max (2.53 ml kg−1 min−1; 95% CI 1.69-3.36; p <0.01; i2 = 0%), but there was no difference in effectiveness between theory-informed interventions and atheoretical ones (129).

There are numerous examples of promising evidence for particular strategies or components (20,67,130–132). For example, Gawlik et al. (2023) reviewed coaching based interventions and reported increases in at least one workplace or total PA outcome in all but one of 17 studies that they reviewed, albeit with some interventions only showing small effects (20). However, fewer syntheses have evaluated differences in outcomes between workplace settings, job types or populations (133–135). Additionally, the effectiveness of any strategy appears to depend on job context. Mänttäri et al.'s (2021) review of workplace PA interventions delivered to workers in physically strenuous roles, found inconsistent or negligible effects on work ability, productivity, and pain, highlighting the need for context-specific tailoring (134).

A recent umbrella-level review by Rouyard et al (2025), synthesized a wide range of workplace movement-behaviour interventions and found that although many strategies can increase PA, no specific strategy was consistently effective (106). The authors highlighted persistent challenges including low participation, short intervention duration, limited long-term follow-up, and difficulties translating controlled-trial effectiveness into diverse real-world workplaces. These findings reflect substantial variation in intervention fidelity, organisational support, job demands, baseline PA levels, and the extent to which interventions were embedded into work routines.

While there are exceptions (122), the evidence on the effectiveness of workplace PA interventions broadly demonstrates small but consistently positive effects on increasing PA and improving a range of health outcomes. However, the heterogeneity of interventions emphasises that while many strategies can work, the workplace is not a uniform setting; what works in office-based, sedentary roles may not translate to shift-based, manual, or high-strain environments (22,133–135).

2.5.1 Workplace PA interventions for mental health outcomes

The effectiveness of workplace PA interventions specifically for mental health will be evaluated more fully in a systematic review of the literature in Chapter 4 of this thesis, but broadly evidence from previous reviews indicates small but meaningful improvements, although findings vary considerably by intervention type, job context, and methodological quality.

Early work by Brown et al (2011) found that increases in PA were associated with improvements in emotional wellbeing (23). However, of the 20 studies included in this review, only two assessed depression and three assessed anxiety as an outcome. The authors also observed that fewer than half of the included studies measured both psychosocial wellbeing and productivity together, despite the established links between the two (136). Additionally, multi-component wellness or health interventions that incorporated nutrition and smoking cessation were included in this review alongside PA focussed programmes, making it more challenging to identify causal effects.

Chu et al. (2014) provided the first systematic review specifically evaluating workplace PA interventions for mental health, evaluating 17 studies (19). The authors reported moderate evidence for improvements in depression (one of two high-quality studies reported a reduction of 26%, $p<0.05$), limited evidence supporting the effectiveness of PA programmes in improving stress (only one high quality study from seven reported a significant reduction in score of 37%, effect size $d = 0.56$) and no evidence for significant reductions in anxiety (in four studies), with some evidence that yoga had a positive effect on stress and anxiety (no effect sizes reported). However, this review prioritised randomized control trials and controlled trials over other study designs, which can limit the translation of effectiveness to real-world settings (106,137,138). The results were mostly comprised of small, short-term studies in office-based populations, and hampered by substantial heterogeneity in intervention content, intensity, and outcome measures. By grouping interventions into either yoga or other forms of PA, the review does bring some limited insight into which PA interventions are most effective for which outcomes. Further expansion of this type of evaluation would be useful for workplaces and researchers, as would insight into which components matter most and how effects differ by job type or workplaces. In effect, the Chu et al. review establishes that workplace PA interventions can improve mental health but leaves unanswered the questions of for whom and under what conditions.

A review by Abdin et al. (2018) narrowed the focus by examining office-based settings and wellbeing outcomes (22). Five studies were included (three high-quality, two low-quality), three walking interventions, one yoga, and one individualised exercise classes. The authors reported that all three intervention types could enhance wellbeing encompassing outcomes such as mood, affect, stress, vitality, and subjective wellbeing. However, this review noted the limitations of their search strategy, which was narrow in terms of outcomes, and the challenge of establishing effectiveness for different PA types in different contexts in so few studies.

More recently, Skold et al. (2019), found only limited positive effects on psychosocial and mental health outcomes in 22 randomised controlled trials and highlighted persistent methodological limitations across the evidence base (21).

This synthesis moved the field forward by assessing the ease of integration, the validity of questionnaires used for self-report measures, and differentiating between healthy and specific populations, as well as group and individual delivery modes. Notably, the review still treats “workplace exercise” largely as a generic exposure and relatively little attention is given to responses in different job types (i.e. high OPA jobs vs low OPA jobs). Furthermore, this review used the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) approach to assess quality in each study (139), when this is an approach recommended for assessing the overall certainty of evidence in different outcome domains. Therefore, it is difficult to judge the certainty of the evidence per outcome domain (anxiety, depression, stress etc.). None of these reviews of workplace PA interventions for mental health found any significant adverse effects following interventions (19,21–23).

Whilst workplace interventions consistently show promise for increasing PA the effects are generally modest (106,123). The evidence specifically for mental health is more limited and warrants an updated review, as previous reviews in this area have been limited in scope, with the King’s College London policy institute calling for more rigor in the evaluation of workplace interventions for mental health (27).

2.5.2 Barriers and facilitators to Implementing Workplace Physical activity and Mental Health Interventions

Workplace PA and mental health interventions face a wide array of implementation barriers that limit both uptake and effectiveness. A scoping review by Garne-Dalgaard et al (2019) identified 109 factors, divided into 57 barriers and 52 facilitators, in only eight studies implementing PA interventions at work (24). The authors found the most common barriers and facilitators to be in the domains of environmental context and resources (36.2% of barriers; 18.4% of facilitators), social influences (13.8% of barriers; 19.5% of facilitators), and social/professional role and identity (8.5% of barriers; 10.3% of facilitators). All eight studies identified lack of time, conflicting work time schedules, or alternating workstations/work locations as barriers; while simple, flexible and tailored programs, as well as opportunities to meet and spend time with colleagues, social and collegial support, and feelings of legitimacy were reported

as facilitators. A more recent systematic review of 18 workplace PA interventions by Dabkowski et al (2023), found similar themes in their narrative analysis (25). Both reviews also noted support, acknowledgement, and active participation from management, along with overall organisational support facilitated up-take when present and led to reductions in motivation when lacking. Several primary studies included in these reviews suggest that impacts could be more sustainable if interventions were implemented from within the organisation (140,141), while others have highlighted the importance of a collective sense of ownership in workplace interventions, allowing employees to take part in the development, a supportive workplace culture, and focus on economic advantages can all facilitate this (142–144).

Low individual motivation is a consistently reported barrier, with some employees believing that PA is not part of their work responsibilities and belongs in the domain of leisure time (24,25). Qualitative evidence in university staff with different PA levels reinforces this pattern, with Safi et al. (2022) reporting that employees with lower baseline PA levels perceived workplace PA initiatives as inaccessible, intimidating, or incompatible with job demands (145). In physically demanding occupations, workers may perceive PA interventions as irrelevant or burdensome, and interventions risk adding physical load to already strenuous roles (134). In Scottish midwives, who generally had a high level of OPA, facilitators to increasing PA included subsidized classes and protected breaks, while barriers included tiredness, stress, family responsibilities, unpredictable breaks and shift patterns (146). However, the evidence on high OPA and health outcomes suggests that increasing overall PA in these working populations may not be the most appropriate goal.

The King's College London review of workplace mental health interventions emphasises that programmes often achieve only limited impact when implemented in isolation from organisational change, and that effects are strongest when interventions address both individual behaviour and working conditions (27). In group-level interventions to improve mental health in low control, high-demand office jobs, Demou et al (2024) found that a key barrier was the changeable nature of workplace environments, while few interventions employed a participatory approach (133). From other reviews that evaluate

workplace PA interventions, it is evident that individual-level interventions are far more common in the literature than organisational-level strategies and that very few are integrated into workplace productivity (19,21–23). It has been suggested that interventions that are “nice to have” add-ons may be more easily implemented and less disruptive in the short-term but are far less likely to be sustained compared with integrated solutions, especially when workplaces face challenges financially, structurally, or culturally (147).

A review by Daniels et al (2017) investigated the wellbeing effects of organisational-level interventions involving job redesign (changes in task variety or skill use) (148). While finding mixed evidence across interventions, they assessed the evidence for training workers to improve their own jobs, combining job redesign with training, and system-wide changes to job design to be ‘promising’. Furthermore, there is evidence that this approach can also be effective in more physically strenuous jobs as well. A recent systematic review of organisational-level workplace mental health interventions in construction workers also found evidence of physiological stress reductions following job redesign (149).

The multilevel dimensions of the barriers and facilitators reported in the literature highlights the complexity of implementing a workplace PA intervention for mental health. Motivational barriers are reflected in often low participation rates, with Conn et al. (2009) reporting recruitment below 30% in many trials, especially for voluntary or individually delivered programmes (123). Other key barriers are a lack of organisational culture and management support, time constraints, workload demands, variable work environments, and inappropriate intervention delivery (24,25,142,146,150). Common opportunities and facilitators found in the literature include flexible and tailored approaches, integration with organisational policies, wellness champions and peer leaders, increased autonomy, cultural support and acceptance (24,25,142,146,150–152).

2.6 Conclusions

In summary, the literature indicates that a wide variety of workplace PA approaches can produce improvements in mental health and related outcomes, but the magnitude of these effects is generally small and highly variable across

studies (19,21–23,153). Evidence also highlights substantial heterogeneity in intervention content, delivery modes, job types, and methodological quality, making it difficult to identify universally effective strategies (19,21). Taken together, these findings suggest that future research must move beyond evaluating decontextualised, short-term, individually oriented programmes and instead focus on real-world feasibility and effectiveness, where outcomes are shaped by workplace context, organisational support, and the extent to which interventions can be implemented and sustained in routine practice. (154,155).

Greater emphasis on fidelity, context, and process evaluation is also needed to understand how and why interventions succeed or fail in real-world settings (140,141,156). Understanding how to tailor interventions to individual and organisational needs, preferences, and contexts remains a key challenge (18,106,145). Very few intervention designs consider the potential of the physical activity paradox (108), while approaches to implementing equitable interventions in 'complex' workplaces comprising both manual and sedentary roles remain underdeveloped (134). Furthermore, adoption of standardised, validated, and feasible measurement tools (combining self-report and device-based methods) are essential for accurate surveillance and evaluation (78,80,89,157,158).

PA is a critical determinant of mental health, with profound implications for wellbeing across the lifespan. While the evidence base for the benefits of PA is robust, the observed differences in the health outcomes associated with occupational and leisure-time PA, and the complexities of heterogenous work environments necessitate ongoing research and innovation. The workplace remains a vital setting for intervention, but success depends on contextually tailored approaches that address the diverse needs of the workforce. Bridging research gaps in measurement, equity, implementation, and sustainability will be essential to realising the full potential of PA promotion for population health in Scotland, the UK, and globally.

2.7 Implications for developing workplace physical activity interventions for mental health

Developing a workplace PA intervention for mental health for a workforce with varied activity levels, while also addressing the above barriers and facilitators, requires a consciously multidisciplinary stance. I adopted a complexity- and systems-informed approach to intervention development and evaluation, aligning with the updated UK MRC guidance (159), which emphasises understanding interventions as events in systems, attention to context, mechanisms, and adaptive implementation rather than linear cause-effect models. The updated MRC framework explicitly centres complexity, context and mechanisms, encouraging iterative, mixed-methods evaluation and engagement with stakeholders. Building on this, I used participatory co-creation methods to surface local knowledge, improve fit with workflows, and enhance legitimacy and uptake; I used Leask et al.'s (2019) framework as my organising guide for planning, conducting, evaluating, and reporting co-created public-health interventions (160). Leask et al. provide practical stages and governance for participatory development and reporting; applying this framework improves contextual fit and equity.

This stance is deliberately ontologically pluralistic in its disciplinary lenses. From public health, I drew on the socio-ecological tradition to situate behaviour within interacting layers (individual, interpersonal, organisational, environmental, policy) (161), which is particularly relevant for workplace PA and mental health where multilevel determinants co-produce outcomes. From occupational health/organisational psychology, I acknowledged job design and psychosocial risk by using the Job Demands–Resources (JD-R) model (162) as a sensitising framework to ensure the intervention does not inadvertently add load in high-demand roles and that it leverages job resources (e.g., autonomy, social support) that can support wellbeing and engagement. JD-R keeps attention on demands/resources balance, relevant to avoiding unintended harms in physically or psychosocially demanding jobs. From behavioural science, I was informed by micro-level behaviour-change mechanisms using COM-B as a light-touch diagnostic (capability, opportunity, motivation) and Framework thematic analysis (163,164) to identify salient barriers and enablers that can be addressed through specific techniques without losing sight of wider system constraints.

Operationally, this meant taking a complexity- and systems-informed route that first grounded design choices in an empirical understanding of the local system. In this case, how health, PA, work patterns, productivity and the physical environment interrelate in the workplace, so that candidate mechanisms and contexts were specified within an initial programme theory co-produced with stakeholders (159). From there, candidate intervention strategies could be selected where stakeholders indicate a good fit with existing capabilities, opportunities and motivations, and where proposals were unlikely to add load to already demanding roles, drawing on JD-R to preserve the balance between job demands and resources (162,164,165). Engagement with workers at ACS remained deliberately light-touch and iterative, privileging practical feasibility and local sense-making over heavy specification, so that the early design could adapt to the realities of routines, roles and resources while still accumulating practice-based evidence. Finally, evaluation focused on whether the intervention functioned as theorised and whether it was workable and acceptable in everyday conditions, using mixed methods to test provisional mechanisms, assess contextual contingencies, and examine the collective work required to embed new practices over time. These approaches are intended to preserve theoretical coherence while remaining pragmatic about implementation in heterogeneous workplaces.

2.8 Hierarchy of research

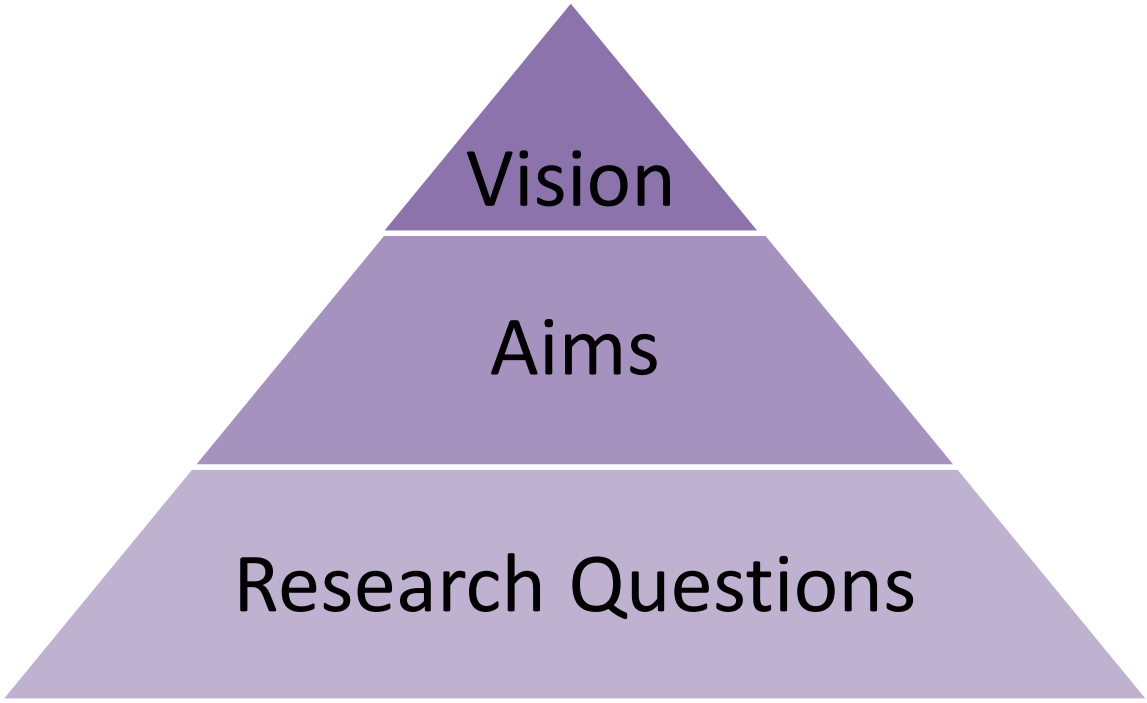

Figure 2-2. The hierarchy of research structure

Vision - The vision driving this PhD research was to develop a route map that workplaces can follow to create their own tailored PA interventions to improve the mental health of workers, which will have significant value to human health.

Aims – To achieve this vision, the aims were:

1. To systematically review the literature on previous workplace PA interventions effects on mental health.

2. To evaluate the physical health, PA, mental health and productivity of employees at ACS through a mapping process.

3. Based on the evidence from the review and mapping, co-create with ACS staff, a workplace PA intervention for mental health that is context sensitive.

4. To run a feasibility trial of the intervention and evaluate the acceptability and effectiveness of the intervention.

Research questions – The research questions that underpin the above aims are:

1. **Study 1 – Systematic review of workplace physical activity interventions and mental health outcomes**

    a. How effective are workplace PA interventions for improving mental health outcomes?

    b. Which outcomes (anxiety, depression, stress etc.) are these interventions most effective at improving?

    c. Is there any pattern in which intervention designs are more effective, and for whom?

2. **Study 2 – A mapping of mental health, productivity, and physical activity in a SME workplace across desk-based and manual labour roles**

    a. What are the existing patterns of PA and mental health across this workforce?

    b. Are there any significant differences in mental health and productivity between workers in desk-based roles and manual labour roles within the same workplace?

    c. Where differences do exist, how influential is PA behaviour at work and in other domains?

    d. What is the potential for improving mental health and productivity through changes to PA behaviour?

3. **Study 3 – Participatory co-creation of a context-sensitive workplace physical activity intervention for mental health**

    a. Informed by the findings of the mapping study and given examples of workplace PA interventions from the literature, which interventions do the staff and managers of ACS suggest would be desirable, acceptable and feasible at their workplace?

b. What barriers and facilitators to implementation do staff and managers anticipate for proposed interventions?

c. What adjustments or considerations can be made to the design or components of proposed interventions to increase the acceptability and feasibility of implementing selected interventions at ACS Clothing?

4. **Study 4 – A feasibility trial of a workplace-wide physical activity intervention for mental health**

    a. What is the feasibility and acceptability of a co-developed workplace PA intervention for mental health?

    b. What are the perceived impacts, and barriers and facilitators to implementation of the intervention?

    c. Can mental health and PA be measured acceptably, and is there evidence for potential beneficial effects?

As discussed in the previous Chapter, this study order was the planned linear trajectory of the PhD project. However, to meet the expectations of the participating workplace (ACS) and sustain engagement with the stakeholders, the mapping study (originally study 2) was prioritised and initiated first. Therefore, this thesis will continue with the reporting of that study in Chapter 3, so as to present the PhD project in a chronological order.

2.9 Key points of Chapter 2

- Mental ill health is major contributor to disease burden globally and productivity losses for workplaces.

- There is strong evidence that higher levels of physical activity are associated with better mental health.

- The workplace is a key setting for physical activity interventions, given the large proportion of time adults spend at work and the potential for organisational and policy-level change.

- The physical activity paradox suggests that occupational physical activity does not confer the same health benefits as leisure-time physical activity and may even be harmful at high levels.

- There is consistent evidence that workplace interventions can increase physical activity and improve mental health, but effects are generally modest, heterogeneous, and often not sustained long-term.

- Evidence of workplace physical activity interventions' feasibility and effectiveness is overwhelmingly from homogeneous workforces; there is a gap in the evidence for intervention development and implementation in mixed-activity profile workforces.

- Implementation and evaluation challenges include organisational culture, equity, measurement, and sustainability, but opportunities exist through systems approaches, tailored approaches, and integration with organisational policies.

Chapter 3 A Workplace Mapping Study and The Evolution of the Annual Wellbeing Evaluations (AWEs)

3.1 Background

Evaluating and systematically measuring current patterns of health and physical activity (PA) prior to intervention development and implementation is widely recognised as a foundational step in the design of effective health promotion initiatives across workplace settings (166). Conducting comprehensive pre-intervention assessments enables the mapping of PA and health status across the target environment, facilitating the identification of specific areas of need, including priority outcomes and subpopulations that may benefit most from intervention efforts (25). Such baseline data are essential not only for tailoring interventions to contextual and individual characteristics but also for establishing a comparator against which the effects of the intervention can be evaluated (167). Furthermore, the process of baseline assessment serves as a critical mechanism for engaging employees and management, by fostering transparency, building trust, and incentivising active participation in both research and subsequent intervention activities (156,168). Review evidence in both workplace and community-based PA interventions underscores that early and meaningful stakeholder involvement, facilitated through needs assessments and baseline data collection, enhances organisational buy-in and program fidelity, ultimately contributing to more successful implementation and sustainable health outcomes (24,169). In sum, robust pre-intervention assessment can inform the design, targeting, and evaluation of PA interventions, while simultaneously promoting stakeholder engagement and ownership, which are key determinants of intervention effectiveness and sustainability (25,156,168).

Therefore, a mapping process was decided upon as a key first step for this PhD project to understand the context and engage the employees in the study, while building trust and rapport with the research team. To assist with design and implementation of the mapping, and future phases of the PhD project, a workplace steering group was established that consisted of ten members of ACS staff. This steering group met once per month, starting in May 2022 and ending

in October 2024. Meetings took place in a meeting room at the worksite and lasted between 30-60 minutes, depending on the meeting agenda, with all attendees granted the time away from their work by ACS. Members of the group varied over the course of the PhD project due to conflicting commitments or staff turnover. However, participants were from a diverse range of job roles at the workplace, with representation from most departments. Anonymous meeting minutes were recorded by researcher field notes.

In collaboration with the steering group, the mapping process was designed to include two components: an audit of the existing health promotion environments and policies within ACS and an observational study of the physical and mental health and PA patterns of employees. The observational study was designed as a workplace-wide offer of personalised wellbeing evaluations. Employees at ACS Clothing were offered the opportunity to take part in Annual Wellbeing Evaluations (AWEs) and would receive an individual report on their outcomes as part of their participation.

The Annual Wellbeing Evaluations (AWEs) were to be repeated annually for three years (2022, 2023, 2024) and used as cross-sectional observations of changes over time, designed to provide evidence on patterns of PA and wellbeing across occupational groups within this workplace. While the purpose of the first year was to generate a baseline and inform the development of feasible workplace-specific PA interventions, it was not viable to use the following years as follow-up testing for the future intervention, which will be reported in Chapter 6. Instead, the aims of repeating the observations were to answer the following three research questions:

1. How much does mental health and wellbeing vary across the workforce throughout the period of the PhD project?

2. Are there any associations between job type and wellbeing?

3. If there are any associations between job type and wellbeing, are they influenced by PA compositions?

4. Which PA behaviours can be changed to improve to improve outcomes?

Yet, once implemented in the workplace, the AWEs quickly evolved beyond their initial remit. As an embedded researcher, I was positioned not only to collect data but also to observe how employees and managers engaged with the process. What emerged was a striking pattern: the AWEs were not experienced as neutral measurement exercises, but as potential mechanisms for change in themselves. Employees interpreted their personalised reports as feedback and often acted upon them, even before an organisation-wide report had been presented to the managers and the board of directors. Some individuals told me directly that they had spoken to their doctor after receiving elevated blood pressure readings, joined fitness challenges, or adopted new dietary practices. Following the organisational level report, I observed tangible changes such as modifications to the cafeteria menu and initiatives to promote active travel. These responses underscored a central reality: observation, when coupled with feedback, can itself be a health intervention, a principle recognised within the International Classification of Health Interventions (ICHI) (170). At both the individual and the organisational level changes were made before the researcher-led intervention of this PhD could be developed and implemented.

Therefore, to reflect this learning and how it impacted the PhD whilst still achieving the pre-defined objectives of the AWE (mapping and baseline), the discussion section of this Chapter is split into two sections. The first section will summarise and interpret the collective findings across three AWEs, then discuss the limitations and strengths of the study. The second section, titled “Strategic pivots” will describe in more detail the adaptations of the AWE design towards an engagement tool as a response to participant feedback and the resulting web-based toolkit developed as part of the study.

3.2 Methods and materials

This was a repeated cross-sectional study, designed to measure workplace wellbeing outcomes across three consecutive annual measurement periods. A repeated cross-sectional design was particularly suited for monitoring changes in workplace wellbeing at the organisational level, as it avoided attrition bias inherent in longitudinal panel studies and facilitated the examination of compositional shifts in the workforce. Each data collection, known as AWE to the

workforce, was carried out at the same time of year to minimise seasonal effects and ensure comparability.

Designed and reported according to the Strengthening and Reporting of Observational Studies in Epidemiology (STROBE) guidelines (171). The study was approved by the College of Medicine, Veterinary, and Life Sciences ethics committee at the University of Glasgow (study number 200210186), statement available in Appendix 3-A.

Participants and setting

This study took place at the main worksite of ACS Clothing Ltd (ACS), in North Lanarkshire, Scotland. The site is host to between 100-120 employees (depending on seasonal fluctuations), and all were invited to take part in the project through internal emails and staff meetings. Any employees that volunteered to take part in the AWEs, were provided participant information on the study, privacy notice, and signed informed consent (Appendix 3-B). Employees were offered an individual report of their personal results from the AWE as an incentive, sent via encrypted email following processing and scoring of their data. These reports contained individual results for each of the outcome measures. Alongside each reported outcome, were normal ranges for each outcome in the physical health measures, guideline recommendations in the case of PA outcomes, or cut point classifications in the case of questionnaire measures for mental health and wellbeing.

Consultation was sought with GR, ED, and PK of the research team on what measurements to include in the AWEs. The consensus amongst the researchers was that the range of measures should satisfy three key stakeholder groups. Firstly, we included measures that we believed would be of interest to the workplace (i.e. employer and employees) and which are relevant to wellbeing and productivity. Secondly, we considered the literature on best methodological practice for measuring PA and mental health in non-clinical populations (Chapter 2). Thirdly, some measures, such as cortisol, were selected to bring a physiological aspect to the outcomes and acknowledged pre-defined outcomes agreed with the medical research charity funder (Medical Research Scotland).

Sociodemographic, physical health, PA, mental health, and work productivity and engagement outcomes were all measured as part of each AWE, which took place during October and November 2022, 2023, and 2024. Participants were asked to complete three phases of data collection: 1. Physical health outcomes, 2. One week wearing an accelerometer and heart rate monitor to track PA patterns, and 3. An electronic survey that included questions on basic demographics, perceived productivity, work engagement, mental health, sleep quality, and physical health. The first and third phase of the AWE were conducted before and after the week of PA tracking respectively. Each took approximately 20–25 minutes to complete in a room separate from the main working environment (boardroom for physical health outcomes and staff training room for the survey). Time away from normal work tasks for the AWE was agreed with ACS and participants were made aware that they did not need to make up the time.

Various job roles exist within this worksite, including roles that involve manual labour tasks, both stationary and ambulatory, within a warehouse, and roles that involve predominantly desk-based tasks either within the warehouse area or in office settings. For the purposes of this evaluation of the employees' mental health and PA, participants were categorised into either of two job types: desk-based workers or manual workers.

3.2.1 Workplace audit

Physical environment

The Checklist of Health Promotion Environments in Worksites (CHEW) was applied as an audit tool to record the available resources and environmental facilitators for healthy behaviours, at the worksite (172).

Health promoting practices and policies

Existing policies and practices that specifically targeted PA, mental health, or physical health were recorded from discussions with the company human resources (HR) department.

3.2.2 Physical health outcomes

Resting heart rate and blood pressure

Resting heart rate and blood pressure (BP) were measured following a 5-minute seated rest period in a quiet room with no talking. Blood pressure was assessed using an automated device (Omron PA350, Omron Healthcare, Japan), with the cuff placed on the upper arm and the tested arm supported at heart level. Resting heart rate was recorded automatically at the end of each BP measurement. Two measurements were obtained for all participants, with a third taken if readings differed substantially or were disrupted. Mean systolic BP, diastolic BP, and resting heart rate from valid measurements were used for analysis.

Height and Weight

Height was assessed using a stadiometer (Seca 213, Seca GmbH & Co. KG, Hamburg, Germany). Participants removed their footwear and stood upright on the stadiometer platform with feet flat, positioned together, and heels aligned with the heel locator. The researcher then lowered the headpiece until it made firm contact with the crown of the participant's head, and height was subsequently recorded from the measurement scale. This measurement was taken again, repeating until two values agreed within 0.2 cm, with an average recorded for analysis.

Weight was assessed using electronic scales (Seca 899, Seca GmbH & Co. KG, Hamburg, Germany). Participants removed their footwear, outer garments, and any heavy items from their pockets prior to measurement. They then stood motionless in the centre of the scale platform until the display stabilised, at which point the researcher recorded the value. The procedure was conducted twice, and the mean of the two concordant measurements was used for analysis.

Hand grip strength

Absolute hand grip strength was assessed using a JAMAR Plus+ hand grip dynamometer (Sammons Preston, Performance Health, Warrenville, IL, USA),

following the National Institute for Health Research guidelines for this procedure (173). Participants were seated with both feet flat on the floor (without footwear) and their arms resting on the chair armrests. After a brief demonstration of the device, participants were instructed to hold the dynamometer in their left hand and exert maximal force. Once the reading had stabilised, the procedure was repeated for the right hand. Each hand was tested three times, and the mean of the three valid trials was used as the representative grip strength value (in kg) for that hand.

Hair cortisol samples

Hair cortisol concentration was assessed as a measure of physiological stress using a standardised sampling protocol. A small lock of hair (~2–3 mm in diameter) was cut as close as possible to the scalp from the posterior vertex region, the site recommended for cortisol analysis due to its low variability and consistent growth rate (174). The proximal one centimetre of hair, representing approximately one month of cortisol deposition, was retained for analysis. Samples were immediately sealed in aluminium foil, labelled, and stored in a dry, dark environment prior to laboratory processing. Cortisol extraction and quantification were performed by trained laboratory technicians using enzyme-linked immunosorbent assay (ELISA) procedures in accordance with established analytical guidelines (175,176). Following repeated assays, a limit of detection of 1.5 nmol/L was applied, and samples below this threshold were winsorised to 15.0 pg/mg to ensure comparability across participants. Hair cortisol sampling was removed from the third AWE cycle after feedback from participants indicated that the procedure was perceived as intrusive and negatively affected willingness to re-engage in future assessments.

3.2.3 Survey outcomes

Wellbeing

Wellbeing was measured using the Warwick-Edinburgh Mental Well-being Scale (WEMWBS) (177). Participants were asked to answer questions by selecting, on a scale of five-point Likert scale, the statement that best matches their experience over the past two weeks. These statements were that they

experienced the feelings described: none of the time, rarely, some of the time, often, or all of the time. With 14 questions, this scale of one to five provides a minimum total score of 14 and maximum score of 70. The overall score for the WEMWBS is calculated by totalling the scores for each item, with equal weights. This scale has a standardised Cronbach's alpha of 0.91, demonstrating a high level of internal consistency. Additionally, test-retest reliability at one week of 0.83 ($p < 0.01$), and robustness against ceiling and floor effects, meant WEMWBS was appropriate for this study's aims (178).

Perceived Stress

Stress was assessed using the 10-item Perceived Stress Scale (PSS), a widely used measure of subjective stress appraisal that captures the extent to which individuals perceive their lives as unpredictable, uncontrollable, and overloaded during the preceding month (179,180). Participants responded to each item on a five-point Likert scale ranging from 0 = never to 4 = very often, indicating how frequently they experienced specific thoughts and feelings associated with stress. Total scores were calculated by summing responses across all items, yielding a possible range of 0 to 40, with higher scores reflecting greater perceived stress. Consistent with established interpretive guidelines, scores between 0–13 represent low perceived stress, those between 14–26 indicate moderate perceived stress, and scores between 27–40 reflect high perceived stress. The PSS has been shown to demonstrate good internal consistency, strong construct validity, and sensitivity to variations in psychological stress across diverse populations, making it an appropriate instrument for evaluating workplace stress within this study (181).

Depression and Anxiety

Depression and anxiety/stress were assessed using the 10-item Depression, Anxiety and Stress Scale (DASS-10) (182). Participants rated how much each of ten statements applied to them over the past week on a four-point scale ranging from 0 (did not apply to me at all) to 3 (applied to me very much, or most of the time). Subscale scores for depression and anxiety–stress, as well as an overall distress score (DASS-10 Total), were calculated by summing the relevant items, with higher scores indicating greater symptom severity. The DASS-10 has

demonstrated strong psychometric properties in clinical and community samples, including a stable two-factor structure and high internal consistency (anxiety-stress scale: α = 0.83, and depression scale: α = 0.85), and has been shown to discriminate effectively between clinical and non-clinical populations while remaining sensitive to changes in psychological distress over time (182). It was selected for this study because it offers a brief, reliable, and validated measure of psychological distress that is suitable for use in workplace settings with minimal participant burden.

Sleep Quality

Sleep quality was assessed using the Brief Version of the Pittsburgh Sleep Quality Index (B-PSQI), a shortened, validated measure designed to capture key dimensions of subjective sleep experience over the preceding month (183). Participants rated a series of items relating to sleep duration, latency, disturbances, and overall restfulness, with responses scored and summed to generate a global sleep quality score, where higher values indicate poorer sleep quality. The B-PSQI has demonstrated strong psychometric properties, including adequate internal consistency (α = .79–.91), excellent model fit in confirmatory factor analyses, and good sensitivity and specificity for identifying poor sleepers (184). The reduced index provides an efficient, low-burden tool suitable for use in workplace-based research while retaining the core psychometric properties of the full PSQI (185).

Absenteeism and presenteeism

Absenteeism and presenteeism were assessed using the absenteeism and presenteeism items from the World Health Organization's Health and Productivity Questionnaire (WHO HPQ) (186). These items form part of a validated self-report instrument designed to quantify workplace productivity loss by capturing sickness-related absences, reduced work performance, and patterns of work attendance. The absenteeism module asks participants to report the number of hours worked, expected hours, and days partially or fully missed due to health or other reasons, while the presenteeism module assesses perceived work performance relative to usual expectations. The HPQ has demonstrated strong psychometric properties, including excellent test–retest reliability for the

presenteeism scale (ICC = 0.89) and high internal consistency across occupational groups (Cronbach's α = 0.74–0.81). These properties, along with its extensive validation across large multinational workforce samples, support its use as a robust measure of productivity-related outcomes in workplace health research (187,188).

Perceived productivity

Workplace productivity, work engagement, and related psychosocial factors were assessed using the Health at Work Questionnaire (HWQ), a multidimensional self-report instrument developed to evaluate productivity in relation to worker health (189). The HWQ consists of items rated on a ten-point scale and captures six key domains identified through factor analysis: productivity, concentration/focus, supervisor relations, impatience/irritability, work satisfaction, and non-work satisfaction. Participants were asked to evaluate their work performance and experiences over the preceding week, considering their own perspective as well as perceptions from supervisors and co-workers to reduce social-desirability bias. The HWQ has demonstrated strong psychometric properties, including high internal consistency across most subscales (α = 0.84–0.96) and statistically significant correlations with objective productivity indicators such as "Time Lost," supporting its reliability and construct validity in workplace settings (190). It was selected for this study because it provides a nuanced, multidimensional assessment of workplace functioning that extends beyond absenteeism and presenteeism to capture broader aspects of employee wellbeing and performance.

Work engagement

Work engagement was assessed using the nine-item Utrecht Work Engagement Scale (UWES-9), a widely used self-report instrument that measures three core dimensions of engagement: vigour, dedication, and absorption. Participants rated items on a seven-point Likert scale ranging from 0 = never to 6 = always/every day, reflecting how frequently they experienced each engagement-related feeling at work (191). Subscale scores for vigour, dedication, and absorption were calculated by averaging their respective items, with higher scores indicating greater work engagement. The UWES has

demonstrated strong psychometric properties, with confirmatory factor analyses supporting its three-factor structure and evidence for good construct validity and high stability over time, particularly for the brief 9-item version (192). The UWES complements the other psychological and productivity-related scales in this study by capturing a positive dimension of employee functioning, work engagement, rather than productivity loss.

3.2.4 Physical activity outcomes

In year one, participants were provided with two devices to take away for a seven-day period. PA and sedentary behaviour data was collected using wrist-worn triaxial accelerometers (Actigraph GT3X-BT, ActiGraph LLC, USA), worn on the non-dominant hand and electrocardiography (ECG) heart rate monitors (Polar H-10, Polar Electro Oy, Finland) secured with an elasticated chest strap, with a standardised 24/7 protocol. Wrist placement for accelerometers was selected following the embedded researcher observation of manual job tasks within the workplace, where many tasks required standing while performing activities with arms and torso, for example ironing and sewing. Accelerometer data were collected at a raw sampling frequency of 30 Hz and later aggregated into 10-second epochs for analysis. To provide context to PA measurements, participants were also asked to complete a seven-day logbook noting their work start and finish times, time in bed, mode of transport to work, reasons for non-wear, and any other PA or exercise outside of work.

In response to participants in the first AWE finding the heart rate monitor chest straps uncomfortable to wear for the seven days, these were removed for years two and three in an effort to maintain recruitment levels within the workplace. Heart rate data was initially intended to be combined with accelerometer data in a machine learning model of PA behaviour classification. However, as this measurement was discontinued and to allow for comparison, PA was classified using only accelerometer data from all three AWEs.

Raw accelerometer data was downloaded using the ActiLife software (versions 6.13–6.15, available 2022–2025), before being exported and scored using a Random Forest Activity Classification Model (randomForest package, R software), which classifies each 10-second window (epoch) into one of four

activity classes: sedentary, stationary+ activities (standing or sitting utilitarian movements i.e. ironing a shirt), walking activities (active commuting, mopping floors), running/high energetic activities (carrying heavy boxes upstairs). These activities were then assigned to one of four activity intensities: sedentary, light, moderate, and vigorous. Walking activities were classified as light (<100mg), moderate (≥100mg) and vigorous (≥400mg) intensity. This two-step method of classification has been validated and applied previously (193). Predictions for each 10-second period were smoothed by modal filter spanning two lead and two lag epochs. Full monitoring days were considered valid if wear time was ≥ 960 minutes (194). Sleep duration was calculated using the van Hees algoirithm (195). Non-wear windows were classified as non-wear if the standard deviation (SD) of the vector magnitude (VM) was < 13 mg for 30 consecutive minutes, this is in line with the procedures established by Ahmadi et al (196), which can differentiate non-wear periods from sleep.

3.2.5 Analysis

Two methods of analysis were applied to the collected data: cross-sectional analysis to answer the mapping research questions and within-person analysis to assess any individual-level changes in mental health and wellbeing over time.

Descriptive data is presented as means with SD for continuous variables and counts with proportions (%) for categorical variables. Comparisons of AWE outcomes by year and job type are presented descriptively and in figures.

3.2.5.1 Cross sectional analysis

Cross-sectional analyses were applied in several structured stages to examine the differences in outcomes across survey years and between job types (manual vs desk-based roles) within each year. Separate linear regression models were fitted for each outcome. For each outcome, an initial confounder set was refined, ensuring that only covariates exerting a meaningful influence on the outcome were retained. Each stage of these analyses corresponds to the stated research questions as follows:

1. *How much does mental health and wellbeing vary across the workforce throughout the period of the PhD project?* → To assess temporal differences, pairwise contrasts between years one and two, and years two and three were estimated.

2. *Are there any associations between job type and wellbeing?* → Occupational differences were assessed by fitting year specific models to compare manual and desk-based workers within each survey year.

3. *If there are any associations between job type and wellbeing, are they influenced by PA compositions?* → Adjusted base models (outcome + retained confounders) were then used to identify which compositions of PA behaviours demonstrated meaningful associations with the outcomes where significant differences between either years or job types were observed. Only compositions that materially altered the outcome or contributed significantly through their components were carried forward.

4. *Which PA behaviours can be changed to improve to improve outcomes?* → In the final step, exploratory modelling of five-minute PA isotemporal substitutions was performed in the relevant outcomes and compositions to identify which changes in PA behaviour are most likely to impact mental health and wellbeing within this workplace. Isotemporal substitution modelling is a statistical approach used to estimate the effect on an outcome when a fixed amount of time (five minutes in this study) in one behaviour is replaced with the same amount of time in another behaviour, while holding total time constant (197,198).

Outcome-specific confounding variables: creating adjusted models

A comprehensive set of potential confounders was identified a priori based on theoretical considerations and prior empirical findings (Chapters 2 and 4). These included: age, sex, ethnicity, highest level of education, years worked at company, BMI, deprivation, and any extenuating circumstances in the previous 12 months (i.e. birth(s), death(s), severe accident or injury, relationship(s) breakdown, loss of home or job). These variables were selected to capture demographic, socioeconomic, and occupational factors that may influence both

PA and wellbeing outcomes. The initial inclusion of a broad set of covariates aligns with recommendations to avoid omitted variable bias and to enable robust confounder selection (199).

To identify outcome-specific confounders, a change-in-estimate (CIE) approach was employed, using a threshold of ≥10% change in the AWE year coefficients compared to a model where only the year of AWE was the independent variable. The CIE method is widely recommended in epidemiology for confounder selection, as it prioritises variables that materially affect the estimate of the exposure on the outcome, rather than relying solely on statistical significance (199,200). As a secondary check, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) were compared between reduced and full models. Covariates were retained if they materially altered exposure–outcome estimates (>10% CIE) or improved model fit as indicated by the AIC and BIC.

The procedure was as follows:

1. For each outcome, a base model including only Year (categorical) was fitted.

2. Each potential confounder was added individually to the base model, and the percentage change in the Year coefficients was calculated.

3. Confounders that altered any Year coefficient by ≥10% were flagged for inclusion.

4. A backward elimination process was then applied: starting from a model with all flagged confounders, each was removed one at a time, and the change in Year coefficients was recalculated. Confounders were retained if their removal resulted in a ≥10% change in any Year coefficient.

This process yielded outcome-specific reduced models that included Year and only influential confounders. Job type (Desk-based vs Manual) was then added to each reduced model to examine occupational differences. A table of influential confounders for each outcome can be found in Appendix 3-C.

Results are presented as adjusted mean differences with confidence intervals and sample sizes for each comparison. Together these analyses allow for a comparison between the cohorts of each AWE across three years and contemporaneous differences between job types in each AWE year.

Compositional analysis of physical activity data: identifying the patterns of physical activity behaviour

The composition of 24-hour PA was analysed using Compositional Data Analysis (CoDA) as PA outcomes represent part of a whole and are co-dependent with other parts of that whole measured within a set timeframe (93,95,96). For example, measurements of sedentary behaviour, LPA, and MVPA make up the whole of the time an individual will spend at work and can therefore be treated as a composition with three parts. A two-step approach was used to define each composition, firstly by setting a timeframe to analyse, and secondly to set the components of compositions to be analysed within that timeframe. Four timeframes were identified for analyses: work time (as defined by the start and end of a participants shift), non-work time (time on a workday outside of work time), whole workday (24 hours on a workday), weekend time (24 hours on a non-workday). Two compositions were analysed for each timeframe, the first focused on PA intensity, which included sleep, sedentary behaviour, light-intensity PA (LPA), and moderate-to-vigorous intensity PA (MVPA), and the second, which focused on PA type and comprised of sleep, sedentary behaviour, stationary+ activities (standing or sitting while physically active), and ambulatory activities (walking or running). In total, eight compositions were calculated as relative mean proportions from raw minutes for each timeframe and sleep was only included as a component of composition in the 24-hour timeframes.

For modelling the influence of each PA composition on outcome differences by year and job type, proportional compositions were transformed to isometric log-ratio (ilr) coordinates.

Identifying meaningfully influential compositions: does physical activity play a role?

The identification of meaningful PA compositions followed a structured two-stage process, based on methodology recommended by Chastin and Palarea-Albaladejo (91). In the first stage, all compositions were screened for potential relevance using model-fit comparisons. For each outcome that demonstrated a significant AWE year or job type difference, a reduced model (including only covariates) was compared with a composition-adjusted model that incorporated the ilr coordinates for each PA composition. Compositions were retained for further consideration if they improved model fit ($\Delta_{AIC} > 2$ or $\Delta_{BIC} > 2$) or contained at least one statistically significant ilr coordinate ($p < 0.05$). This stage produced a broad set of candidate compositions.

In the second stage, a subset of meaningful compositions was identified for interpretation. Because improvements in AIC and BIC were consistently large across all compositions, reflecting the orthogonality of ilr coordinates and the relatively simple structure of the reduced models, AIC/BIC alone were not considered sufficient indicators of meaningful association. Instead, compositions were classified as meaningful if they met at least one of the following criteria:

1. At least one ilr coordinate was statistically significant ($p < 0.05$);

2. The composition produced a substantial increase in explained variance, defined as an adjusted R^2 change of ≥ 0.15;

3. The composition was behaviourally plausible in relation to the outcome (e.g., weekend activity for work engagement, work-time activity for work-related outcomes).

Attenuation of the job type contrast was not used as a criterion because the Manual versus Desk-based contrast could not be estimated in several models, resulting in undefined attenuation values.

This process yielded a refined set of meaningful compositions for each outcome, which were subsequently carried forward to interpretation and exploratory isotemporal substitution analyses.

Isotemporal substitutions: predicting physical activity behaviour change outcomes

With influential compositions identified, exploratory isotemporal substitution modelling was implemented to quantify the predicted change in each outcome resulting from reallocating time between behavioural components. Five-minute substitutions were generated either for outcome × year × job type (for compositions identified in the job-type models) or for outcome × year (for compositions identified in the year-comparison models). This approach allowed the analysis to focus specifically on the behavioural reallocations most likely to influence wellbeing, based on evidence from the adjusted base models.

To highlight the most impactful isotemporal substitutions within each PA composition across AWE years, substitutions were ranked by the absolute magnitude of the predicted change, and only the largest effect within each composition were retained.

The resulting substitution estimates provide a map of how reallocating five minutes between PA behaviour components may affect outcomes across years where there are significant differences between AWE years or job types. These estimates form the basis for identifying the substitutions with the strongest potential influence and for interpreting how patterns of PA behaviour may differentially shape wellbeing across the workforce.

3.2.5.2 Within-person analysis for change between consecutive years

To assess potential effects of repeated participation in AWEs, within-person changes in survey outcomes were examined among participants who completed assessments in consecutive years (n=32). For each survey outcome, change scores were calculated between Year1→Year2 and Year2→Year3. Linear mixed-effects models were fitted with change in score as the dependent variable, comparison period (Year1–2 vs Year2–3) as a fixed effect, and a random intercept for participant to account for repeated measures among three-year completers. Models were run both unadjusted and adjusted for reported extenuating circumstances.

In the within-person analyses, participants served as their own controls across consecutive years. Accordingly, only time-varying covariates were considered for adjustment with the potential to influence year-to-year changes in wellbeing were considered for adjustment. Extenuating circumstances were included as the primary time-varying covariate, reflecting their plausible impact on both exposure and outcome over time. Models incorporated random intercepts to account for repeated observations within individuals, and results are presented for both unadjusted and adjusted specifications to allow transparent comparison of coefficient stability. This parsimonious approach avoids unnecessary over-adjustment in a modest sample while appropriately controlling for meaningful within-person confounding.

Results are presented as mean changes with 95% confidence intervals and p-values. Analyses were conducted in R (version 4.4.1) using the lme4, lmerTest, and compositions packages.

3.3 Results

In total, 122 employees took part in the AWEs over three years, providing a total of 181 evaluations. 78 participants attended one AWE, with 67 of those providing complete data across health measures, PA measurement, and survey. 29 participants attended two AWEs, 20 with complete data sets and 21 participants attended for 2 consecutive years (n=11 for years 1-2 and n=10 for years 2-3). 15 participants took part in all three years, 11 of which provided complete data for each AWE. Including those who went on to attend three AWEs, there were 32 participants who took part in back-to-back years and were included in the within-person analysis of outcome changes between AWEs.

The most often completed component of the AWEs was the physical health outcomes performed by the researcher, as this was the entry requirement to take part and where devices were provided to participants. Therefore, all 181 observations included physical health measures. Surveys were the second most completed component (89%) and device measurements the least often completed (79%).

Across all three years cohorts for the AWE cohorts were similar in number (65 in year one, 56 in year two, and 60 in year three). In years one and two, more males than females took part, while this reversed in year three. In every year, participants were predominantly White Scottish, while non-British Whites were also a consistently large proportion of each sample (range 29.23-36.84%). Table 3-1 shows the sociodemographic characteristics and mean results for physical health measures in each AWE year cohort.

Table 3-1 Sociodemographic characteristics and physical health measures of each AWE cohort.

CHARACTERISTICS	2022	2023	2024	OVERALL
***Sample size, n* (%)**	65 (35.91)	56 (30.94)	60 (33.15)	181 (100.00)
Sociodemographic				
Sex, *n* (%)				
Females	30 (46.15)	25 (44.64)	33 (55.00)	88 (48.62)
Males	35 (53.85)	31 (55.36)	27 (45.00)	93 (51.38)
Ethnicity, *n* (%)				
White Scottish	37 (56.92)	28 (50.00)	27 (47.37)	92 (52.27)
White Other British	3 (4.62)	2 (3.57)	5 (8.77)	10 (5.68)
White Other	19 (29.23)	19 (33.93)	21 (36.84)	59 (33.52)
Asian (Scottish or British)	1 (1.54)	1 (1.79)	0 (0.00)	2 (1.14)
Other Asian	1 (1.54)	0 (0.00)	2 (3.51)	3 (1.71)
Other Black	1 (1.54)	4 (7.14)	1 (1.75)	6 (3.41)
Other Ethnic Group	1 (1.54)	1 (1.79)	1 (1.75)	3 (1.71)
Prefer Not to Say	1 (1.54)	0 (0.00)	0 (0.00)	1 (0.57)
Age, Mean Years	40.35 ± 14.37	39.76 ± 12.45	42.03 ± 13.40	41.00 ± 14.69
Years Worked at Company	5.32 ± 6.23	3.73 ± 5.11	5.49 ± 5.72	4.91 ± 5.77
Physical Health Outcomes				
Male, Right Grip Strength (Kg)	42.63 ± 8.64	45.55 ± 7.40	46.27 ± 8.53	44.64 ± 8.28
Female, Right Grip Strength (Kg)	26.74 ± 5.05	29.08 ± 6.12	28.79 ± 5.58	28.16 ± 5.60
Male, Left Grip Strength (Kg)	40.19 ± 8.26	42.18 ± 7.65	43.24 ± 8.29	41.72 ± 8.08
Female, Left Grip Strength (Kg)	24.33 ± 5.58	26.97 ± 6.11	26.87 ± 5.20	26.02 ± 5.66
BMI (kg/m2)	27.03 ± 5.92	26.34 ± 5.19	26.93 ± 5.28	26.78 ± 5.47
BMI categories				
Underweight	1 (1.54)	2 (3.57)	0 (0.00)	3 (1.66)
Normal	26 (40.00)	22 (39.29)	24 (40.00)	72 (39.78)
Overweight	38 (58.46)	32 (57.14)	36 (60.00)	106 (58.56)
Cardiovascular				
Resting Heart Rate (BPM)	75.45 ± 12.79	71.63 ± 13.18	73.66 ± 10.63	73.68 ± 12.28
Diastolic Blood Pressure (mmHg)	78.29 ± 11.44	78.20 ± 9.45	81.32 ± 11.88	79.27 ± 11.05
Systolic Blood Pressure (mmHg)	131.43 ± 16.82	131.57 ± 12.46	136.46 ± 19.66	133.14 ± 16.74
Physiological Stress				
Cortisol (pg/mg of hair)	196.31 ± 408.33	218.36 ± 598.65	N/A	205.38 ± 492.98

3.3.1 Workplace audit

Physical environment

The CHEW audit of the worksite physical environment found that the single freestanding building, encompassing three floors, contained: four changing rooms (two male, two female); nine bulletin boards; zero signs or posters referring to or encouraging PA, sports, or exercise; two notices about dietary information on bulletin boards; one poster about mental health; nine total staircases and no elevators; no fitness centre, gym, or open grassy spaces on or near the worksite; one onsite canteen; and two vending machines (one for snack and soft drinks, the other for hot drinks). Full results from the checklist can be found in Appendix 3-D.

Health promoting practices and policies

ACS Clothing started offering employees mental health first aid training in the Spring of 2022 and repeated the course offering in 2023 and 2024. Photographs and names of certified mental health first aiders were then added to workplace posters to raise awareness of their availability and training.

Two new practices were proposed following and as a result of the workplace summary report from the first AWE. First, executive management implemented a change in the worksite cafeteria supplier in 2023, with an aim of improving nutritional offerings to employees. This was accompanied by a proposal to launch an active travel promotion for employees, in conjunction with a local charitable organisation. However, the active travel promotion did not progress beyond the planning stage.

No other PA, sedentary behaviour, or mental health initiatives or practices were reported by the HR team.

3.3.2 Physical activity compositions

Across all three years, manual workers spent a higher proportion of their time during work and across the whole workday in stationary+ physical activities (standing or sitting utilitarian movements i.e. ironing a shirt) and LPA, while

desk-based workers remain substantially more sedentary, as is shown in Figure 3-1 and Figure 3-2. Outside work (non-work time and at the weekend) the compositions were similar, with sleep proportions slightly higher on workdays for desk-based workers compared with manual workers in most years.

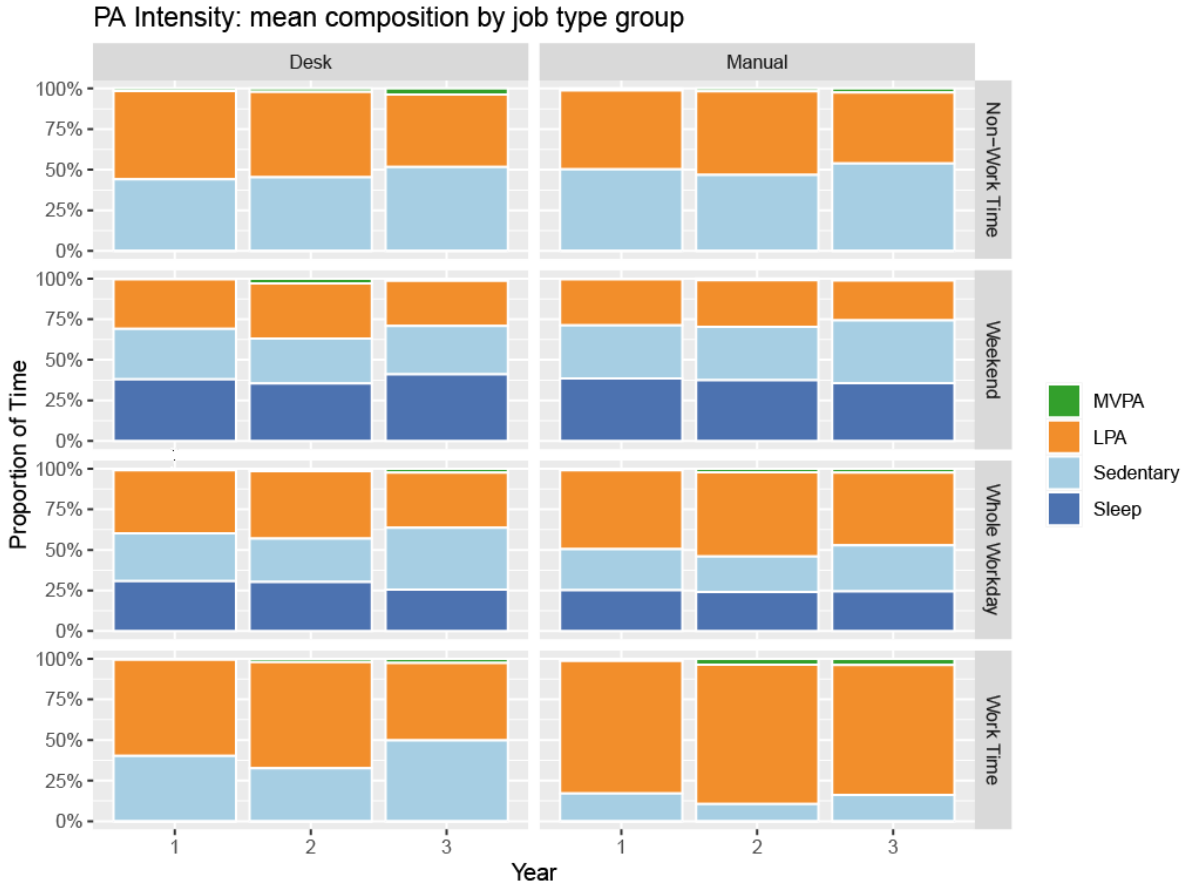

Figure 3-1 Shows mean PA intensity compositions in each of four timeframes (non-work time on a workday, weekend, whole workday, and work time) for manual vs desk-based workers in each year

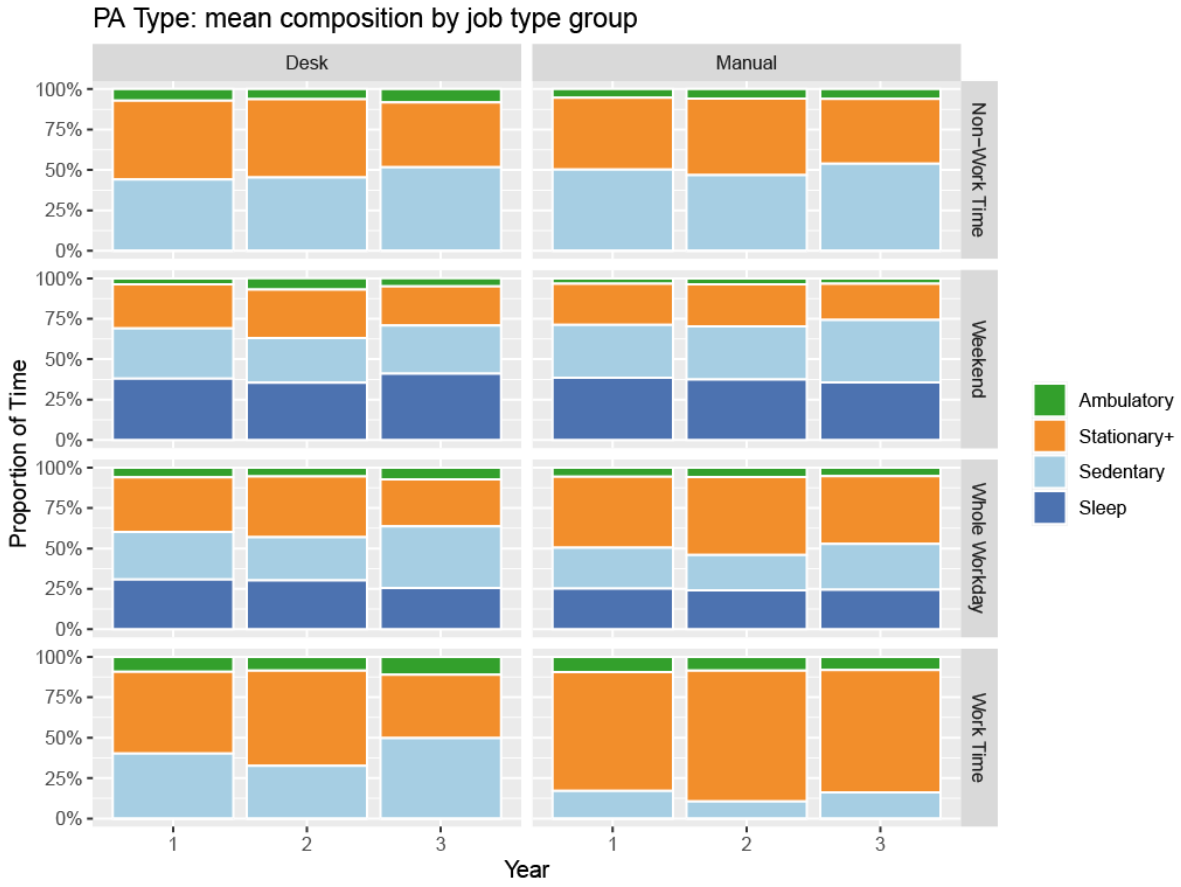

Figure 3-2 Shows mean PA type compositions in each of four timeframes (non-work time on a workday, weekend, whole workday, and work time) for manual vs desk-based workers in each year

Across both PA intensity and type domains, the most consistent pattern was that higher-intensity behaviours (MVPA and ambulatory activity) showed the lowest between-individual variability, regardless of job type, timeframe, or year. This reflects the very small mean proportions of time spent in these behaviours (range across job types, timeframes and years: MVPA = 0-4%; Ambulatory PA = 3-11%), leaving little room for meaningful variation between workers. In contrast, LPA, sedentary time, and stationary+ showed substantially greater variability, with wider standard deviations and interquartile ranges across all timeframes. This was particularly evident during work time, where both desk-based and manual workers displayed large between-individual differences in how they accumulated LPA and sedentary time. Outside work (Non-Work Time and Weekend), variability remained higher for LPA and stationary+ activities compared with MVPA and ambulatory PA but these low-intensity behaviours were consistently higher for manual workers during non-work time on a workday and

desk-based workers on the weekend. Overall, the variation structure aligns with the mean composition, such that behaviours occupying the largest proportion of the day (sedentary, LPA, stationary+) display the greatest heterogeneity, whereas less frequent behaviours (MVPA, ambulatory) show uniformly low levels across individuals. Means, standard deviations, interquartile ranges, and sample sizes are available for each job type, year, timeframe, and composition part combination in Appendix 3-E and 3-F.

3.3.3 Cross-sectional analysis

Consecutive year contrasts

Pairwise contrasts showed no differences in any survey outcomes between year one and year two. In contrast, comparisons between year two and year three indicated that depression and anxiety–stress scores (DASS-10) were significantly higher in year three, while all other outcomes remained consistent across years.

Job type contrasts (manual vs desk-based workers)

Within-year contrasts by job type showed that manual workers consistently reported poorer outcomes than desk-based workers across multiple domains. In year one, manual workers had significantly higher DASS-10 total scores, indicating worse depression and anxiety–stress profiles. Subscale analyses further demonstrated that depression scores were significantly higher among manual workers in both year one and year two, highlighting a persistent disadvantage in mental health across consecutive waves.

Occupational differences extended beyond mental health. In year one, manual workers reported significantly higher HPQ relative presenteeism, reflecting reduced productivity compared to desk-based workers. Manual workers also reported significantly higher HWQ-measured impatience, while UWES-measured absorption and dedication were significantly lower, indicating reduced positive engagement with work tasks. Sleep quality differences emerged in year two, with manual workers showing significantly higher PSQI scores, reflecting poorer sleep compared with desk-based workers.

Across all three years, no outcome was significantly worse for desk-based workers compared with manual workers. The only exception approaching significance was HWQ-measured non-work satisfaction in year three, which was marginally lower among desk-based workers (β = 1.69, 95% CI [-0.06, 3.45] p = 0.06). Full results, including effect estimates, 95% confidence intervals, p-values, and sample sizes for each comparison, are presented in Table 3-2.

Table 3-2 Adjusted models for AWE year comparisons and job type comparisons within each AWE year.

Measure	Sub-scale	Year1 - Year2	Year2 - Year3	Manual vs Desk (Year 1)	Manual vs Desk (Year 2)	Manual vs Desk (Year 3)
PSS↓		β = 1.60, 95% CI [-1.54, 4.73] p = 0.416; Year1: 59; Year2: 47	β = -0.83, 95% CI [-2.49, 3.92] p = 0.792; Year2: 47; Year3: 53	β = 1.95, 95% CI [-2.69, 6.58] p = 0.402; Desk: 14; Manual: 45	β = -0.21, 95% CI [-5.72, 5.29] p = 0.938; Desk: 12; Manual: 35	β = 1.63, 95% CI [-6.04, 9.30] p = 0.667; Desk: 12; Manual: 41
PSQI↓		β = 0.20, 95% CI [-1.05, 1.46] p = 0.907; Year1: 62; Year2: 47	β = 0.06, 95% CI [-1.20, 1.32] p = 0.991; Year2: 47; Year3: 53	β = 0.74, 95% CI [-0.98, 2.46] p = 0.392; Desk: 15; Manual: 47	***β = 1.94, 95% CI [0.44, 3.45] p = 0.013; Desk: 12; Manual: 35**	β = 1.78, 95% CI [-0.39, 3.96] p = 0.106; Desk: 12; Manual: 41
WEMWBS↑		β = -0.25, 95% CI [-4.56, 4.07] p = 0.988; Year1: 62; Year2: 47	β = 2.24, 95% CI [-2.24, 6.72] p = 0.427; Year2: 47; Year3: 53	β = -2.33, 95% CI [-8.15, 3.48] p = 0.424; Desk: 15; Manual: 47	β = 0.44, 95% CI [-6.87, 7.74] p = 0.904; Desk: 12; Manual: 35	β = 2.69, 95% CI [-8.45, 13.84] p = 0.626; Desk: 12; Manual: 41
DASS -10	Total↓	β = -0.26, 95% CI [-2.60, 2.08] p = 0.954; Year1: 62; Year2: 47	****β = 9.46, 95% CI [6.99, 11.92] p = < .001; Year2: 47; Year3: 55**	***β = 4.15, 95% CI [0.72, 7.59] p = 0.019; Desk: 15; Manual: 47**	β = 0.34, 95% CI [-4.51, 5.19] p = 0.887; Desk: 12; Manual: 35	β = -0.24, 95% CI [-5.90, 5.42] p = 0.932; Desk: 13; Manual: 42
	Anxiety and Stress Score↓	β = -0.29, 95% CI [-1.72, 1.15] p = 0.86; Year1: 62; Year2: 47	****β = 5.62, 95% CI [4.11, 7.14] p < .001; Year2: 47; Year3: 53**	β = 1.99, 95% CI [-0.22, 4.20] p = 0.076; Desk: 15; Manual: 47	β = 0.01, 95% CI [-2.92, 2.94] p = 0.996; Desk: 12; Manual: 35	β = -1.05, 95% CI [-4.04, 1.954] p = 0.481; Desk: 12; Manual: 41
	Depression Score↓	β = 0.03, 95% CI [-0.98, 1.03] p = 0.997; Year1: 62; Year2: 47	****β = 3.97, 95% CI [2.94, 4.99] p = < .001; Year2: 47; Year3: 53**	***β = 1.73, 95% CI [0.37, 3.08] p = 0.014; Desk: 15; Manual: 47**	***β = 1.72, 95% CI [0.06, 3.38] p = 0.042; Desk: 12; Manual: 35**	β = 1.00, 95% CI [-0.70, 2.71] p = 0.242; Desk: 12; Manual: 41

Measure	Sub-scale	Year1 - Year2	Year2 - Year3	Manual vs Desk (Year 1)	Manual vs Desk (Year 2)	Manual vs Desk (Year 3)
HPQ	Total (Combined Productivity) ↑	β = -0.00, 95% CI [-0.18, 0.17] p = 1.000; Year1: 61; Year2: 47	β = -0.08, 95% CI [-0.27, 0.10] p = 0.510; Year2: 47; Year3: 53	β = 0.26, 95% CI [-0.08, 0.61] p = 0.133; Desk: 14; Manual: 47	β = -0.05, 95% CI [-0.38, 0.29] p = 0.787; Desk: 12; Manual: 35	β = 0.17, 95% CI [-0.06, 0.41] p = 0.136; Desk: 12; Manual: 41
	Absolute absenteeism↓	β = 3.46, 95% CI [-8.74, 15.66] p = 0.749; Year1: 61; Year2: 47	β = 1.45, 95% CI [-11.24, 14.14] p = 0.953; Year2: 47; Year3: 53	β = -10.22, 95% CI [-31.65, 11.22] p = 0.343; Desk: 14; Manual: 47	β = 5.21, 95% CI [-20.57, 30.99] p = 0.685; Desk: 12; Manual: 35	β = 2.20, 95% CI [-11.03, 15.43] p = 0.737; Desk: 12; Manual: 41
	Relative Absenteeism↓	β = 0.03, 95% CI [-0.05, 0.12] p = 0.590; Year1: 61; Year2: 47	β = 0.01, 95% CI [-0.07, 0.10] p = 0.909; Year2: 47; Year3: 53	β = -0.07, 95% CI [-0.24, 0.09] p = 0.369; Desk: 14; Manual: 47	β = 0.03, 95% CI [-0.12, 0.18] p = 0.689; Desk: 12; Manual: 35	β = 0.02, 95% CI [-0.07, 0.10] p = 0.677; Desk: 12; Manual: 41
	Relative Hours of Work-	β = -0.03, 95% CI [-0.12, 0.05] p = 0.590; Year1: 61; Year2: 47	β = -0.01, 95% CI [-0.10, 0.07] p = 0.909; Year2: 47; Year3: 53	β = 0.07, 95% CI [-0.09, 0.24] p = 0.369; Desk: 14; Manual: 47	β = -0.03, 95% CI [-0.18, 0.12] p = 0.689; Desk: 12; Manual: 35	β = -0.02, 95% CI [-0.10, 0.07] p = 0.677; Desk: 12; Manual: 41
	Absolute Presenteeism Percentage↓	β = 4.78, 95% CI [-0.92, 10.48] p = 0.113; Year1: 61; Year2: 47	β = -2.33, 95% CI [-8.26, 3.60] p = 0.582; Year2: 47; Year3: 53	β = 5.19, 95% CI [-5.01, 15.38] p = 0.312; Desk: 14; Manual: 47	β = 6.86, 95% CI [-1.58, 15.30] p = 0.108; Desk: 12; Manual: 35	β = 9.61, 95% CI [-1.08, 20.31] p = 0.077; Desk: 12; Manual: 41
	Relative Presenteeism↓	β = 0.02, 95% CI [-0.12, 0.16] p = 0.950; Year1: 61; Year2: 47	β = -0.06, 95% CI [-0.21, 0.09] p = 0.607; Year2: 47; Year3: 53	**β = 0.28, 95% CI [-0.01, 0.57] p = 0.054; Desk: 14; Manual: 47**	β = -0.00, 95% CI [-0.23, 0.23] p = 0.991; Desk: 12; Manual: 35	β = 0.20, 95% CI [-0.03, 0.43] p = 0.083; Desk: 12; Manual: 41

Measure	Sub-scale	Year1 - Year2	Year2 - Year3	Manual vs Desk (Year 1)	Manual vs Desk (Year 2)	Manual vs Desk (Year 3)
HWQ	Total↑	β = -0.20, 95% CI [-0.71, 0.32] p = 0.598; Year1: 57; Year2: 47	β = 0.24, 95% CI [-0.29, 0.76] p = 0.498; Year2: 47; Year3: 53	β = 0.24, 95% CI [-0.49, 0.96] p = 0.514; Desk: 13; Manual: 44	β = 0.50, 95% CI [-0.55, 1.55] p = 0.342; Desk: 12; Manual: 35	β = 0.50, 95% CI [-0.80, 1.80] p = 0.438; Desk: 12; Manual: 41
	Productivity↑	β = 0.11, 95% CI [-0.36, 0.59] p = 0.814; Year1: 60; Year2: 47	β = 0.13, 95% CI [-0.36, 0.62] p = 0.771; Year2: 47; Year3: 53	β = 0.03, 95% CI [-0.67, 0.72] p = 0.942; Desk: 14; Manual: 46	β = 0.46, 95% CI [-0.41, 1.33] p = 0.287; Desk: 12; Manual: 35	β = 0.53, 95% CI [-0.66, 1.72] p = 0.369; Desk: 12; Manual: 41
	Concentration↑	β = 0.11, 95% CI [-0.74, 0.95] p = 0.942; Year1: 61; Year2: 47	β = -0.03, 95% CI [-0.92, 0.86] p = 0.996; Year2: 47; Year3: 53	β = 0.03, 95% CI [-1.29, 1.36] p = 0.959; Desk: 14; Manual: 47	β = 1.51, 95% CI [-0.22, 3.24] p = 0.084; Desk: 12; Manual: 35	β = 1.47, 95% CI [-0.73, 3.66] p = 0.182; Desk: 12; Manual: 41
	Supervisor Relationship↑	β = -0.72, 95% CI [-1.63, 0.19] p = 0.140; Year1: 60; Year2: 47	β = 0.51, 95% CI [-0.44, 1.45] p = 0.380; Year2: 47; Year3: 53	β = 0.61, 95% CI [-0.55, 1.76] p = 0.297; Desk: 14; Manual: 46	β = 0.04, 95% CI [-1.97, 2.05] p = 0.967; Desk: 12; Manual: 35	β = 0.21, 95% CI [-1.72, 2.14] p = 0.827; Desk: 12; Manual: 41
	Non-work Satisfaction↑	β = -0.61, 95% CI [-1.48, 0.25] p = 0.199; Year1: 61; Year2: 47	β = 0.80, 95% CI [-0.10, 1.70] p = 0.087; Year2: 47; Year3: 53	β = 0.47, 95% CI [-0.57, 1.51] p = 0.370; Desk: 14; Manual: 47	β = -0.53, 95% CI [-2.49, 1.43] p = 0.587; Desk: 12; Manual: 35	β = 1.69, 95% CI [-0.06, 3.45] p = 0.058; Desk: 12; Manual: 41
	Work Satisfaction↑	β = -0.47, 95% CI [-1.16, 0.21] p = 0.214; Year1: 57; Year2: 47	β = 0.36, 95% CI [-0.34, 1.07] p = 0.413; Year2: 47; Year3: 53	β = -0.06, 95% CI [-0.98, 0.86] p = 0.897; Desk: 13; Manual: 44	β = 0.06, 95% CI [-1.37, 1.49] p = 0.930; Desk: 12; Manual: 35	β = -0.01, 95% CI [-1.61, 1.59] p = 0.993; Desk: 12; Manual: 41

Measure	Sub-scale	Year1 - Year2	Year2 - Year3	Manual vs Desk (Year 1)	Manual vs Desk (Year 2)	Manual vs Desk (Year 3)
UWES	Impatience↓	β = -0.19, 95% CI [-0.99, 0.62] p = 0.821; Year1: 61; Year2: 47	β = 0.22, 95% CI [-0.65, 1.10] p = 0.793; Year2: 47; Year3: 53	**β = 1.89, 95% CI [0.71, 3.06] p = 0.002; Desk: 14; Manual: 47	β = 1.64, 95% CI [-0.32, 3.59] p = 0.098; Desk: 12; Manual: 35	β = 1.53, 95% CI [-0.33, 3.40] p = 0.104; Desk: 12; Manual: 41
	Own Productivity↑	β = 0.24, 95% CI [-0.29, 0.76] p = 0.502; Year1: 60; Year2: 47	β = -0.08, 95% CI [-0.62, 0.47] p = 0.928; Year2: 47; Year3: 53	β = -0.17, 95% CI [-0.97, 0.62] p = 0.663; Desk: 14; Manual: 46	β = 0.67, 95% CI [-0.13, 1.46] p = 0.096; Desk: 12; Manual: 35	β = 0.67, 95% CI [-0.72, 2.06] p = 0.332; Desk: 12; Manual: 41
	Productivity Other-	β = -0.05, 95% CI [-0.61, 0.52] p = 0.974; Year1: 60; Year2: 47	β = 0.26, 95% CI [-0.30, 0.82] p = 0.476; Year2: 47; Year3: 53	β = 0.01, 95% CI [-0.77, 0.79] p = 0.982; Desk: 14; Manual: 46	β = 0.57, 95% CI [-0.38, 1.51] p = 0.234; Desk: 12; Manual: 35	β = -0.02, 95% CI [-0.83, 0.80] p = 0.971; Desk: 12; Manual: 41
	Total↑	β = -0.07, 95% CI [-0.68, 0.53] p = 0.944; Year1: 62; Year2: 47	β = 0.08, 95% CI [-0.55, 0.70] p = 0.945; Year2: 47; Year3: 53	β = -0.66, 95% CI [-1.59, 0.27] p = 0.162; Desk: 15; Manual: 47	β = -0.06, 95% CI [-1.27, 1.14] p = 0.914; Desk: 12; Manual: 35	β = 0.07, 95% CI [-1.05, 1.18] p = 0.905; Desk: 12; Manual: 41
	Vigour↑	β = 0.39, 95% CI [-0.28, 1.06] p = 0.320; Year1: 62; Year2: 47	β = -0.18, 95% CI [-0.88, 0.51] p = 0.777; Year2: 47; Year3: 53	β = 0.48, 95% CI [-0.48, 1.45] p = 0.320; Desk: 15; Manual: 47	β = -0.13, 95% CI [-1.22, 0.96] p = 0.808; Desk: 12; Manual: 35	β = 0.20, 95% CI [-0.86, 1.26] p = 0.710; Desk: 12; Manual: 41
	Dedication↑	β = -0.32, 95% CI [-0.94, 0.31] p = 0.419; Year1: 62; Year2: 47	β = 0.28, 95% CI [-0.39, 0.95] p = 0.549; Year2: 47; Year3: 53	*β = -1.06, 95% CI [-2.04, -0.08] p = 0.035; Desk: 15; Manual: 47	β = -0.04, 95% CI [-1.35, 1.28] p = 0.956; Desk: 12; Manual: 35	β = 0.14, 95% CI [-0.93, 1.20] p = 0.795; Desk: 12; Manual: 41

Measure	Sub-scale	Year1 - Year2	Year2 - Year3	Manual vs Desk (Year 1)	Manual vs Desk (Year 2)	Manual vs Desk (Year 3)
	Absorption↑	β = -0.22, 95% CI [-0.88, 0.43] p = 0.661; Year1: 62; Year2: 47	β = -0.01, 95% CI [-0.69, 0.67] p = 0.999; Year2: 47; Year3: 53	***β = -1.17, 95% CI [-2.13, -0.22] p = 0.017; Desk: 15; Manual: 47**	β = -0.58, 95% CI [-1.89, 0.73] p = 0.376; Desk: 12; Manual: 35	β = 0.59, 95% CI [-0.88, 2.06] p = 0.419; Desk: 12; Manual: 41

***P value <0.05**

****P value <0.01**

↑Positive coefficients indicate better than reference

↓Negative coefficients indicate better than reference

3.3.4 Influence of physical activity compositions

Of the three of the outcomes showing significant differences between the cohorts of AWE years two and three (depression score, anxiety-stress score, and total score from DASS-10), only the depression score was meaningfully influenced by any of the PA compositions (Appendix 3-G). PA type compositions for work time and whole workday, and the PA intensity composition for whole workday met the predefined criteria of containing at least one significant ilr coordinate and/or meaningfully increasing adjR^2 (>0.15). These results suggest that the distribution of PA behaviours during work time and across the full workday, may be relevant for depressive symptoms.

For the job type comparison models within each AWE year, where the outcomes DASS-10 total and depression score, HWQ impatience, PSQI sleep quality, and UWES absorption and dedications scores all had significant differences between manual and desk-based workers in at least one of the three years, there were 24 meaningfully influential PA compositions across work time, whole workday, and weekend timeframes (Appendix 3-H).

Isotemporal substitutions

In the models contrasting outcomes between AWE years, where only depression scores met the pre-defined criteria, the same reallocations of time within each of the meaningfully influential PA compositions were predicted to have the largest effect across all three years. Reallocating five minutes from sedentary type PA to ambulatory type PA across the whole workday produced the largest reductions in depressive symptoms, with the strongest effect observed in Year 2 when the predicted difference in score for this change in behaviour was -4.70 (-4.61 and –4.49 predicted change in score for years one and three, respectively). While the same substitution during work time also improved depression by reducing predicted scores by -3.12 in year one, -3.18 in year two, and -3.16 in year three. In terms of compositions of PA intensities, swapping five minutes of MVPA for sedentary time across the whole workday produced predicted changes in depression score of -4.60, -4.34, and -4.02 for years one, two and three, respectively.

To identify the single most impactful behavioural change for each outcome across job types and years, the strongest beneficial isotemporal substitution was extracted for every outcome–year–job-type combination. This approach collapses across compositions, retaining only the five-minute substitution that produced the largest improvement in the outcome of interest. The heatmap in Figure 3-3, presents the single most beneficial substitution per outcome and year, restricted to the job type with poorer scores (manual workers in all cases). By focusing on the most influential behavioural reallocations, the results highlight the specific changes in PA patterns that are most likely to yield meaningful improvements in wellbeing. A matrix showing the strongest five-minute substitutions for each outcome-year-job-type combination is provided in Appendix 3-I.

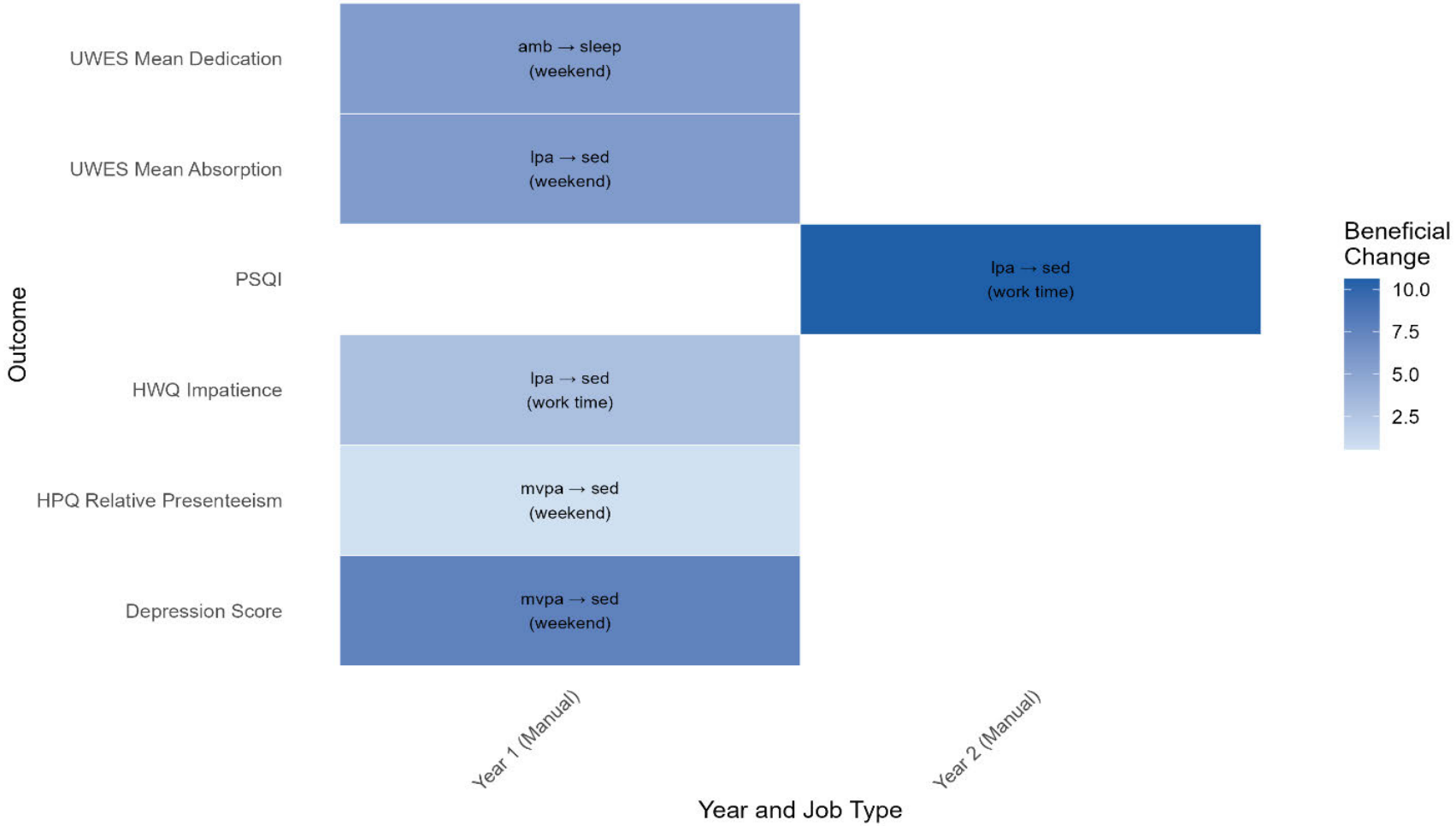

Figure 3-3. Heatmap showing the most beneficial isotemporal substitution per outcome and year for manual workers, who consistently exhibited worse scores. Each tile indicates the substitution direction and the composition timeframe (e.g., weekend, work time) in which the change is modelled. Colour intensity reflects the predicted magnitude of improvement.

Five-minute substitutions that reduced weekend PA (*mvpa → sed*, *lpa → sed*, *ambulatory → sleep*) were associated with predicted improvements in survey scores for depression (-8.98), presenteeism (-0.56), and dedication (+5.69) and absorption (+7.75) at work, suggesting that weekend recovery time may be particularly protective for manual workers. During work time, swapping five minutes of LPA for sedentary time was predicted to improve sleep quality scores by 10.63 in the 21-point PSQI scores for manual workers. The same isotemporal substitution was also predicted to reduce HWQ-measured impatience (scale 1-10) at work by 2.96 points.

3.3.5 Within-person analysis

Among participants with consecutive assessments (n=32), mean changes in all survey outcomes can be seen in Table 3-3 for Year 1 → Year 2 and from Year 2 → Year 3. No changes were found in wellbeing, sleep, perceived stress, work engagement, and productivity between any two AWEs. Mirroring the cross-sectional findings, only depression, and anxiety-stress scale (DASS-10) scores were significantly worse between Year 2 → Year 3. Adjustment for extenuating circumstances did not materially alter the results.

Table 3-3 Unadjusted and adjusted models of within-person changes between two consecutive years

Outcome	comparison	n	Adjusted estimate	Adjusted 95% CI	Unadjusted estimate	Unadjusted 95% CI	Adjusted p-value	Unadjusted p-value
WHO HPQ	Year1-Year2	19	-0.06	(-0.27 - 0.16)	0.00	(-0.20 - 0.21)	0.61	0.98
WHO HPQ	Year2-Year3	18	-0.07	(-0.35 - 0.22)	-0.05	(-0.34 - 0.24)	0.66	0.74
DASS-10	Year1-Year2	19	-0.22	(-2.40 - 1.96)	-0.41	(-2.40 - 1.58)	0.85	0.69
DASS-10	Year2-Year3	18	10.74	(7.85 - 13.63)	10.69	(7.84 - 13.54)	**0.00**	**0.00**
HWQ	Year1-Year2	17	-0.37	(-0.88 - 0.14)	-0.35	(-0.81 - 0.12)	0.16	0.16
HWQ	Year2-Year3	18	-0.06	(-0.73 - 0.61)	-0.05	(-0.70 - 0.60)	0.86	0.88
PSQI	Year1-Year2	19	-0.94	(-2.47 - 0.60)	-0.79	(-2.19 - 0.61)	0.24	0.28
PSQI	Year2-Year3	18	0.86	(-1.17 - 2.90)	0.90	(-1.11 - 2.91)	0.41	0.38
PSS	Year1-Year2	18	0.09	(-2.78 - 2.97)	0.11	(-2.56 - 2.78)	0.95	0.94
PSS	Year2-Year3	18	0.21	(3.65 - 4.08)	0.22	(3.56 - 4.00)	0.91	0.91
UWES	Year1-Year2	19	-0.24	(-0.85 - 0.38)	-0.21	(-0.77 - 0.35)	0.45	0.47
UWES	Year2-Year3	18	0.32	(-0.50 - 1.14)	0.33	(-0.48 - 1.13)	0.45	0.43
WEMWBS	Year1-Year2	19	-0.98	(-4.95 - 2.98)	-1.05	(-4.66 - 2.56)	0.63	0.57
WEMWBS	Year2-Year3	18	0.46	(-4.81 - 5.73)	0.44	(4.74 - 5.62)	0.86	0.87

3.4 Discussion

3.4.1 Summary of findings

Across the three years of AWEs, most outcomes remained stable between years with the exception of depression and anxiety-stress, which worsened significantly between years two and three. The compositional analysis demonstrated that PA behaviours during work time (start to end of shift) and across the full workday meaningfully influenced the increase in depression, but not in anxiety-stress. This mapping study also highlighted consistent disadvantages for manual workers across multiple wellbeing domains. Elevated depression and anxiety-stress scores, alongside poorer sleep quality and greater presenteeism, suggest that manual workers experience a heavier burden of psychological distress and reduced productivity compared with desk-based colleagues. The additional findings of higher impatience and lower work engagement components (absorption and dedication) further indicate that manual workers may face challenges in sustaining positive workplace behaviours. Compositional analysis showed that differences in PA behaviour during work time, across the whole workday, and at the weekend, meaningfully contribute to the disparities in mental health and wellbeing between manual and desk-based workers. Together, these results emphasise the need to consider occupational context when designing workplace mental health and wellbeing interventions and provide a rationale for examining whether PA compositions explain or mitigate these observed disparities.

Between years two and three, the organisation (ACS) underwent restructuring, redundancies, and ownership changes, which may have influenced mental health outcomes, particularly the observed worsening of depression and anxiety in year three. A systematic review of organisational change found that 11 out of 17 studies reported elevated risks of mental health problems following restructuring, with early evidence indicating that major downsizing can double the risk of health problems compared with periods of stability (201). More recent large-scale survey data similarly demonstrates that organisational changes, including downsizing and restructuring, are associated with increased psychosocial risks and poorer mental-health outcomes, with pooled analyses

showing elevated prevalence ratios for depressive symptoms (PR = 1.82; 95% CI 1.61–2.04) in employees exposed to such changes (202).

The observed differences in mental health and wellbeing between manual workers and desk-based workers can be partly explained by differing job demands. Manual work environments frequently involve low job control, high demands, and job insecurity, all of which are recognised psychosocial risk factors for mental health (133). For example, construction workers in China were found to have high levels of occupational stress, depression, and sleep disorders, with anxiety mediating the relationship between occupational stress and depression (203). In contrast, desk-based workers often face risks linked to sedentary behaviour and poor break habits, which can elevate stress and reduce wellbeing (204).

This mapping study also assessed mental health and wellbeing alongside measures of productivity that are relevant to the motivations of the workplace on an organisational level. The findings from the AWEs align with those of a survey of 4,953 workers across multiple workplaces and sectors, which found that depression and anxiety negatively affected occupational outcomes, including productivity loss and presenteeism, particularly in roles with high physical demands and limited flexibility (205). These results from a much larger sample population support the current observation that manual workers reported significantly worse depression in two of three years and greater presenteeism in the first year, suggesting that psychological distress in manual roles may lead to reduced workplace functioning. Globally, the World Health Organization estimates that depression and anxiety cost 12 billion working days annually, equating to US$1 trillion in lost productivity (7).

While previous research has consistently documented disparities between manual workers and desk-based workers, fewer studies have explored whether PA behaviours meaningfully contribute to these differences. A recent meta-analysis examining the associations of domain-specific PA with mental health found that work-related PA was associated with mental ill health (correlation effect size = 0.134, 95% CI 0.069 – 0.199) (58). However, only 54 of 372 studies included in this meta-analysis assessed mental health associations with work-

related PA, compared with 338 studies assessing leisure-time PA, highlighting that evidence in the workplace setting remains underdeveloped.

Against this backdrop, the present study adds new insight by identifying the PA compositions and contexts (i.e. work time, non-work time, and weekend) that exerted meaningful influence on job-type differences in mental health within the same real-world workplace. Furthermore, the isotemporal substitution models in this study provided exploratory predictive estimates of how reallocating five minutes between behaviours might affect mental health, wellbeing, and productivity outcomes. While these models lacked statistical power and should be interpreted cautiously, they nevertheless illustrate the feasibility of applying such methods in workplace research and indicate that larger samples may enable more robust predictive modelling that would be applicable to intervention design.

3.4.2 Limitations and strengths

Limitations

Several limitations should be acknowledged when interpreting the findings of this mapping study. First, the study design was cross-sectional, with partial overlap of participants across the three AWE cohorts. This limited the ability to draw conclusions about temporal change in mental health, wellbeing, and productivity across the workforce. While a within-person analysis of participants who completed consecutive AWEs confirmed the worsening of depression, anxiety and stress observed in the year-to-year contrasts in the cross-sectional analysis, this sample was underpowered for detecting differences between job types. Additionally, reverse causality cannot be ruled out. It is plausible that poorer mental health influenced PA behaviours, rather than PA patterns contributing to mental-health outcomes. The cross-sectional nature of the majority of the data prevents disentangling these bidirectional effects. Furthermore, as this study was in a real-world workplace setting that benefitted the external validity of the design, this meant important external factors that likely influenced outcomes, such as company restructuring, could not be controlled.

Despite strong participation rates, recruitment and engagement varied naturally across years, and participants self-selected into the AWEs. This raises the possibility of selection bias, whereby individuals with greater interest in health or higher wellbeing may have been more likely to participate. Furthermore, physiological stress indicators, specifically hair cortisol and heart rate monitoring, were not included in the final cross-year analyses due to processing delays and participant burden. Their absence meant that subjective measures of wellbeing could not be triangulated with biological markers, reducing opportunities for validation across measurement domains.

The isotemporal substitution models used in the analysis were exploratory and cannot be interpreted as prescriptive or causal. These models provide predictive estimates based on hypothetical reallocations of time between behaviours, rather than effects of actual behavioural change. Their limited statistical power further constrains the strength of any inferences that may be drawn.

Strengths

The key strength of this mapping study is its provision of mental health, wellbeing, PA behaviour, and productivity data collected over three consecutive years within the same workplace. This repeated cross-sectional design offered a rare opportunity to examine patterns at the organisational level while simultaneously comparing outcomes between job types. The consistency in timing, setting, and measurement protocols across years enhances the internal comparability of the data. Participation levels remained stable at approximately half of the workforce each year, and compliance with the multi-component data collection procedures was generally high. This degree of engagement is notable given the intensity of the assessments and was likely supported by the methodological pivots introduced throughout the study, which improved acceptability and reduced participant burden. The sustained involvement of employees over three years increases confidence that the data meaningfully represent the broader workforce rather than a small or highly selective subset.

Another important strength lies in the integration of self-reported mental health and wellbeing measures with device-measured PA in a real-world occupational setting. Such combined datasets remain uncommon in workplace health

research, where studies often rely solely on questionnaires or focus exclusively on PA monitoring. By incorporating both subjective and objective indicators, the study provides a more comprehensive understanding of how workers' behavioural patterns relate to their mental health and workplace functioning, and it highlights distinctions between manual and desk-based roles that may otherwise have remained obscured.

Finally, the application of compositional data analysis and exploratory isotemporal substitution modelling represent a methodological advancement within workplace PA and mental health research. These approaches allowed the study to move beyond simple volume-based metrics and instead consider the interdependent nature of time-use behaviours. Although exploratory, the predictive models demonstrated the feasibility of using such analytical techniques to estimate which reallocations of daily activity might be most impactful for improving mental health and wellbeing. This provides a useful foundation for future, more statistically powered studies seeking to model the potential effects of behavioural change in occupational settings.

3.5 Strategic pivots

Pivot One: From Literature to Action

The first pivot occurred before the AWEs had even begun. Rather than commencing with a systematic review, as would be expected in a traditional academic trajectory, the project was compelled to begin with recruitment and implementation of the AWEs. This was driven by organisational imperatives: management sought swift, visible impact, and employees were eager for practical engagement. The academic timeline of sequential, staged research was therefore compressed and reordered to align with the rhythms of the workplace. This pivot illustrates a broader methodological tension: the divergence between academic ideals of rigour and the pragmatic demands of real-world settings.

Pivot Two: From Data Collection to Intervention Through Observation

The second pivot emerged once the AWEs were underway. Although designed as a surveillance tool, the evaluations functioned as a catalyst for behaviour

change. The provision of individualised reports transformed the AWEs into a feedback mechanism, prompting employees to reflect on their health and wellbeing. At the same time, the group-level reports provided to management spurred organisational initiatives. In this sense, the AWEs became a dual-level intervention, simultaneously influencing individual behaviour and organisational practice.

Pivot Three: From Intervention to Engagement Tool

Sustaining participation in the AWEs required further adaptation. Employee feedback revealed that some measures, such as hair cortisol sampling and chest-worn heart rate monitors, were perceived as intrusive and burdensome. Furthermore, substantial time was needed for the processing and analysis of hair samples by university lab technicians, meaning that employees waited months for their feedback reports. Since the AWE had shifted focus from purely an observational data collection tool for mapping the workplace to a key part of the PhD project, these measures were removed in subsequent iterations to maintain engagement. The AWEs were streamlined to be more employee-friendly, balancing the need for robust data with the imperative of acceptability. This pivot reframed the AWEs as a mutually beneficial process: employees received personalised feedback, management gained actionable insights, and the research retained sufficient methodological integrity to generate publishable findings. The evaluations thus evolved into an engagement tool, fostering a culture of participation and reflection within the workplace.

Methodological Reflections

These successive pivots shaped not only the design of the AWEs but also the character of the data ultimately available for analysis. The removal of more intrusive measures, such as hair cortisol sampling and chest-worn heart rate monitors, inevitably reduced the physiological aspects of the dataset, while the emphasis on streamlined, employee-friendly protocols improved recruitment and retention across survey years. In this sense, the findings presented in this chapter must be interpreted with an appreciation of the AWEs' dual role as both research and engagement. The very adaptations that limited certain forms of measurement also enhanced ecological validity, ensuring that the evaluations

remained acceptable, relevant, and impactful within the workplace. The results therefore reflect not only patterns of wellbeing and PA, but also the organisational reality of conducting longitudinal health research in a dynamic, real-world setting.

3.5.1 Sustaining and Reframing the AWEs

A notable outcome of the Annual Wellbeing Evaluations (AWEs) has been the organisation's enthusiasm for their continuation. In the context of the methodological pivots and adaptations, ACS Clothing Ltd expressed a clear commitment to sustaining the AWEs as a recurring feature of workplace practice. This organisational buy-in is itself an indicator of feasibility: the evaluations were not only tolerated but valued by both employees and management, to the extent that they have become embedded within the company's annual rhythm.

From a conceptual standpoint, the adaptations of the AWEs align with the World Health Organization's International Classification of Health Interventions (ICHI) (170). Within the ICHI, observation and feedback, among others, are recognised as legitimate forms of health intervention. The AWEs therefore occupy a dual role: they are simultaneously a data collection tool for researchers and an intervention that engaged participants, increasing interest in their own health. This duality was evident in the behavioural responses observed at both individual and organisational levels, ranging from employees consulting their doctors or joining fitness challenges, to management introducing healthier cafeteria options and promoting active travel.

The reaction of the employees within this workplace to the AWEs is not a novel response, in fact a systematic review of evaluation studies found that most studies across clinical and public health settings showed behaviour change following observation or assessment (206). This behaviour change response to formal observation is often known as the "Hawthorne effect" and was first observed in factory workers at the Hawthorne Works Plant during a series of illumination experiments in the factory between 1924-1927 (207,208). These original studies have long been questioned for their methodological quality, but the Hawthorne effect continues to be a construct that is applied and evaluated

in health sciences (209,210). When it comes to changing PA behaviours, there is conflicting evidence for feedback as an effective mechanism. A recent meta-analysis of PA self-monitoring interventions found that feedback increased activity levels compared with no feedback (effect size d = 0.29) (211). While in contrast, a RCT delivering personalised feedback of PA measured by accelerometer to UK adults aged 32-54 years, found that despite increasing participants awareness of PA, there were no short-term increases in PA levels or intention to increase PA (212).

The iterative adaptation of the AWEs also resonates with the Plan–Do–Study–Act (PDSA) cycle widely used in quality improvement programmes (213). Each year of the AWEs represented a cycle of planning, implementation, reflection, and adjustment: intrusive measures were dropped, turnaround times for feedback were shortened, and reports were redesigned to be more visual and accessible. These changes were not deviations from the study design, but deliberate refinements aimed at strengthening engagement and sustaining participation.

This evolution of the AWEs offers a model for embedded evaluation that bridges academic and organisational domains. It demonstrates that workplace health research cannot be neatly separated from workplace practice: the act of measurement, when coupled with feedback, becomes intervention. The AWEs illustrate how observation, engagement, and intervention can be integrated within a single framework, producing outcomes that are simultaneously academically defensible and practically meaningful. The dual role of research and engagement, is promoted by the MRC complex intervention development framework that guiding this PhD (159), and may be a necessary feature of workplace health studies, particularly when conducted in partnership with organisations seeking both evidence and impact.

Employee Wellbeing Assessment Portal

In response to the reprioritising of engagement and feedback through the AWEs, a web tool has been developed to address the need for more time-efficient feedback and user-friendly reporting. This web tool, named the Employee Wellbeing Assessment Portal (EWAP), is designed for researchers and participants to submit data that can generate reports, as well as be exported for

analysis. Researchers are able to input the demographic and physical health data that was collected in the AWEs and have that data added to the data set for the project, while simultaneously generating a report for each individual and on an organisational level for assigned company administrators. The EWAP tool also allows individuals to answer survey questionnaires through the web portal directly. These responses, as with the physical health data, are then added to the data set for the project, scored by the system and outcomes (cut point classifications) are generated in the reports. It is planned that device-measured PA data will be added as a third component that also be directly uploaded to portal.

The EWAP tool meets the aim of faster feedback, is more convenient for participants, and increases the visualisation of feedback. Its potential is in the duality of engaging individual employees and organisations on health and its impact on productivity, while allowing researchers to collect and analyse workplace health data across multiple organisations, working populations and timeframes. Further development and expanded use of this tool could address workplace-specific research questions, which are often challenging to address due to underpowered primary studies.

3.6 Conclusion

This mapping study began as a programme of yearly cross-sectional observations of mental health and wellbeing, job engagement, and PA patterns, but in practice evolved into a sustained mechanism of engagement and change. Through successive pivots, accelerating implementation ahead of formally completing the literature review, reframing observation as intervention, and streamlining protocols to enhance acceptability, the AWEs became embedded within the workplace as both a research tool and an organisational resource. Their continuation reflects not only feasibility, demonstrated by the company's commitment to repeat cycles, but also acceptability, evidenced by employees' willingness to participate and act on feedback. The knowledge contribution of this work lies in showing that workplace health evaluations can be sustained when they are designed for engagement as well as rigour, producing data that is both practically impactful and provides a strong foundation for workplace intervention design.

The findings of the study provide a clear foundation for the development of targeted workplace interventions. The consistent disadvantages observed among manual workers across multiple wellbeing domains, coupled with the exploratory evidence that certain reallocations of PA behaviours may be beneficial, highlight the need for interventions that address both psychosocial job demands and patterns of movement during the workday. The data generated through the AWEs offer valuable insight into what changes to PA behaviours interventions should target and for whom efforts may be most impactful. Ultimately, the study supports the design of strategies that are context-specific, feasible within this workplace, and responsive to the behavioural and organisational realities identified through the mapping process.

3.7 Key points of Chapter 3

- This chapter reports on the mapping study, which was designed to provide contextual data for the design of a workplace physical activity intervention while evaluating any broader changes in mental health outcomes during the PhD project.

- Annual Wellbeing Evaluations (AWEs) were conducted at the workplace to measure mental health, physical health, physical activity, and productivity outcomes.

- Embedded research allowed for the observation of employee and organisational behaviour changes following feedback from the AWEs. As an adaptive response, the AWEs were pivoted to reflect their impact as intervention through observation, by reducing barriers to participating and streamlining feedback.

- Findings from three years of AWEs show that mental health, wellbeing, and productivity outcomes remained relatively stable across three years, with the exception of a worsening in depression and anxiety/stress in the third year.

- Job type comparisons showed that manual workers were worse off than desk-based workers in mental health, sleep quality, and work engagement across the first two years.

- Compositional analysis found that physical activity was meaningfully influential to the difference in depression between years and in all outcomes where a job type difference was observed.

Chapter 4 A systematic review of physical activity and exercise interventions for mental health or wellbeing in workplace settings

The current chapter has been submitted for publication:

Tumblety, C., Demou, E. Rosaini, N. D., Lu, J., Ryde, G. C. (2026). A systematic review of physical activity and exercise interventions for mental health or wellbeing in workplace settings. *In review – Occupational Medicine*.

4.1 Background

Poor mental health is one of the main causes of disease and disability worldwide (29,33,214,215). The World Health Organisation states that poor mental health is affecting every community and age group across all income groups and countries worldwide with 332 million people said to be suffering from depression alone (216). Depression is thought to be the leading cause of disability worldwide and contributes significantly towards preventable deaths from suicide and ischemic heart disease (29–32). The pandemic exacerbated this health crisis with some countries reporting a 3-fold increase in the prevalence of depressive symptoms since then (216,217). Strategies to reduce this burden and improve quality of life are therefore urgently needed.

Physical activity (PA) is a key strategy to prevent and treat both physical and mental health conditions. Numerous systematic reviews and meta-analysis have shown that exercise is highly beneficial for improving symptoms of depression, anxiety and distress across a wide range of populations and in those with or without a diagnosis of a mental health disorder (16,46,58). It is recommended as a 'mainstay' approach for improving mental health and can be as effective as anti-depressants (7-9), with intervention research showing that those who undertake exercise can have significant improvements in depressive symptoms that are comparable to those receiving psychotropic treatment (60). Prospective cohort studies suggest that regular engagement in PA can reduce the onset of depression in healthy adults without diagnosed clinical depression, highlighting its importance as a preventative strategy for those with good mental health (218). Despite this, 27.5% of adults globally are insufficiently active and

therefore missing the potential benefits of PA for mental health (12). Increasing PA at a population level is therefore a desirable solution to improve mental health.

The workplace is a potential setting in which to target the improvement of mental health through PA due to the amount of time adults spend in this environment and the prevalence of poor mental health in this setting. Approximately three-quarters of UK adults aged 16–64 are employed, with full-time work typically comprising 35–40 hours per week (219). Mental health problems are also prevalent in this setting with 1.7 million workers in 2023/24 reported to have work-related ill health; of these, 46% were due to mental health issues (220). Evidence regarding the effectiveness of workplace PA interventions on employee mental health and wellbeing remains inconsistent (19,21,22). A systematic review of 17 controlled and quasi-experimental studies by Chu et al. (2014) reported moderate evidence for reductions in depressive symptoms, while benefits for stress and anxiety were largely confined to yoga-based interventions (19). However, a more recent review of 22 randomised controlled trials found only limited positive effects on mental health outcomes and highlighted significant methodological limitations across the evidence base (21).

Previous reviews have predominantly prioritised randomised controlled trials, potentially overlooking evidence from non-randomised designs that may offer greater ecological validity by capturing intervention effectiveness within real-world organisational contexts. Given the complexity of workplace health promotion, where strict experimental control is often impractical, incorporating a broader range of study designs may provide a more comprehensive understanding of how PA interventions influence employee mental health in practice (27,137,140). An updated review that critically synthesises evidence across diverse methodological approaches is warranted to address these uncertainties and better inform evidence-based workplace health promotion strategies. Therefore, the aim of this review was to update the evidence of whether PA and exercise interventions in workplace settings are effective at increasing mental health or wellbeing outcomes.

4.2 Methods

Protocol and registration

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (221) and registered PROSPERO (registration number CRD42024585175).

Eligibility criteria and search strategy

The population, intervention, comparison, outcomes and study type (PICOS) framework (222) was used to develop the inclusion criteria as follows: Population: Working age adults employed by an organization; those involving self-employed, volunteer, or non-working populations, or cohorts with specific health conditions (e.g., cancer, diabetes, back pain), were excluded. Intervention: PA or exercise as the primary activity and be workplace-based and delivered, and supported or approved by the employer. Interventions where PA was only a minor component of broader programs (e.g., nutrition or wellness) were excluded. Comparison: Baseline or pre–post data, alternative PA interventions, waiting-list or standard practice controls, and clusters from similar work environments. Controls from different contexts i.e. not workplace, were excluded. Outcomes: Mental or psychological health and wellbeing via validated self-report measures (e.g., depression, anxiety, stress, mood, self-esteem, resilience) or biomarkers such as cortisol. Study type: randomised controlled trials, controlled or uncontrolled pre–post studies, controlled before-after trials, observational, pilot, and quasi-experimental studies. Cohort and case-control studies offering contextual insights were included, while cross-sectional, case, and feasibility or acceptability-only studies were excluded.

Systematic searches were conducted in the Medline, EMBASE and CENTRAL databases using the Ovid and Cochrane interfaces with no date restriction applied. Keywords and subject headings were tailored for each database to align with the setting (e.g. work, workplace, employee), intervention (e.g. PA, exercise, sports), and outcome measures (e.g. mental health, wellbeing, stress, anxiety, depression) of interest (see Appendix 4-A for full list of keywords and subject headings). Database searches were limited to peer-reviewed journal

articles published in English language from inception to 20th June 2024. References of the included studies were also screened for relevant articles.

Data management and extraction

Search results were imported into EndNote V.x9 (Clarivate, Philadelphia) deduplicated and exported into Rayyan.ai. Title/abstract and full-text screening were independently conducted, by two reviewers with 10% cross checked by at least one other reviewer. Two reviewers (CT and NDR) independently screened full texts. In cases where eligibility was not agreed, a third reviewer (GR or ED) helped to reach consensus.

A bespoke data extraction form was created and tested by three members of the review team (CT, GR, and ED). The same three reviewers used this form to extract data on study's title, authors, year of publication, country, workplace setting, job type, participant numbers and basic demographics, study design, intervention (including components, delivery, and duration), comparators, workplace/employer contribution, outcome measures, results relevant to this review, and barriers and facilitators to intervention reported by authors. All extracted data was independently reviewed by CT.

Risk of bias and certainty

One author (CT) appraised the quality of the included studies. The Cochrane Collaboration Risk of Bias Tool – version 2 (ROB-2) was applied for RCT studies (223) and the Risk of Bias in Non-Randomised Studies of Interventions tool (ROBINS-I) for all others (224). The National Institutes of Health (NIH) Quality Assessment tool was used for any study which had only pre-post data with no control group(225).

Certainty of evidence across outcome domains was assessed with the GRADE framework (139,226). The five GRADE domains (risk of bias, inconsistency, indirectness, imprecision, and publication bias) were evaluated for each outcome. As pooling was not feasible, certainty ratings were based on the direction and consistency of effects across studies, following guidance for applying GRADE to non-meta-analysed data (139). While GRADE begins with

randomised controlled trials (RCTs) as high-certainty evidence, this review applies a contextual adaptation, recognising that non-randomised designs in workplace settings may offer robust and relevant insights. Certainty ratings were informed by study quality, consistency, and applicability rather than design alone. This approach aligns with emerging perspectives in rehabilitation and public health research, where rigid design hierarchies may not reflect the complexity of real-world interventions (227). In addition, for outcomes with substantial heterogeneity in study design and risk of bias, exploratory subgroup assessments restricted to higher-quality studies (e.g., RCTs with low or some concerns for risk of bias) were conducted. Where such subgroups were sufficiently large in terms of total participant sample and met optimal information size (OIS) thresholds, their findings were considered as an anchor for the overall certainty rating. This approach reflects GRADE's allowance for upgrading certainty when a subset of robust studies provides consistent, precise evidence, even if the full body of evidence is weaker (139).

Data synthesis and analysis

Characteristics of the selected studies were tabulated according to author and year of publication, workplace/sector, job type and country, study design, intervention duration, participants, target outcome/s and measures/s, and description of PA intervention. It was not possible to conduct a meta-analysis due to the heterogeneity of the data. Instead, an Effect Direction Plot (EDP) was created to synthesise the findings of effectiveness of workplace PA interventions on outcome measures. This EDP is shown in Table 4-2 and follows the methods of Boon and Thomson (228,229). Outcome measures were grouped into the outcome categories of stress, anxiety, depression, quality of life, mood/affect and general mental health and wellbeing by CT and GR. General mental health and wellbeing was the most diverse category incorporating measures such as SF-36, GHQ, WEMWBS, COPSOQ, WHO-5, and concepts such as burnout. Whilst items such as vigour, vitality, work engagement, work limitations and productivity were reported in many studies these were deemed as out of scope for this review. Arrow size represents the sample size in the intervention group for a given study and outcome domain, with a large arrow indicating a sample size of more than 300, a medium arrow indicating a sample size of 50–300, and a small

arrow indicating sample size of less than 50. Up arrows indicate favourable effects, down arrows non-favourable effect, or two outwards pointing indicate mixed effects or no effect. A sign test was conducted to determine whether the distribution of positive versus negative findings within each outcome category differed from the null expectation of equal results (GraphPad (https://www.graphpad.com/quickcalcs/binomial1/)). Studies in the plot have been grouped by risk of bias with results of the EDP by outcome reported and PA type (categories agreed by CT and GR based on the description of PA intervention), and study design.

Subgroup analysis

Post-hoc subgroup analysis was used to investigate heterogeneity among study results by effect direction (favourable and non-favourable effects) and intervention attributes. Intervention attributes reported in previous literature to influence either mental health outcomes or effectiveness of PA and exercise interventions in the workplace and observed during data extraction were included (16). Intervention attributes included in subgroup analysis were PA type, whether the intervention reported an aspect of mindfulness, prescribed dose of PA (total minutes over the intervention) and group sessions. The prescribed dose of PA was calculated using the mean number of expected or delivered minutes of exercise per day/session multiplied by the expected number of sessions per week and the intervention duration. Where PA was said to be 'everyday' as opposed to a specific number of days, five workdays were assumed. Study duration and intervention duration were assumed the same where it was not specifically stipulated. It should be noted that 'dose' in this context did not include a measure of intensity as this was not frequently described (only four studies) and would therefore be subjective. For example, it is not easy to quantify the intensity of yoga, nor should it be assumed to be low intensity. To explore potential sources of heterogeneity within outcomes a priori thresholds were applied to identify potential patterns. Studies were grouped according to favourable and non-favourable effect directions. Intervention attributes were coded as present (1) or absent (0), and the proportion of studies containing each attribute was calculated within each effect direction group. A pattern was considered present when more than 60% of studies in one effect

direction reported the attribute and fewer than 40% reported it in the opposite direction, representing a minimum difference of 30 percentage points. This threshold was selected to indicate a clear majority while reducing the likelihood of spurious patterns. Dose was examined separately as a continuous variable; a pattern was considered present when there was a difference of greater than 15 hours between favourable and non-favourable effect groups.

4.3 Results

Search results

Initial searches returned a total of 14,457 reports (Figure 4-1 PRISMA flow chart). After de-duplication and title and abstract screening, 140 reports were selected for full text screening. Primary exclusion reasons included: wrong setting or population (n=27) and not primarily a PA intervention (n=19). Finally, 54 studies were eligible and included in the review with effect direction plot for 58 interventions where four studies reported more than one intervention or an eligible active control. These 58 are referred to from here on as interventions.

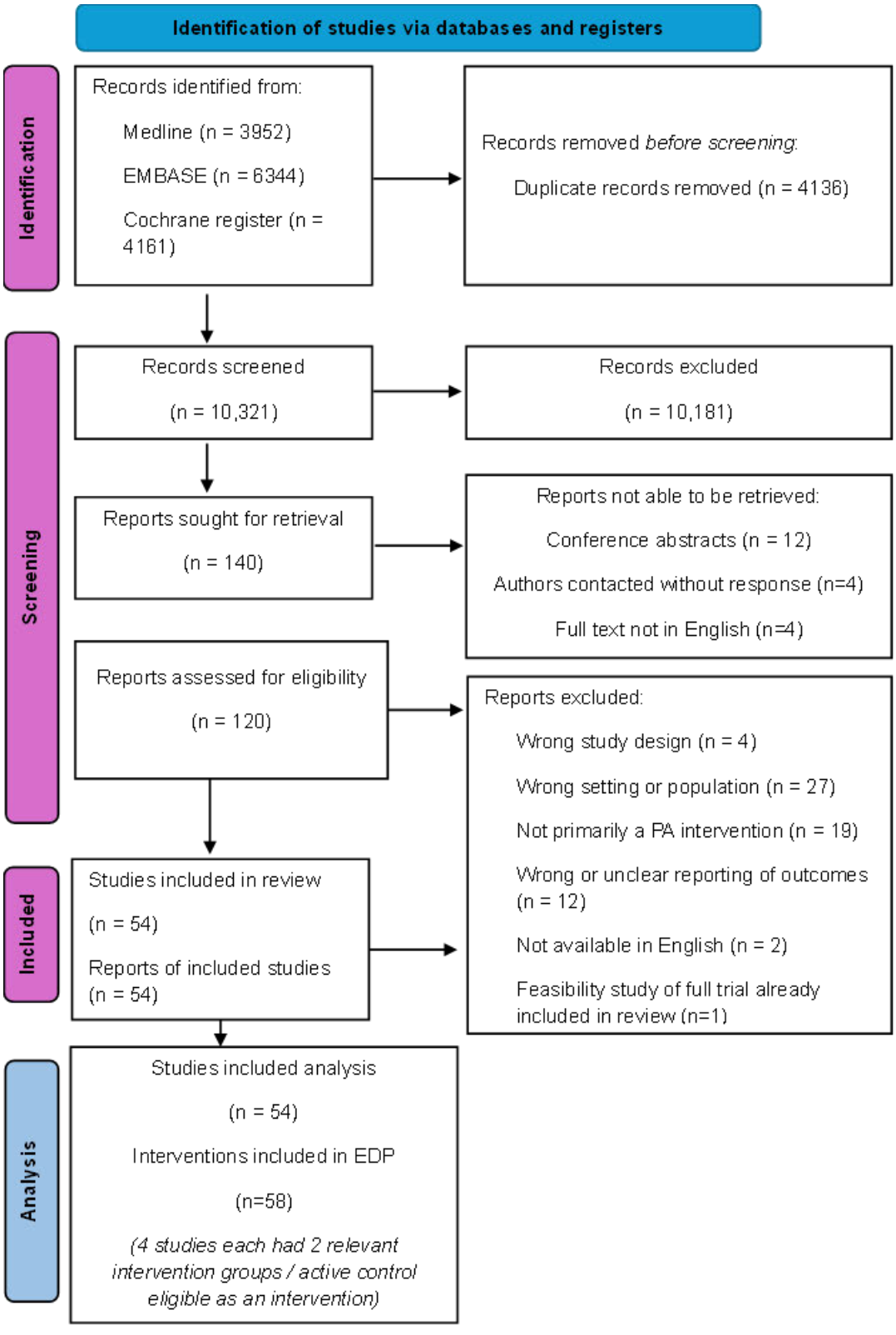

Figure 4-1. PRISMA Flow Chart of literature search and study selection

Study characteristics

The overall characteristics of the included studies are reported in Appendix 4-B. The included studies took place across five continents, with 28 studies from Europe [UK (n-5) , Spain (n-5), Germany (n-5), Finland (n-3), Denmark (n-2) and one each from Turkey, The Netherlands, Norway, Iceland, Belgium , Greece, Sweden and France], 11 studies from Asia [India (n-4),Taiwan (n-2), Japan (n-2), Iran (n-2), China (n-1)], eight studies from North America [USA (n-6), Canada (n-2)], six studies from Australasia [Australia (n-5), New Zealand (n-1)], and one study from South America [Brazil]. Thirty-three studies were randomised control trials (RCT), eight cluster-randomised control trials (CRCT) and five non-randomised control trails (NRCT) or quasi-experimental studies. Eight studies were pre-post intervention trials (PP). The most common workplace setting was a university (16 studies), followed by hospitals (11 studies). Other workplace settings included residential care, local authority government, industrial settings, telecommunications and manufacturing. Most interventions only reported one outcome (n=31), with 20 reporting two and seven reporting 3 or more. Twenty-seven interventions reported general mental health or well-being, 26 reported stress, 12 reported mood/affect, 11 reported anxiety, ten reported depression and nine reported quality of life. This review included 6,379 participants, with the smallest included study having 20 participants and the largest having 459 participants.

Risk of Bias and Certainty

Most studies were assessed using the ROB 2 tool for RCT study designs (223) (n=41). In these studies, the criteria most frequently assessed as having a low risk of bias were randomisation (n=26; 63.4%) and missing outcome data (n=24; 58.5%). The two main reasons for a judgement of high risk or some concerns were selection of reported results (e.g. a lack of predefined data analysis plan) (n=35; 85.4%) and measurement of outcomes (e.g. self-report measures) (n=32; 78.1%). A breakdown of the ROB 2 assessment is shown in Figure 4-2.

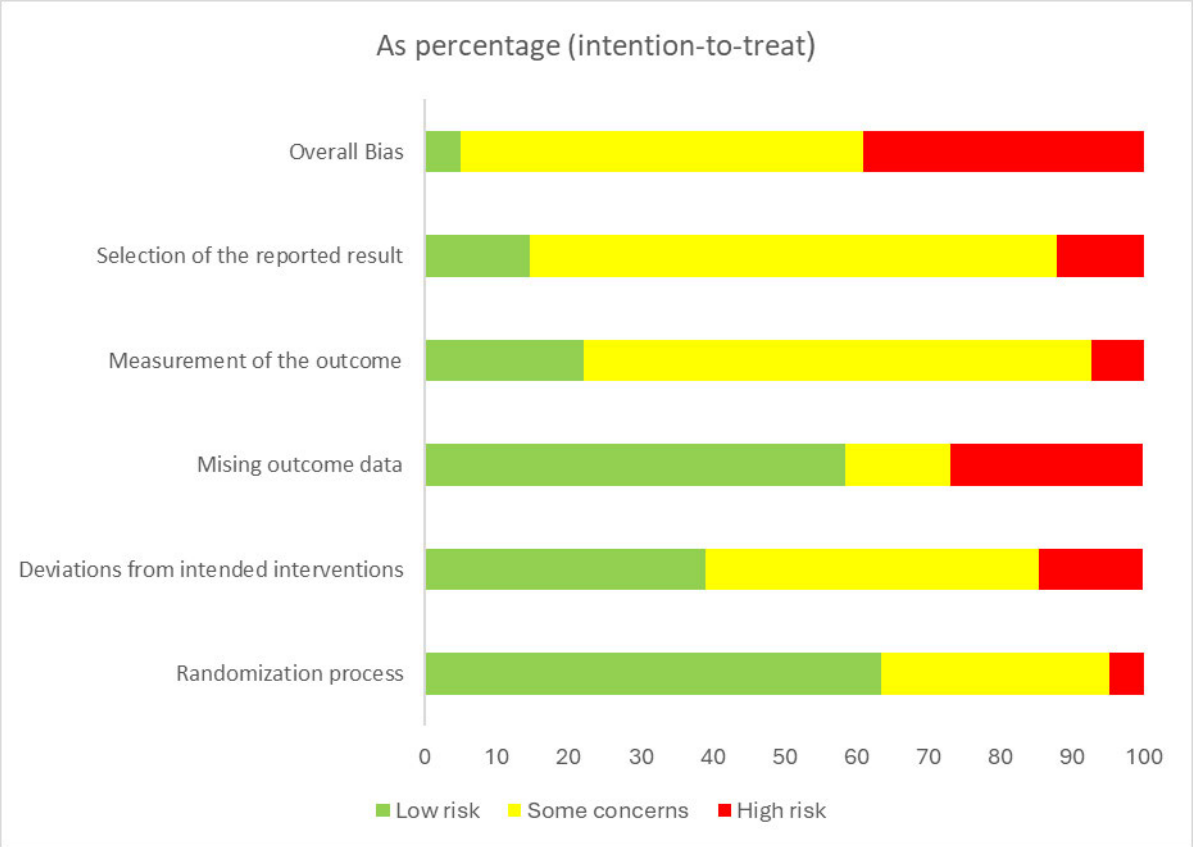

Figure 4-2. ROB 2 tool risk of bias assessment breakdown

Eight studies, identified as non-randomised studies, were assessed using the ROBINS-I tool (224), and five observational studies were assessed via the NIH Quality Assessment (225). The domain most frequently judged as 'serious concern' for potential bias in studies assessed with ROBINS-I was lack of controlling for confounding variables (7 of 8 studies). While blinding for assessors (participants in these outcomes) and measures being taken at multiple time points (i.e. interrupted time-series) was judged to be lacking in all five of the studies assessed by NIH Quality Assessment. Three interventions were deemed as having low risk of bias reporting on four outcomes (two each for stress and mental health/wellbeing, one each for anxiety and depression and none for mood/affect), with 26 at high risk of bias across all six outcomes (14 stress, 5 anxiety, 6 depression, 5 mood/affect, 9 mental health/wellbeing).

Results of GRADE ratings are presented in Table 4-1. Overall, the certainty rating for workplace PA interventions resulting in mental health outcomes is low for stress, mood/affect and wellbeing. Given the mix of study designs and poor

methodological quality, the baseline certainty rating for each outcome domain was determined by the dominant design type and the overall strength of evidence. For example, in the stress domain, a moderate initial rating was applied, reflecting the contribution of both randomised and non-randomised studies and used as an anchor to raise the overall rating from very low to low.

Table 4-1. Results of GRADE ratings

Outcome	N of studies	N of interventions	Total sample	Direction of effect	Certainty of Evidence	Justifications for GRADE
Stress	25	26	3325	15 positive, 11 null	●●○○ Low	Downgraded for risk of bias and inconsistency; imprecision not downgraded at domain level given OIS met. Overall rating upgraded from Very Low based on higher-quality RCT subgroup anchor.
Anxiety	10	11	1133	4 positive, 7 null	●○○○ Very Low	Downgraded for risk of bias, inconsistency, and imprecision (CIs likely cross the null in absence of pooled estimate), despite OIS met.
Depression	10	11	1195	3 positive, 8 null	●○○○ Very Low	Downgraded for risk of bias, inconsistency, and imprecision (CIs likely cross the null), despite OIS met.
Psychological quality of life	9	10	682	3 positive, 7 null	●○○○ Very Low	Downgraded for risk of bias, inconsistency, and imprecision (no pooled CI; majority null); higher-quality subset did not meet OIS.
Mood/Affect	10	11	1435	5 positive, 5 null (6/11 positive arms)	●●○○ Low	Downgraded for risk of bias and inconsistency; no imprecision downgrade (OIS met).
Mental health/Wellbeing	24	25	3109	6 positive, 19 null	●●○○ Low	Downgraded for risk of bias and inconsistency; no imprecision downgrade (OIS met).

Stress: Higher quality RCT subgroup (9 trials; N = 1,054; low/some concern RoB) met OIS for d = 0.20/0.30 and showed moderate certainty evidence; used as an anchor to raise the overall rating from Very Low to Low.
Anxiety: Higher quality RCT subset (6 trials) met OIS but had only 2 positive studies; inconsistency and likely CI overlap with the null persisted; no upgrade.
Depression: Higher quality RCT subset (4 trials) showed no positive effects; confirms Very Low certainty.
Psychological QoL: Higher quality subset (5 trials; N = 196) did not meet OIS and had mixed results; no upgrade.
Mood/affect: Study count corrected to 10 studies (11 interventions). Although 6/11 arms were positive, study level results split 5/10; inconsistency downgrade retained.

Based on the GRADE assessment, the certainty of the evidence was rated as low for stress (downgraded for risk of bias and inconsistency and upgraded from very low based on higher-quality RCT subgroup anchor), mood/affect (downgraded for risk of bias and inconsistency) and mental health/wellbeing (downgraded for risk of bias and inconsistency). Certainty of the evidence for positive effects in anxiety, depression, and psychological quality of life outcomes was rated as very low.

Effect direction with certainty

The direction of effect for workplace PA interventions by outcome and PA type is shown in Table 4-2 and a summary of overall effect from the Effect Direction Plot in Figure 4-3. Only stress and mood/affect had more studies favouring the intervention than those reporting mixed effect/no effect and significant sign tests were reported for these outcomes (Stress: 15/26 interventions $P<0.0001$; Mood/affect 7/12 interventions $P =0.02$). Significant sign test was also reported for mental health and wellbeing ($p=0.02$), despite more interventions with mixed effect/no effect than those favouring the intervention (7/27 interventions)

Table 4-2. Effect direction plot - Direction of effect for workplace physical activity and exercise interventions by outcome domain and physical activity type

Study	Physical Activity Type	Study Design	Stress	Anxiety	Depression	QoL	Mood/Affect	Mental Health/ Wellbeing
Low Risk of Bias								
Schellewald et al. 2018	Desk bikes	PP						▲
Larisch et al. 2024	Various types - Behaviour change	CRCT	◄►	◄►	◄►			◄►
Sianoja et al. 2018	Walking	RCT*	▲					
Some Concerns								
Diaz-Benito et al. 2022	Mixed (resistance and aerobic)	pilot RCT				▲		▲
Nurminen et al. 2002	Mixed (resistance, aerobic, stretch)	RCT	◄►					◄►
Gerodimos 2022	Mixed (resistance, aerobic, stretch, balance)	RCT						▲
Eather et al. 2020	HIIT (aerobic and resistance)	RCT		◄►				◄►
Taylor et al. 2020b	Strength/resistance	PP**				◄►		◄►
Tveito and Eriksen 2009	Aerobic (Dance)	Pilot RCT				◄►		◄►
Buuck et al. 2023 a	Motor-cognitive coordination training	PP**					▲	
Odhiambo et al. 2023	Desk bikes	Crossover RCT					◄►	
de Freitas-Swerts et al. 2014	Stretching	PP	◄►					
Chen et al. 2016	Stretching	RCT		▲				
Opdenacker and Boen 2008	Various types - Coaching	PP**		▲				▲
Puig-Ribera et al. 2017	Walking	CRCT						◄►
Stone et al. 2023	Walking	PP	▲					
Thogersen-Ntoumani et al. 2015	Walking	RCT					▲	
Vert et al. 2020	Walking	RCT					▲	◄►
Tamim et al. 2009	Tai Chi	PP	▲					
Cheema et al. 2013	Yoga	RCT		◄►				◄►
Hartfiel et al. 2011	Yoga	RCT					▲	▲

Hartfiel et al. 2012	Yoga	RCT	▲				▲	
Wolever et al. 2012	Yoga	RCT	▲		◀▶			
Taylor et al. 2020a	Yoga	PP**				◀▶		◀▶
Melville et al. 2012	Yoga (Seated)	Crossover RCT	▲					
Buuck et al. 2023 b	Relaxation and mobility training	PP					▲	
Diaz-Silveira et al. 2020	Mindfulness and exercise	RCT	▲					◀▶
Van Rhenen et al. 2005	Physical exercise and relaxation	RCT	◀▶	◀▶	◀▶			◀▶
Hinman 1997	Chair-based mobility and relaxation	RCT	◀▶					
Jakobsen et al. 2017	Strength/resistance	CRCT						◀▶
Mulla et al. 2018	Strength/resistance	RCT			◀▶			
Sjogren et al. 2006	Strength/resistance	Crossover CRCT						◀▶
High Risk of Bias								
Michishita et al. 2017	Mixed (resistance, aerobic, stretch)	CRCT	▲				▲	
Genin et al. 2018	Mixed (resistance and aerobic)	PP		▲	▲			◀▶
Hargreaves et al. 2023	Various types – Behaviour change coaching	PP					◀▶	
Patel et al. 2022	Various types - Behaviour change	CRCT						◀▶
Lennefer et al. 2020	Various types - Behaviour change	RCT						◀▶
Roessler et al. 2013	Strength/resistance	CRCT						◀▶
Matsugaki et al. 2017	Strength/resistance	PP**			▲		◀▶	
Saavedra et al. 2021 b	Circuit training	Quasi-experimental	◀▶	◀▶	◀▶			
Yancey et al. 2004	Aerobic dance	RCT - Post test only					◀▶	
Mohebbi et al. 2019	Aerobic (some stretching)	RCT	▲					
Brandt et al. 2024	CrossFit	NRCT						◀▶
Vainre et al. 2024	Stretching	Feasibility RCT	◀▶	◀▶	◀▶			◀▶

Bastug 2021	Stretching	NRCT	▲					▲
Holzgreve et al. 2020	Stretching	NRCT						▲
Smith-McLallen et al. 2017	Walking	PP**	◀▶				◀▶	
Ryde et al. 2022	Walking	PP	▲					
Saavedra et al. 2021a	Walking	quasi-experimental	◀▶	◀▶	◀▶			
Puig-Ribera et al. 2008 a	Walking (whilst working)	RCT				◀▶		
Puig-Ribera et al. 2008 b	Walking (routes)	RCT				◀▶		
Griffith et al. 2008	Qigong	RCT	▲					◀▶
Biman et al. 2021	Yoga	RCT	▲			▲		
Chhugani et al. 2018	Yoga	NRCT	◀▶	▲	▲			
Fang and Li 2015	Yoga	RCT	▲					
Lin et al. 2015	Yoga	RCT	◀▶					
Mandal et al. 2021	Yoga	RCT	▲			◀▶		
Rostami and Ghodsbin 2019	Yoga	RCT				◀▶		

Studies are ordered by risk of bias and within each risk of bias, further grouped by physical activity type. Physical activity type categories agreed by CT and GR based on the description of physical activity interventions in Appendix 4-B. **Study design:** RCT: Randomised Controlled Trial; CRCT: Cluster Randomised Trial; NRCT: Non-Randomised Control Trial; PP: Pre-Post design; *Within-person analysis; ** Comparison trial of two implementation strategies or two types of physical activity, where pre-post analysis used for effect direction. **Effect direction:** upward arrow ▲= positive health impact, downward arrow ▼= negative health impact, sideways arrow

◀▶= no change/mixed effects/conflicting findings. **Sample size:** Final sample size (individuals) in intervention group large arrow ▲ >300; medium arrow ▲ 50-300; small arrow ▲ <50.

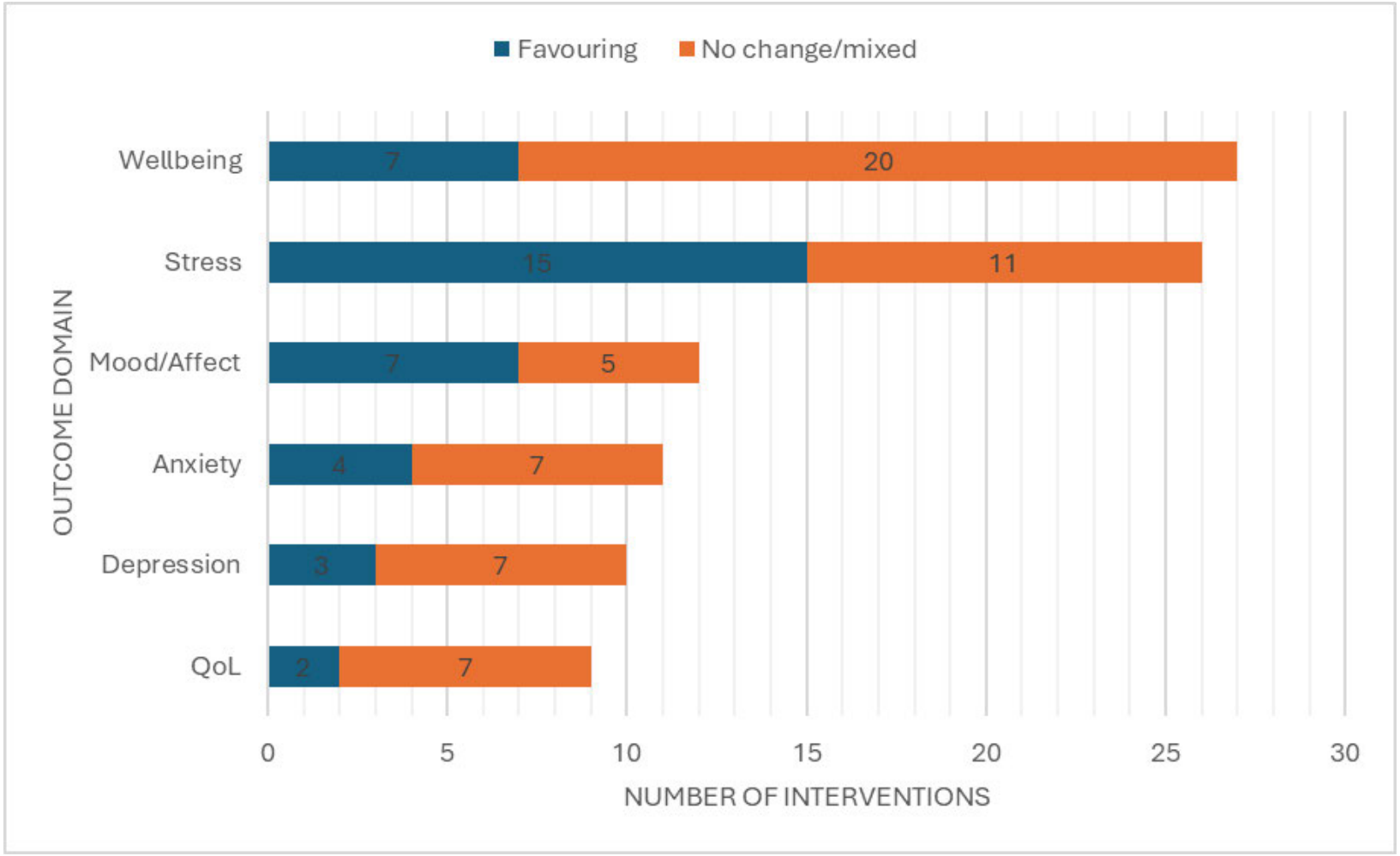

Figure 4-3. Tally of effect direction for each outcome domain in the Effect Direction Plot

Sub-group analysis

A post-hoc subgroup analysis was conducted to investigate heterogeneity among study results. Since no non favourable effects were reported, comparisons were made between favourable and mixed effect/no effect. For PA type and mindfulness, there was a pattern in favourable interventions for yoga and similar exercise (Tai Chi, Qigong) for stress only. For delivery via group sessions, there was a pattern of group delivery in favourable interventions for mood/affect only. For dose of PA, there was a pattern in favourable interventions for a higher dose for depression and anxiety.

4.4 Discussion

This review aimed to provide an updated and comprehensive synthesis of whether PA and exercise interventions in workplace settings are effective at improving mental health or wellbeing outcomes. Drawing on 58 interventions and a wide range of workplace settings and PA types, it extends the scope of previous reviews in this area. The findings indicate low-certainty evidence that such workplace-based PA and exercise interventions can improve stress, mood/affect, and overall mental health and wellbeing. Evidence regarding effects on anxiety, depression, and quality of life was less conclusive. Yoga and other activities with a focus on mindfulness may be particularly beneficial for improving stress, with group-based PA potentially important for mood/affect. The dose of PA may also influence outcomes with a higher total exposure over time potentially beneficial for some outcomes. However, many included studies were characterized by a high risk of bias, limiting the strength of the conclusions.

These findings are broadly consistent with existing literature on workplace PA interventions, which reports positive effects for certain outcomes but not others, with variation between studies on which outcomes are influenced. For example, similar to the present study, Abdin et al. (22) examined five studies involving office workers (three high-quality) and reported that PA interventions could enhance wellbeing encompassing outcomes such as mood, affect, stress, vitality, and overall wellbeing. Chu et al. (19) reviewed 17 studies, including randomized controlled trials and quasi-experimental designs, and unlike the

current findings, found moderate evidence for improvements in depression (one of two high-quality studies), limited evidence supporting the effectiveness of PA programmes in improving stress (only one high quality study of seven studies) and similarly reported no evidence for reductions in anxiety (in four studies), although some evidence that yoga had a positive effect on stress and anxiety. Taken together, the variability in outcomes and study quality across the literature continues to limit the ability to draw firm conclusions regarding effectiveness, underscoring the importance of continued critical evaluation of workplace PA interventions.

The current review findings suggest that the type of PA might be important in the relationship between workplace PA interventions and some mental health outcomes, specifically stress and yoga. Wolever *et al*. 2012 (230) delivered a yoga intervention to 90 employees in an insurance company and found that compared with a control group, the yoga group had greater improvements in their perceived stress, but there was no difference in stress outcomes when yoga was compared to a mindfulness intervention. A 2019 systematic review of 13 studies that targeted yoga in the workplace also reported that the relationship between yoga and mental health was the strongest when stress was the primary outcome with four out of five trials reporting positive effects (130). These benefits may reflect the dual therapeutic profile of mind–body activities. Yoga practice has been shown to increase calming brain activity and reduce overactive stress responses, which may help alleviate anxiety, depression, and stress (131,231). Similarly, Tai Chi, a slow and rhythmic mind–body exercise emphasizing breath control and mindfulness, has been associated with increased parasympathetic activity and reduced sympathetic arousal, helping to counteract physiological hyperarousal (232). Regardless of these potential benefits, the feasibility of mind–body activities within workplace cultures remains uncertain. Whilst few studies have directly examined employee attitudes toward workplace mind–body activities, qualitative research exploring PA more broadly at work suggests that a supportive movement culture is critical for acceptability (145). Moreover, mind–body activities may be perceived as impractical or even stressful rather than restorative in time-pressured work environments, particularly when employees face competing priorities and

limited time for engagement, a consideration that is important for future implementation (233).

Our subgroup analysis also suggested other factors such as group support and dose could be important. For dose, it would seem intuitive that greater exposure is better for mental health. Schuch et al. 2016 meta-analysis (n=25 RCTs) showed associations between PA and depression can vary by frequency, intensity and duration of activity although none of these studies were workplace specific (234). Similarly, Gordon et al. 2018 meta-analysis and meta-regression of 33 randomized clinical trials of resistance exercise and depression reported that associations differ by these same variables but not for total volume and again not workplace specific (235). In addition, as with other previous research, being active as part of a group could be an important aspect of the benefits between workplace PA interventions and mental health (145). Similar to the findings from mind-body activities, potential mechanisms are likely both physiological from the movement aspect and psychological from additional benefits, such as reduced loneliness, a sense of belonging, and social identity (236). However, most research again is not workplace specific and whilst additional benefits of group activity for the workplace could be seen (building relationships, group cohesion) these should be further explored.

The high risk of bias and low certainty of evidence in workplace PA and exercise interventions should be acknowledged, as this has also been reported in previous reviews in this field (19,21,22). Common limitations include reliance on self-reported outcomes and the absence of pre-specified analysis plans. Some of these issues are difficult to avoid in workplace settings, where mental health outcomes are typically self-assessed and participants cannot be blinded to PA interventions. As a result, studies are inherently susceptible to expectation, placebo, and Hawthorne effects (79). Moreover, conventional risk-of-bias tools tend to favour highly controlled designs and may be overly stringent for workplace contexts. Nevertheless, many of these risks can be mitigated through improved study design and reporting. While most studies achieve low risk of bias for randomisation, fewer blind data processing or analysis, use appropriate active control conditions (e.g., meditation) to address expectancy effects (237,238), publish predefined analysis plans, adequately report deviations from

intended interventions, or assess the impact of missing data. Overall, there is an urgent need for workplace-specific tools to assess risk of bias and certainty of evidence in this area.

4.4.1 Strengths and limitations

This systematic review has several strengths. It provides an up-to-date synthesis of workplace PA interventions for mental health across a broad range of study designs, extending beyond the restrictive inclusion criteria of previous reviews (19,21). The inclusion of non-randomised studies enhances external validity and captures evidence that is more representative of real-world workplace settings. The review synthesises data from a large and diverse employee population spanning five continents, industries, and job types, supporting the generalisability of the findings. Including studies in which mental health was not the primary outcome enabled the identification of a wider range of intervention designs and potential mechanistic pathways influencing mental health. Methodologically, the application of the GRADE framework reflects both rigour and contextual sensitivity. While GRADE typically prioritises randomised controlled trials, this review recognises the limitations of design-based hierarchies in workplace research, where non-randomised designs may offer greater ecological validity (227). Certainty was therefore assessed at the outcome-domain level, supported by Effect Direction Plots, allowing transparent interpretation of heterogeneous evidence where meta-analysis was not feasible. Integrating study-level risk of bias with domain-level GRADE ratings enabled robust yet context-appropriate judgments about the strength of the evidence.

Although the broad inclusion of study designs strengthened the scope of this review, it also exposed the findings to biases inherent in uncontrolled studies, particularly participant selection bias. Overall methodological quality was poor across designs, with few studies rated at low risk of bias. Substantial heterogeneity in interventions, workplace contexts, job types, and outcome measures limited evidence synthesis and precluded firm conclusions on effectiveness. Future reviews should therefore focus on specific mental health domains and, where feasible, particular occupational groups (e.g. office workers, healthcare professionals, construction workers) to better identify

patterns of effectiveness. In addition, the broad definitions of mental health and wellbeing used in this review may have contributed to heterogeneity; adopting more homogenous outcomes or single, domain-specific measures would improve comparability and support meta-analysis.

4.4.2 Conclusion

This review found low-certainty evidence that workplace-based PA and exercise interventions can improve stress, mood/affect, and overall mental health and wellbeing, while evidence for anxiety, depression, and quality of life was inconsistent. Mind–body activities such as yoga and Tai Chi, mindfulness, group-based delivery, and higher intervention dose were more frequently associated with favourable effects in some outcomes. However, the evidence base is limited by heterogeneity and a high risk of bias across studies. Future research should focus on clearly defined mental health outcomes, improved study design and reporting, and greater attention to organisational context to strengthen the evidence for effective, ecologically valid and feasible workplace PA interventions.

4.5 Key points of Chapter 4

- Workplace physical activity interventions are increasingly promoted to address the high burden of poor employee mental health, yet the existing evidence base is fragmented, methodologically inconsistent. A comprehensive, updated synthesis was therefore needed to clarify effectiveness across mental health outcomes, determine which intervention characteristics matter, and identify key contextual and occupational gaps.

- This current systematic review conducted searches in the Medline, EMBASE and CENTRAL databases for reports of interventions that were delivered at the workplace. Randomised, quasi-experimental, and pre-post designs were included.

- The review identified 54 studies reporting 58 interventions across Europe, Asia, North America, Australasia, and South America, with most conducted in universities, hospitals, and other public-sector or white-collar workplaces.

- Certainty of evidence was low for stress, mood/affect, and general wellbeing, and very low for anxiety, depression, and quality of life, primarily due to heterogeneity, methodological weaknesses, and inconsistent reporting.

- The current evidence base is constrained by substantial heterogeneity and consistently high risk of bias. Strengthening this field will require clearer mental health outcome definitions, more rigorous study design and reporting, and greater consideration of organisational context to support the development of effective, feasible, and ecologically valid workplace PA interventions.

Chapter 5 Co-Creation of a Context-Sensitive Workplace Physical Activity Intervention

5.1 Background

Traditional top-down workplace health programmes often struggle to achieve sustained engagement, contextual fit, and long-term impact, possibly because they typically fail to reflect the day-to-day realities and priorities of employees (124,126). In response, co-creation or co-design has emerged as a promising framework for generating meaningful and sustainable intervention strategies that are grounded in the lived experience of the workforce (239–242). The Medical Research Council (MRC) guidance on developing and evaluating complex interventions, which guided this research project, recommends the use of theory, evidence, and stakeholder engagement throughout the intervention development process (159). This Chapter reports on how stakeholders, in this case ASC employees, were engaged to co-create a workplace physical activity (PA) intervention to improve mental health while considering context, identifying uncertainties, and refining candidate components for feasibility testing. For clarity, hereafter, those in senior positions and responsible for other employees are referred to as “managers” (including supervisors), those in non-management roles as “core staff” or “staff” and the term “employees” is used when both groups are referred to as a workforce.

Co-creation is broadly understood as a collaborative process that involves stakeholders, such as staff and managers, throughout the design, implementation, and evaluation of interventions (239,243). Rather than positioning employees as passive recipients, co-creation emphasises their role as partners who help identify needs, generate solutions, and shape intervention content to the specific organisational context. Reviews by Vargas et al. (2025) and Constantin et al. (2022) highlight the diversity of definitions in the literature relating to “co-creation” but converge on key features: inclusivity, shared decision-making, and iterative cycles that support the creation of interventions tailored to the needs of specific populations (239,244). In practice, co-development employs a range of participatory activities, such as workshops, prototyping, and iterative feedback, to harness the experiential expertise of employees (160,243). These methods are designed to increase the likelihood

that interventions are both acceptable and feasible within the constraints and opportunities of the workplace (159,245,246). This PhD project adopted similar participatory methods to generate and refine workplace PA intervention strategies.

Theoretical Foundations Underpinning the Co-Creation Approach

The rationale for co-creation draws on several complementary theoretical frameworks, each reinforcing core values of participation, empowerment, and contextual fit (239,240,247). Below I outline three relevant to this thesis namely, Participatory Action Research, Self-Determination Theory and the Social-Ecological Model.

Participatory Action Research (PAR) is a foundational approach underpinning co-creation (245,247). PAR is characterised by collective, self-reflective inquiry, where researchers and participants collaborate to understand and improve their practices and contexts. The process is iterative, involving cycles of reflection, data collection, action, and further reflection, with the goal of empowering participants and increasing their control over decisions affecting their health and wellbeing. PAR explicitly addresses power dynamics, advocating for the deliberate sharing of power between researchers and participants, and is recognised for its capacity to foster ownership, capacity-building, and sustainable change (247,248). In workplace settings, PAR is especially valuable because it addresses the implicit norms, power structures, and operational constraints that shape daily work, enabling employees at different hierarchical levels to collaboratively design interventions that are both context-specific and practically feasible.

Self-Determination Theory (SDT) is another key theoretical underpinning, particularly relevant to health interventions (249,250). SDT posits that individuals are more likely to adopt and sustain health behaviours when their basic psychological needs for autonomy, competence, and relatedness are supported (251). Co-developed interventions inherently support these needs by offering staff choice, opportunities to contribute skills and insights, and shared discussion with colleagues. Systematic reviews have found that SDT-based

interventions are more effective in promoting PA in the workplace than those lacking a theoretical foundation (129,250).

The Social-Ecological Model (SEM) provides a multi-level perspective, recognising that health behaviours are influenced by factors at the individual (e.g. employee motivation or physical capability), interpersonal (e.g. managerial support or influences from peers), organisational (e.g. workplace culture and resources), and policy (e.g. health and safety guidelines or national regulations requiring employers to support employee wellbeing) levels (252). In workplace settings, the organisation itself functions as a key determinant of health, as workplace structures, cultures, and routines directly shape employees' daily opportunities for PA and overall wellbeing. Co-creation aligns with this model by engaging stakeholders across these levels, ensuring that interventions address not only individual motivation but also organisational culture, leadership, and environmental supports.

Evidence for co-creation of workplace programs

Evidence on whether co-created workplace interventions systematically achieve higher participation than traditional programmes is limited and mixed (239). However, organisational context and engagement at multiple levels, as supported by the SEM, has a clear impact on the reach of workplace interventions (121,250). For example, a cross-company study of 61 firms reported mean enrolment of 15.4% in workplace health programmes (range = 1–100%), and showed that strong managerial/programme support was positively associated with enrolment ($\beta = 0.051$ $p < 0.001$), whereas financial cost to employees and larger organisational size were negatively associated, implicating leadership support and implementation design as practical levers for participation (152). Furthermore, a review and comparative analysis of occupational health intervention methods concluded that interventions were most likely to have impact when they followed a structured, staged process with active employee participation and strong implementation planning (151).

In terms of workplace mental health, there is promising evidence that co-creation of interventions can lead to positive outcomes. Ravalier (2022) demonstrated that participatory action research methodologies, involving

interviews and focus groups with healthcare workers, led to the co-creation of wellbeing interventions that were both feasible and well-received, resulting in improvements in work engagement and working conditions (253). However, this study was a pre-post design and therefore did not compare acceptability and feasibility against non-PAR methods. A cluster randomized controlled trial involving manual workers on 11 assembly lines, compared a participatory workplace improvement program to control assembly lines. The authors observed a significant intervention effect (p=0.048) on work performance (WHO Health & Work Performance Questionnaire), while mental health (General Health Questionnaire) was maintained in the intervention arm but decreased for workers in the control arm (254). For workplace PA initiatives, a multiple case mixed methods study found that co-developed interventions were successfully implemented in nursing settings and identified context-specific factors such as commitment, empowerment, ownership, embedment, and relevance that positively influenced implementation (255). These findings suggest that co-creation can support feasibility and implementation in workplaces, but that outcomes are dependent on meaningful engagement with employees (242).

Approaches and aims

The participatory co-creation process in the study reported in this chapter was informed and guided by Leask et al.'s (2019) framework for utilising participatory methodologies in the co-creation and evaluation of public health interventions (160). This framework provided a clear process for organising the co-creation activities into four stages: Planning, Conducting, Evaluating, and Reporting, ensuring transparency, methodological rigour, and alignment with best practice for participatory intervention design. Figure 5-1, taken from Leask et al. (2019), shows the procedural components of the iterative co-creation processes, which will be evident in the methodology of this study (160). These principles complement the stakeholder engagement component of the broader scoped MRC framework applied across the PhD (159).

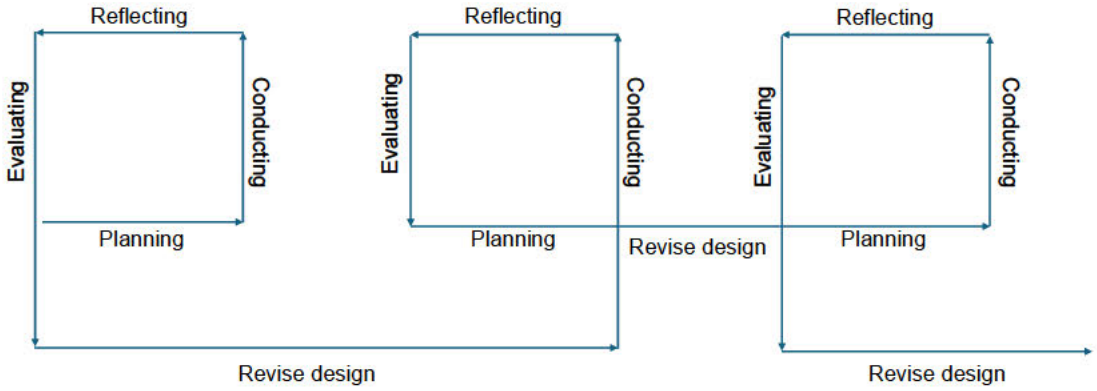

Figure 5-1. Iterative co-creation process, taken from Leask et al. (2019)

The aims of this Chapter were:

1. To collaborate with stakeholders on the design and development of a workplace-wide PA intervention for mental health.

2. To gain insights on employee preferences and their perceived anticipated barriers and facilitators to implementing and engaging with interventions.

5.2 Methods

Study design

Intervention development was designed as a participatory collaboration between the lead researcher (CT) and ACS employees, with consultation and guidance from PhD supervisors. Following the workplace mapping process (collection of Annual Wellbeing Evaluation (AWE) data and a workplace audit of health promoting environments and policies) in Chapter 3, and during the review of workplace PA interventions reported in Chapter 4, four collaborative small-group employee workshops were conducted to co-create and collectively prioritise intervention proposals for feasibility trails. Workshops are a central feature of

co-creation, providing a forum for stakeholders to share experiences, generate ideas, and collaboratively develop solutions (239,256). These workshops were planned and designed in collaboration with the project steering group (ACS employees), established prior to the first AWE and who met monthly to discuss contextual matters and assist in the planning of all practical phases of the project (see Chapter 3). Results from the workshops were presented to the steering group following thematic analysis of data by the lead researcher. The steering group then participated in the refinement of interventions before implementation. More detailed accounts of each stage of the intervention development process follows.

As an extension to the mapping study reported in Chapter 3, this study was approved by the College of Medicine, Veterinary, and Life Sciences ethics committee at the University of Glasgow (study number 200210186), statement available in Appendix 3-A.

5.2.1 Participants and setting

Participants that had taken part in the first AWE were invited to participate in the follow-up workshops at the end of the online survey portion of the AWE. Those who had indicated a willingness to participate, were sent invite emails after they had received their individual feedback reports from the 2022 AWE. Those who were still interested, still employed in the same workplace, and available on the scheduled dates were assigned to one of two workshop groups: 1. core staff or, 2. managers. The decision to create a separate management group for the workshops was taken following consultation with the ACS steering group, who suggested that some employees may be reluctant to share their views in front of senior staff. Separating the two hierarchical levels also aligns with the recommendations of participatory and co-design frameworks, including PAR, which emphasise minimising power imbalances to enable more open dialogue and ensure that contributions from employees at different organisational levels are not inhibited by perceived authority dynamics (160). The workshops took place during working hours, in the boardroom at ACS Clothing Ltd's worksite in North Lanarkshire, in August and September of 2023, shortly before the second wave of the AWE. Each workshop was comprised of two one-hour sessions held in consecutive weeks.

The participant's demographics were collected during the previous mapping phase of the research project using a questionnaire and include age, gender, job role, years employed at ACS and salary. This information was used to ensure a range of employees were represented at the workshops.

5.2.2 Workshop contents and delivery

In session one, employees were provided with a brief re-introduction to the research team and a reminder of the background and aims for the research. Participants were then given a PowerPoint presentation with the definitions of PA and mental health, summarised results of the physical and mental health profiles of the workforce collected from the AWEs, alongside device-measured PA patterns for each job type described in Chapter 3, and examples of workplace PA interventions for mental health based on the findings of previous reviews discussed in Chapter 2 (19,21–23). The systematic review of this PhD project was, at the time of these participatory workshops, being conducted in a different format before its final iteration, which is presented in Chapter 4. Therefore, the initial literature searches conducted in April 2023, also provided further examples of workplace PA interventions that could be added to this presentation in session one. Following the presentation, participants were asked how important they think doing PA is to them and how it relates to their mental health, whether they would consider changing their PA behaviours (in or out of work) and their knowledge of the current PA guidelines.

In session two, employees were given the chance to try or roleplay (where feasible) example PA interventions based on those found in the literature, to generate impressions of implementing these in a workplace setting. For example, participants were encouraged to try yoga or aerobic excises in office spaces, and roleplay resistance and stretching exercise at imaginary workstations. Working in three small groups of two to four people, staff were then given time to discuss facilitators and barriers to conducting the various PA intervention strategies in the workplace, and when they could occur (during working time and/or breaks). After the roleplay and discussion participants took part in a drawing exercise to visualise the potential interventions further. In the same small groups, participants were asked to use coloured pens to draw interventions that they favoured on a sheet of A4 paper, with a maximum limit

of three potential interventions per group and nine in total. Each A4 sheet represented one potential intervention, that was then presented to the group for discussion of perceived facilitators or opportunities and barriers or challenges to implementation and engagement. Drawing was selected as visual methods can lower linguistic demands, redistribute power, and enable participants to express tacit or hard-to-verbalise experiences, thereby supporting more inclusive and meaningful participation (257). After discussing potential interventions, the entire workshop group was asked to collectively rank each in terms of their agreed priority for trialling at ACS and annotate the drawings with suggested facilitators and barriers. Figure 5-2 shows the diamond ranking system template used for the ranking exercise (258). Diamond ranking, also known as diamond 9s was chosen because its non-linear structure encourages participants to compare and justify the relative importance of ideas within priority 'bands,' (259,260). Compared with simple sequential listing, this spatial activity can foster richer discussion and clearer articulation of shared values by prompting participants to make explicit the overarching relationships that structure their thinking, thereby revealing how they organise knowledge in ways that can be analysed and compared (257).

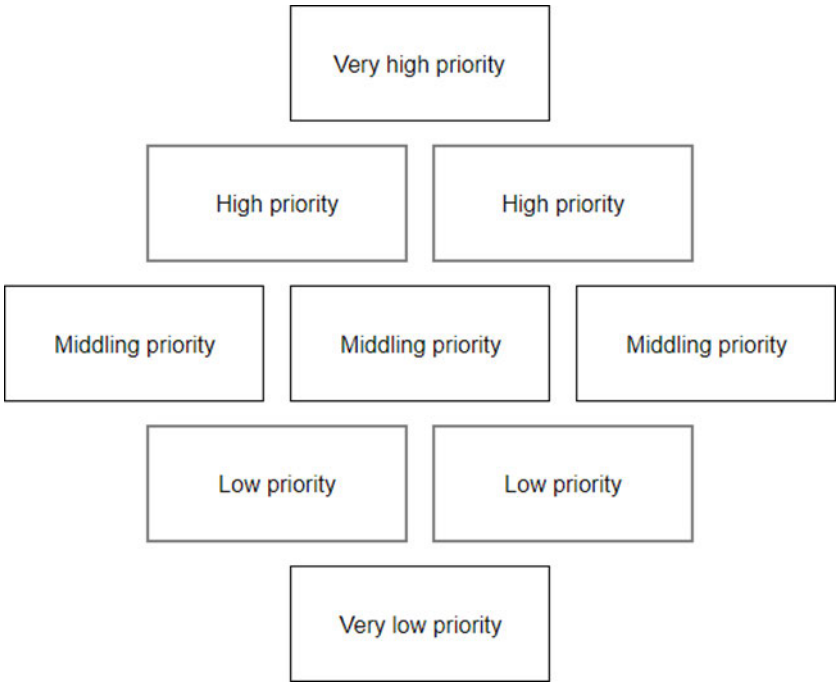

Figure 5-2. A template of the diamond ranking system used in ACS employee workshops

The core staff workshops were intentionally scheduled first to establish an initial set of ideas and contextual insights, which were then fed forward to the managers group as part of a deliberate iterative co-creation cycle. Manager workshops followed the same process as core staff, other than being presented the interventions proposed and ranked by core staff when the drawing exercise was introduced. This sequencing aligns with participatory best practice as outlined by Leask et al. (2019), in which early-stage stakeholder inputs are iteratively refined across groups (Planning → Conducting → Evaluating) before synthesis and reporting (160). It also reflects the MRC development phase's emphasis on stakeholder engagement and progressive refinement, by allowing managers to review the modifiable factors and emerging mechanisms of change identified by core staff before contributing their own perspectives (159).

Data was collected by compiling the A4 sheets of paper that contained participants' drawings and annotations. In addition, the researcher took field notes of points raised and anonymous quotes throughout the workshops to assist with thematic analysis.

5.2.3 Thematic analysis and intervention selection

Drawings from participants and notes taken by the researcher during the workshops were thematically analysed and used to create a list of candidate interventions. After review by the researcher, each drawing was assigned a code to allow grouping of intervention suggestions. Diamond ranking results of the workshops were recorded, and a combined ranking was created using a five-point system (very high priority = 5 points; high priority = 4 points; middling = 3 points; low = 2 points; very low = 1 point). Proposed intervention themes, alongside perceived facilitators and barriers are reported in a narrative summary.

Guided by evidence gathered during the literature review of workplace PA interventions for mental health (see Chapter 4) and in consultation with the PhD supervisory research team, a set of criteria was established for intervention proposals to meet before being presented to the steering group for implementation discussions. Proposals should be deliverable during working time (i.e. not at home, not active travel, not on the weekends), considerate of

productivity for the business (i.e. either be neutral, or have the potential to increase productivity either directly or indirectly), be scalable to the whole workplace, and context specific (i.e. sensitive to ACS current practices and policies). It was hypothesised that interventions meeting these criteria would have a higher chance of success and sustainability.

5.2.4 Steering group implementation meetings

Based on the above criteria and the ranking of priority by participants in the workshops, applicable proposals were presented to the steering group. Feasibility trials for each applicable intervention were proposed to measure acceptability and feasibility of the changes, and the ability to measure changes to PA and perceived wellbeing. The MRC framework and Leask et al.'s participatory methodology both emphasise small-scale feasibility testing as an essential stage for refining intervention components, assessing contextual fit, and ensuring that co-created proposals are acceptable, workable, and ready for iterative optimisation before full implementation (159,160). Once the steering group were presented with the feasibility trial proposals, they collectively evaluated potential facilitators and barriers to implementation and discussed refinements that could be made to improve acceptability. Figure 5-3 shows how the methodology mapped onto the iterative framework for participatory co-creation that was used to guide the design and implementation of this study (160).

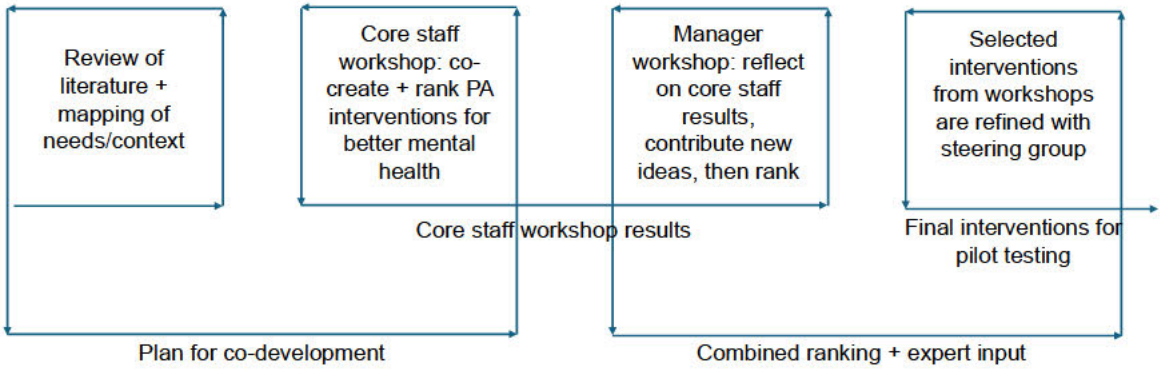

Figure 5-3. Co-development process for ACS interventions, adapted from Leask et al. (2019)

5.3 Results

Twenty members of staff took part in collaborative intervention development workshops; eleven in the core staff workshops and nine in the manager workshops. Table 5-1 shows the characteristics of the two workshop groups.

Table 5-1. Characteristics of the two workshop groups

	CORE STAFF	MANAGERIAL STAFF
N	11	9
SEX	5 Female; 5 Male	2 Female; 7 Male
AGE (RANGE)	39.2 (23 - 72)	43.7 (28 - 58)
YEARS WORKED AT ACS (RANGE)	3.4 (0 - 9)	8.9 (2 - 16)
JOB TYPE	3 Desk; 7 Manual	5 Desk; 4 Manual

The intervention strategies developed and then ranked in the workshops were as shown in Figure 5-4, while Figure 5-5 shows the diamond ranking as applied by the core staff group to their drawings of interventions.

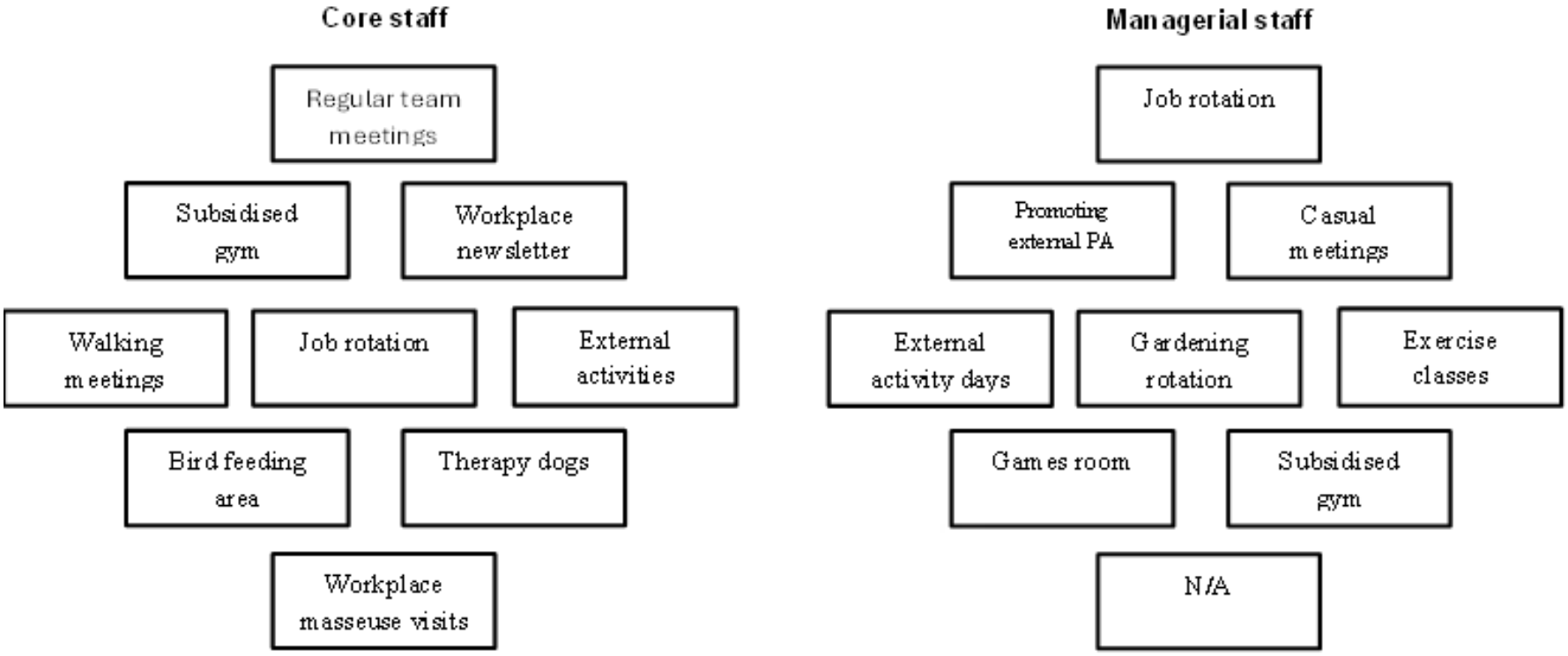

Figure 5-4. Diamond ranking results from the core staff and managerial workshop groups (very high priority at the top; very low priority at the bottom).

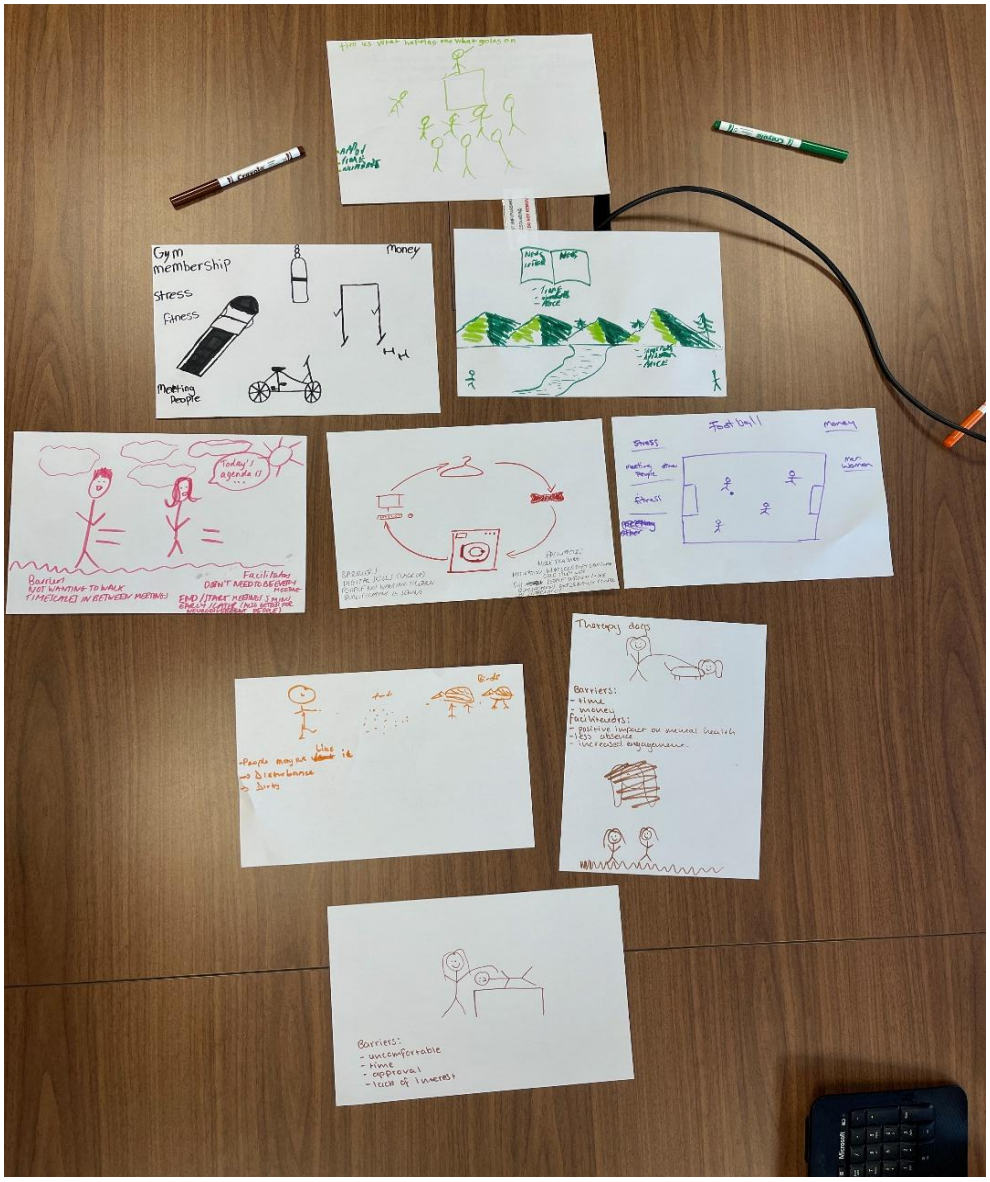

Figure 5-5. Drawings by core staff workshop group, arranged into a diamond ranking

5.3.1 Workshop Intervention proposals and themes

Data from the workshops was synthesised into five main intervention themes, which are presented below, along with perceived facilitators and barriers to implementation, in order of their combined ranking between the two groups. Some suggested interventions that were focussed on improving wellbeing, but did not contain a PA component, such as installing a bird feeding area, therapy dogs, and regular workplace masseuse visits were excluded from thematic analysis and combined ranking.

1. **Regular/casual/walking meetings** – Participants in the core staff group stated that they felt a need for more regular updates on the activities and goals of the workplace. It was generally agreed amongst this group that the lack of regular meeting opportunities increased feelings of isolation and reduced job engagement. Walking meetings appealed to this group as a means of increasing regularly scheduled meetings with colleagues. Additionally, desk-based workers were enthusiastic about opportunities to go outside or move away from their desks:

   "I'd love a chance to get away from my desk and see some daylight." – Core staff workshop attendee.

   Several attendees in the management group mentioned that regular meetings had previously been in place but were discontinued as key implementors left the company or changed roles. After reflecting on the popularity of this intervention with core staff, the management group ranked this intervention as a high priority:

   "I feel like the team moral would benefit from an opportunity to meet every morning." - Manager workshop attendee.

   Barriers discussed were loss of productive time when adding additional meetings to the weekly schedule, and the location or route for walking meetings. Managerial motivation and commitment were viewed by both groups as a barrier and facilitator.

2. **Job rotation/Job redesign** – Job rotation was mentioned to participants, as part of the evidence from the review of workplace interventions for physical and mental health. This concept generated discussion in both workshop groups, but more so in the management group who stated that they could envision wider benefits for the organisation. An opportunity for desk-based and standing staff to work on the maintenance of a small garden area, where staff can take their lunch, was suggested as one

means of rotating to a different work task for an hour while also reducing the workload of the maintenance team.

In terms of challenges to implementation, it was noted in the workshops that any job rotation would require additional training time, which would vary depending on the complexity of each role. However, it was discussed and hypothesised among the managerial group that this time would likely be compensated for by increased productivity and less staff turnover due to "burn out". In terms, of the gardening rotation, it was agreed that as the garden area is relatively small, opportunities to garden would be very limited.

3. **Promoting/communicating PA opportunities** – Educational and informing centred interventions were suggested in both meetings: core staff discussed the possibility of a regular workplace newsletter to prompt staff into making changes to their PA; while managerial staff brought up the prospect of promoting internal and external opportunities for PA through workplace emails.

   It was recognised by both groups that either an individual or small group of staff would need to take responsibility for these communications and the gathering of information for their content, which would add additional workload. Additionally, when asked by the researcher which type of employees they would expect to respond well to this type of intervention, both groups responded that those with higher existing motivation for PA would be most likely to use this information.

4. **Subsidised gym memberships/Exercise classes** – Staff discount on membership to local a local gym was raised as a possibility by the core staff group but ranked lowly by the managerial group. Exercise classes delivered either at the worksite or at the local gym were proposed as an alternative by the managerial group, but when it came to ranking were given middling priority.

   Again, individual motivation was recognised as a barrier for this type of intervention. When asked by the researcher which employees would be

most likely to attend gym sessions or exercise classes, the managerial group were in agreement that both suggestions would only be used by a small proportion of the workforce who are already physically active. To attract those who were less physically active to such an intervention, it was suggested that this would need to be delivered in combination with the promotion and communication themed interventions.

5. **Internally organised extra-curricular activities** – Group activities that could be arranged before or after work, or at the weekends were suggested and included football, golf, and hill walking. Staff who had been at the company longer recalled that these activities had all been arranged in the past, but participation and organisation dwindled over time.

   Both workshop groups recognised that the sustainability of these activities is reliant on a handful of individuals and is vulnerable to those individuals leaving the workplace or losing motivation. It was also discussed that these activities were limited to once per week at the most and usually less often than once every month in the case of golf and hill walking days. Culturally embedding annual sporting or active events was discussed as a means of better sustaining such activities.

5.3.2 Proposals for trial interventions and steering group feedback

Based on the criteria set by the research team and the ranking of priority by participants in the workshops, two of the co-created interventions, job rotation and walking meeting, were presented to the steering group as proposed feasibility trials. The steering group was informed that the focus of the trials would be to assess the feasibility of implementation and sustainability. This would allow the research team and ACS management implementing the interventions to further refine the delivery in future iterations to better fit the context of ACS (159). To put it in business terms, this was described to ACS management as our “minimum viable product”, and it was made clear that the aim should be to build more robust interventions following the responses to the evaluation of feasibility (Chapter 6).

Intervention 1: Job/task rotation

Among intervention proposals which directly involved PA changes, job/task rotation ranked highly. This strategy involves employees swapping roles or tasks on a scheduled basis. It was agreed with the steering group that this type of intervention may be most applicable to the processing department, where manual labour tasks were described by those in the core staff group as "repetitive", and AWE results showed that depression and anxiety scores were worse in these job roles (Chapter 3). The management workshop group also noted that this department had a higher turnover of staff compared with other departments and suggested that this could be related to the repetitiveness of some of the jobs. Therefore, a job rotation system feasibility trial within the processing department was proposed and accepted by the steering group.

Following feedback from the steering group, it was decided that rotations would be implemented on a bi-weekly basis with staff working at one station Monday, Tuesday, and Wednesday, then another Thursday and Friday. This was suggested to align with expectations of workflow during the working week, with Fridays usually being a slower paced day. Rotations would also be a combination of changes within and between departments to ensure that each team within the processing department had the appropriate number of staff at any one time.

Intervention 2: Walking meetings

Several other proposals centred around increasing regular meetings and/or changes to the format of meetings. One proposal that most directly fits with the aim of changing PA behaviours was walking meetings. Based on the findings of the mapping study reported in Chapter 3, this intervention would be most applicable to those in desk-based jobs, who spent a higher proportion of their time at work in sedentary behaviours compared to manual workers (40% vs 17%).

When discussed in the steering group meetings, it was pointed out that the addition of more meetings to the weekly schedule could increase workload pressures for employees. It was also suggested that only certain meetings would fit with this type of intervention. Those would be small groups, one-on-one or two-on-one, and more casual catch-up style meetings. As an embedded

researcher, I noted that there were initiatives in ACS at this time that were focussed on swapping larger meetings for more regular small meetings, within departments. This appeared to be an opportunity to introduce this intervention as part of that workplace change without adding to existing work demands.

Overall implementation feedback from the steering group

There was a consensus in one of the ACS steering group meetings, that motivation for previous interventions, attempted by the workplace, has been low when employees do not feel well informed. It was therefore agreed that team leaders would be involved throughout the implementation period and that participants in the feasibility trials would receive briefings before and during intervention delivery. Implementation would also be evaluated in semi-structured interviews following completion of the trials. Furthermore, the steering group pointed to the seasonality of workload and the potential to increase employee and managerial stress if the interventions were implemented during a busy period. Guided by this contextual information, feasibility trials were scheduled to take place in May and early June of 2024, before the busiest months of July and August.

5.4 Discussion

5.4.1 Summary of findings

The aim of this Chapter was to collaborate with stakeholders on the design and development of the workplace intervention(s) and to gain insights into employee preferences and their anticipated barriers and facilitators to implementing interventions. This iterative collaborative exercise, that totalled four workshop sessions, produced two sets of intervention proposals that were collectively ranked by participants. From the employee-generated intervention ideas, job rotation/redesign and walking meetings emerged as the highest-priority options for trialling at the workplace. Results showed that while staff identified clear facilitators for both interventions (e.g., improved communication, reduced monotony, leadership support), they also highlighted practical barriers such as training requirements, limited time, and reliance on key individuals.

Much of the evidence for job rotation interventions comes from occupational health research and is often focussed on ergonomic changes and exposure risks for musculoskeletal pain rather than health promotion, as proposed in this PhD. Systematic reviews have found weak evidence for benefits in musculoskeletal pain but highlight study quality as an issue (261,262). However, positive effects have been found in the studies measuring psychological outcomes (5,261).

A meta-analysis of 56 primary studies, including 284,086 employees, moderated for the overlap in the terminology of job rotation and task rotation (5). Studies were either assigned to task or job rotation based on their design, with job rotation defined as move between functions, departments or units at the same level of workplace hierarchy and task rotation as changing to different skills or responsibilities within the same department. The authors found that overall rotation was significantly associated with psychological health (Pearson correlation coefficient r = 0.20) and job satisfaction (r = 0.27), with job rotation having a stronger relationship than task rotation. This evidence indicates that while rotation between departments or functions may be preferable, both types of rotation are associated with improvements in mental health.

In workplace walking interventions, randomised controlled trials and quasi-experimental studies have observed small to moderate positive effects (263–270). However, studies with longer follow-up often find high rates of attrition and challenges in sustaining compliance (263,271). For example, Haslam et al, who followed 1120 workers from 10 worksites over 24 months, found that those following an information-led intervention to increase walking and PA significantly improved in psychological health outcomes in comparisons to a control group, but those who reported to be maintaining their activity levels fell from 19.4% at the end of the 12-month intervention period to 7.7% after a further 12 months of follow-up (263).

Kling et al. (2016) found that walking meetings involving two or three desk-based workers met feasibility and acceptability criteria, whilst also increasing average moderate-vigorous PA per week from 107±55 to 117±65 minutes over a three-week pilot trial (272). In this trial, existing meetings were transformed from seated to walking. Using a similar approach seemed prudent at ACS, as the

steering group suggested that adding additional meetings to the weekly schedule may increase workload pressures.

Workshop results show that communication was a central theme in both groups. Many of the participants prioritised this over any direct changes to their PA, as they perceived frequency and clarity of communication as having an impact on employee wellbeing. This reflects Maslow's hierarchy of needs, which proposes that lower-order needs, such as clear communication, must be sufficiently met before individuals are able to prioritise higher-level goals like behaviour change or health and wellbeing improvement (273). The issues with communication would also suggest that any intervention to change PA in the workplace would be reliant on how well it was communicated to those involved. This is consistent with wider workplace intervention research, which repeatedly identifies clear, consistent communication, particularly leadership-endorsed messaging, as a critical determinant of whether employees engage with and sustain participation in PA programmes (142,150). Safi et al. (2022) found that lack of communication and management support are among the most frequently cited barriers to workplace PA participation, with over 75% of employees reporting insufficient communication or support as limiting engagement (145).

When asked about barriers and facilitators by the researcher, both groups generally agreed that some of the proposed interventions were heavily reliant on individual motivation and more likely to benefit those with existing high levels of motivation. These designs were therefore not ranked highly in the collective diamond ranking exercise, particularly by the management group. Suggestions such as exercise classes, subsidised or free gym sessions, and information-based approaches (i.e. newsletter and promotion of external PA opportunities) can be widely found in the workplace PA intervention literature but often show limited and short-lived effects (19,21,106,123). Large quasi-experimental and policy analyses note that when employers offer gym memberships or similar wellness options, those who enrol tend to be individuals already inclined to be active, this self-selection limits population reach and impact (274,275). Whilst, in a large longitudinal mHealth programme (22,797 participants), generic email nudges sent from researchers to employees yielded only a small, short-term increase in PA (276). In this study, participants receiving an email prompt had a 67% probability of being inactive in any given week, compared with a 68%

likelihood in participants not receiving an email, highlighting engagement attrition when interventions rely on individual initiative.

Workshop discussions often differed by SEM levels; where the core staff would discuss potential mechanisms and outcomes on an individual and inter-personal level, the managers group tended to focus on organisational and policy level. The difference in perspective here was a consistent theme during discussions, reflecting how roles and responsibilities impact priorities. This divergence is consistent with the SEM, which posits that determinants of health behaviour operate across multiple levels, and that stakeholders' perspectives tend to align with the level at which they have most influence (161). In workplace PA research specifically, SEM-informed analyses argue that interventions should not rely solely on individual motivation but instead combine strategies across interpersonal, organisational, environmental and policy levels to create capability and opportunity for sustained change (161,277). Moreover, Golden and Earp's (2012) review of SEM-guided health promotion demonstrates a persistent tendency for interventions to prioritise individual- and interpersonal-level strategies while comparatively neglecting organisational and policy determinants, underscoring the value of design processes that deliberately integrate perspectives across hierarchical levels (278).

5.4.2 Strengths and limitations

Separating workshops by organisational level (core staff first, followed by managers) enhanced the ecological validity of the co-creation process, ensuring that ideas and delivery constraints were contributed from the vantage points where participants hold the most agency. This approach aligns with the SEM emphasis on engaging actors positioned at different levels of influence (277,278). Moreover, sequencing the exercises iteratively, by feeding outputs from core staff to the managers group, operationalised best practice in participatory methodology (Planning → Conducting → Evaluating → Reporting), strengthening the transparency, credibility, and traceability of design decisions as recommended by Leask's framework (160).

The use of visual methods in this co-creation process effectively broadened participation by providing alternative, low-threshold ways for participants to

articulate their perspectives. As Clark et al. (2013) argue, visually mediated activities can relax participants, reduce reliance on literacy, and support co-constructed meaning-making by shifting the focus from the researcher to a shared visual object (257). This aligns closely with Leask et al.'s (2019) framework for participatory methodologies, which emphasises creating equitable conditions for contribution, valuing diverse forms of knowledge, and enabling participants to shape the direction of the encounter (160). In this sense, visual methods not only enhanced engagement but also strengthened the participatory integrity of the research by allowing participants to "set the agenda" and provide insights that may not have emerged through verbal discussion alone (257,259,260).

The first limitation of this design regards participation, which was voluntary and scheduled within working hours, potentially leading to under-representation of employees with less schedule flexibility or lower initial interest in wellbeing initiatives. Second, although visual and dialogic methods were used to mitigate hierarchies, residual researcher–participant and intra-organisational power dynamics may still have shaped contributions; this is a recognised challenge in participatory research and underscores the importance of explicitly attending to power throughout planning, conduct, and evaluation phases (160). Finally, despite efforts to highlight the key role of PA changes within intervention discussions, participants of both workshops deviated towards non-PA focussed interventions and other issues that they felt affected their mental health and wellbeing. This pattern reflects guidance from the MRC framework (159), which emphasise that participants often prioritise foundational individual and organisational (i.e. workplace) needs before engaging with higher order behaviour change targets, thereby underscoring the importance of providing clearer parameters to ensure PA components remain central during co-design processes (160).

5.4.3 Recommendations for future collaborative intervention design

Building on these findings, future collaborative intervention design would benefit from continuing to engage staff across organisational levels through staged, iterative co-creation, whilst ensuring that foundational practical and

organisational needs are explicitly acknowledged at the outset. To enhance representativeness, co-design activities should incorporate strategies to involve employees with limited schedule flexibility or lower baseline engagement, thereby reducing participation bias and broadening the range of perspectives captured. Moreover, given the persistence of implicit power dynamics in participatory settings, future work should embed more structured reflexive practices, such as facilitated role rotation, anonymised idea generation tools, or presession capacity building, to further mitigate hierarchical influence and support more equitable knowledge contributions (279). Together, these refinements would strengthen both the inclusivity and ecological validity of co-created workplace interventions.

5.4.4 Conclusions

This chapter demonstrates how a theoretically informed, multi-stage co-creation process supported the collaborative development of context-sensitive workplace PA interventions. The findings show that engaging staff across organisational levels, using inclusive visual and dialogic methods, and iteratively refining proposals allowed participants to articulate context-specific priorities and generate intervention ideas grounded in their everyday work practices. Through this process, two feasible and theoretically aligned intervention candidates that are supported as effective in the literature, job rotation and walking meetings, emerged as the most acceptable and context-appropriate options for trialling, thereby providing a foundation for the feasibility testing presented in the following chapter.

5.5 Key points of Chapter 5

- This chapter adopts a co-development approach to address limitations of traditional top-down workplace health programmes, drawing on participatory action research, self-determination theory, and the social-ecological model to ensure contextual fit, shared decision-making, and multi-level relevance.

- Intervention ideas were generated and refined through workshops, participatory drawing, and diamond-ranking exercises, enabling inclusive engagement and prioritisation across diverse staff groups.

- Staff identified multiple potential interventions, with walking/regular meetings and job rotation/redesign emerging as the highest-ranked options.

- Participants highlighted practical challenges (time, training needs, workload pressures, reliance on key individuals) and facilitators (leadership support, improved communication, reduced monotony).

- After reviewing workshop outputs, a steering group consisting of employees and the lead researcher decided on feasibility trials of job rotation (for manual roles) and walking meetings (for desk-based roles).

- Evidence base alignment: Selected interventions are supported by existing research showing small-to-moderate benefits for rotation and workplace walking, tempered by known challenges with sustainability and implementation fidelity.

- Implementation considerations: Leadership involvement, clear communication, and scheduling (avoiding peak workload periods) were identified as critical for successful intervention delivery.

Chapter 6 A Mixed-Methods Feasibility Study of Two Co-Developed Workplace Physical Activity Interventions for Mental Wellbeing

6.1 Background

Workplace physical activity (PA) interventions have been implemented in diverse forms to support employee mental health, ranging from structured exercise programmes and active breaks, environmental modifications such as sit–stand desks and walking meetings, to organisational strategies including job redesign and multi-level health promotion initiatives (153,280). Systematic reviews and meta-analyses indicate that such interventions can yield small-to-moderate improvements in mental wellbeing, depression, anxiety, and stress, yet findings are inconsistent (19,21,22,123,281). Variability in effectiveness has been attributed to heterogeneity of intervention type, intensity, and duration (19,23,282); baseline mental health and PA levels (21); and the degree of organisational and managerial support (25,282). Moreover, most previous studies assessing mental health outcomes have failed to measure the effectiveness of workplace interventions to change PA behaviour or evaluate participant perceptions, limiting the exploration of the mechanisms through which workplace PA interventions influence mental health (Chapter 4).

Previous workplace PA interventions targeting improvements in mental health and wellbeing have often been delivered outside of productive work time and often placed the emphasis on employees to use existing breaks, such as lunch breaks (283,284). Interventions which require employees to use their existing breaks from work are removing autonomy from individuals, because they limit employees' ability to choose how they spend their own rest time, shift control of break periods from employees to employers, and reduce the voluntary, self-directed nature of break activities, which is essential for psychological recovery (285). A qualitative study of employers' and employees' perspectives found that although employees and managers recognise mental health and productivity benefits of PA during paid work time, employee fears of increased workload pressures, cultural norms, and organisational concerns around the cost of additional breaks meant the idea was largely viewed as unworkable (284).

One solution proposed, has been to implement PA behaviour changes as part of job redesign thereby negating the need to implement new breaks or use employees existing break times. Straker, Mathiassen and Holtermann (2018), proposed the 'Goldilocks principle', which refers to designing workplace PA so that its intensity, frequency and duration are 'just right', neither too much nor too little, for promoting health (286). This principle aligns with the findings of the mapping study in Chapter 3, which showed that higher work-related PA was not associated with better mental health, with predictive models indicating that recovery-orientated changes in PA could improve wellbeing outcomes for manual workers. The feasibility of this concept has been demonstrated in childcare and industrial settings, with mixed findings on effectiveness (287,288), but it has so far not been adapted for desk-based workers or mental health outcomes.

The present feasibility study addresses these gaps by combining compositional data analysis (CoDA) of accelerometer-derived PA with Framework thematic analysis of semi-structured interviews, to evaluate two workplace PA interventions for mental health that involve job redesign (91,92,94,163). This mixed-methods approach enables a nuanced examination of both the ability to measure quantitative effects and the organisational, cultural, and environmental conditions that shape implementation and effectiveness, providing a novel insight into how workplace interventions can be optimised for mental health benefit.

Study context

A mapping study (Chapter 3) collected data from approximately 50% of the ACS Clothing Ltd (ACS) workforce on physical and mental health, PA patterns, and productivity. This data highlighted that employees in manual labour roles were more likely to have worse mental health and wellbeing than their desk-based colleagues. Additionally, results from the first year of the study, which were used to inform the co-creation process reported in Chapter 5, showed substantial differences in the composition of PA during work time between the two job types. Manual workers spent on average 82% of their work time in light-intensity PA (LPA) compared with 59% for desk-based workers spent, while both groups spent 1% of time at work in moderate-to-vigorous PA (MVPA) (Appendix 3-D and 3-E). Despite manual workers displaying higher overall levels of PA at

work, employee feedback during steering group meetings and co-creation workshops, indicated that those in the Process department of the workplace often had very monotonous tasks (e.g. ironing, pressing, folding), with low variability in their PA. Both groups were targeted for workplace PA interventions, with the aim of improving mental health through increased variability in PA for those working in Process and increased time in ambulatory (walking) activities for the desk-based workers. As is discussed in more detail in Chapter 5, a job rotation (JR) intervention was selected for those working in the manual labour roles within the Process department, and a walking meeting (WM) intervention was developed for employees working in desk-based jobs at ACS Clothing Ltd.

6.1.1 Aims

The research aims of this study were to 1. To evaluate the acceptability and feasibility of two workplace PA interventions delivered during productive work, 2. To identify the challenges and facilitators to the implementation of the interventions, and 3. To test the feasibility of measuring the effectiveness of each intervention to improve mental health.

Research questions

1. Can appropriate participants be recruited to a scheduled JR for manual workers and a weekly WM for desk-based workers at ACS?

2. How appropriate are the selected data collection procedures and outcome measures for the purpose of the study?

3. Are study procedures and interventions suitable for and acceptable to participants?

4. What adaptations were made to the interventions to increase acceptability and the likelihood of sustainability?

5. Do the workplace PA interventions show any promising effects on mental health in the target workers and are changes in PA related to the outcome?

6.2 Methods and materials

This study was approved by the Medical, Veterinary, and Life Sciences College ethics committee at the University of Glasgow (reference number 200230360). Ethics approval can be found in Appendix 6-A. An adaptive and flexible methodology was applied to all aspects of this feasibility study as guided by the work of Orsmond and Cohn (2015) (289).

Study design

This was a mix-methods feasibility study of two workplace interventions that were delivered by the company and informed by feedback from the PhD project reported in this thesis (Chapter 5). Feasibility of recruitment and retention of participants, data collection, and acceptability of procedures were all evaluated through a combination of quantitative and qualitative data. Participant perceptions of acceptability, impact, and facilitators and challenges for implementation were assessed through a thematic analysis of semi-structured interviews. For the purposes of evaluating the potential effects of both interventions on wellbeing, participants acted as their own controls. A single-group repeated measures design and a within-person repeated-measures design were applied for the JR and WM interventions, respectively (290).

Recruitment and retention

Participants were recruited from the Processing department in the Operations division and the Operations managerial team, for the JR and WM interventions, respectively. As the two interventions being tested were specifically designed for the job demands of the personnel within these specific departments, inclusion in the study was exclusive to employees who had been working regularly within one of these two departments for more than 3 months, and were physically able to either engage in walking for 30 minutes or complete job specific tasks (loading and unloading machines etc.). For the job rotation group, 19 staff working in the processing department were contacted directly by their team leader and informed about the study. Ten employees volunteered to be participants and signed informed consents (Appendix 6-B) to provide data for the feasibility study during the JR initiative. In the WM group, a managerial team of

seven employees, who would meet for a weekly meeting every Friday, were approached in person, by the researcher and informed about the study. All seven departmental managers volunteered to take part in the study and signed informed consent forms (Appendix 6-B) for data collection. In total, this study recruited 17 employees from ACS, ten of which were involved in the JR intervention and seven of which took part in the WM intervention.

Participants from the JR group were all from the same department (Processing) that processes garments and textiles for resale or hire. Work tasks involved in this department and within the JR schedule include packing and unpacking, cleaning (by hand and by operating machinery), repairing, pressing or ironing, and quality control checks on garments. Those within the WM group were comprised of employees with senior roles in the organisation. Participants in this group were responsible for tasks such as supervising manual workers, organising work schedules, and monitoring department outputs, with most tasks involving the using of computers whilst seated or at standing desks. All participants involved worked full-time and had been employed by the company for more than a year. A short demographic survey was issued to all participants to collect data on sex, age, ethnicity, and body mass index (BMI).

6.2.1 Delivery of two physical activity interventions

6.2.1.1 Job rotation

The JR schedule was designed in collaboration with the senior manager of the workplace department in which it took place. For full details on this iterative design process, please refer to Chapter 5. In brief, it was decided that employees would work at their normal workstation or in their normal role Monday through Wednesday and then work at a different workstation on Thursdays and Fridays. Due to the nature of the work and variability between job tasks, it was not possible to match for changes in job tasks across all participants when changing between workstations. So, some participants rotated between workstations with very similar tasks, while others rotated between workstations that had substantial differences in both the type of PA (including posture, intensity and variability of movement) and sociocultural surroundings (coworkers and team leaders) (Table 6-1). A sub-analysis of variance within- and

between-persons showed no difference in wellbeing outcomes when employees were swapped to a similar workstation to their regular one when compared to being swapped to a workstation with completely different job tasks.

Table 6-1. Job rotation schedule showings the tasks that participants in the program rotated between

No. of staff	Section(s)	Mon-Wed	Thu-Fri	Task similarities & differences
2	Dry Cleaning *	Operating machines	Spot cleaning	Operating machines requires reaching and lifting of clothes. While spot cleaning is more stationary but requires more specific training.
2	Laundry *	Shirt Press	Shirt sortation & Operating machines	Shirt press is performed standing in the same spot, while sorting shirts involves changing postures and moving between machines.
2	Jackets *	Jacket check	Final Jacket QC	Very similar, both standing.
1	Trousers *	Trouser check	Topper (Pressing)	Topper requires more reach with trunk and arms, both in standing posture.
1	Returns and pressing	Stripping bags (Returns)	Kilt Check or Legger (Pressing)	Stripping has more PA variation and intensity. The legger is repetitive with lower intensity. Both standing.
1	Dresses and trousers	Dress Check	Trouser Check	Some similarities in skills, and very similar PA in standing posture.
1	Repairs and pressing	Repairs	Shirt Press	Repairs is a seated job and less physically active, with less demands on frequency of output.

***Rotations that happened within the same section within the department.**

The departmental management team informed the participants individually and in-person, on Monday morning (first working day of the week), as to which workstation they would be moving to that week. Then on the Thursday of each week, participants would report to their assigned alternative workstation for the final two days of their working week.

6.2.1.2 Walking meetings

Participants in the WM group were asked to adapt a weekly scheduled meeting, so that instead of sitting in a meeting room within the worksite, they would walk outside for a minimum of 15 minutes while conducting the meeting. These meetings were amongst team leaders who would meet at the end of each week on a Friday to discuss departmental targets and updates. To reduce the impact on productivity, no specific walking pace was assigned or targeted. It was originally intended that all walks during the three meetings that were included in the intervention phase, would be along a public path from the worksite to a café within the surrounding business park and then back again. However, this route included a stop at the café, which participants found too noisy to have productive discussions in. As a result, the second and third meetings began with a 15-minute walk around the outside worksite carpark and delivery area, before walking inside the worksite to visit each department that was discussed during the meeting.

6.2.2 Data collection procedures and outcome measures

Data was collected in two separate phases during 2024, June (JR) and April-May (WM), which allowed for the best use of resources as some of the participants in the WM were team leaders to those in the JR group. Each study lasted three working weeks, with data collected for five days of each week for the JR (Monday-Friday) and two days each week (Thursday and Friday) for the WM. For the JR intervention, week 1 acted as a control week, where participants provided outcome measurements while following their normal working routines. Daily measurements continued in weeks 2 and 3, when the JR intervention was delivered. In the study of WM, each Thursday acted as a control day in which participants performed their normal working routines, which included seated meetings for each participant. Participants were then exposed to the WM

intervention each Friday. This allowed for a focus on the within-person effects of WM on wellbeing and an analysis of whether wellbeing was better on days when participants had a WM compared with days with only seated meetings.

Physical activity

Wrist-worn accelerometers (Actigraph wGT3X-BT) were used to collect participants' PA data. Participants in both groups were asked to wear the devices continuously on their non-dominant wrist during work time (8 hours) during the intervention. JR participants wore the device all five working days (Monday-Friday), while WM participants wore theirs on Thursdays and Fridays only. The accelerometers were then collected at the end of each week of the study period and raw data was downloaded via the Actigraph software (ActiLife v6.15).

Mental health (wellbeing)

An adapted version of The World Health Organization-Five Well-Being Index (WHO-5) was used to collect subjective mental wellbeing data (291). The WHO-5 consists of five statements about feelings and asks how often someone has had those feelings over the previous two weeks. The WHO-5 was developed as a generic mental health scale without any diagnostic specificity, as positive wellbeing was considered by the WHO to be another term for mental health (292). A systematic review of 213 studies found the scale performed well against a number of gold standard screening tools for mental health and was a valid measure of depression (sensitivity 0.86 and specificity 0.81) (293). Given the sensitivity of this index to short-term changes in wellbeing and its strong clinimetric properties, a daily adaptation was used in this feasibility study so as to reduce recall bias and capture temporal change during the interventions (294). As some participants were not native English speakers and to minimise burden, the WHO-5 index was adapted to a visual Likert scale (scored 0-4) with the same 5 feelings stated as opposites (i.e. “anxious” versus “calm”) at opposing ends of the scale, as shown in Figure 6-1. For workplace health and safety reasons, no phones are permitted at workstations. Therefore, printed copies of this scale were provided to participants at the end of their working day, when they were asked to mark in pen where the felt they were on each of the 5 emotional scales at that moment. Answers on the left of the scale

indicated better wellbeing. The term “wellbeing” will be used to describe the mental health outcome throughout the rest of this chapter.

Happy						Sad
Energetic						Lethargic
Calm						Anxious
Fresh						Tired
Interested						Uninterested

Figure 6-1. Adapted WHO-5 visual scale used to measure wellbeing. Participants marked on each row where they felt the expression related most closely with their own feelings.

Semi-structured employee interviews

Semi-structured interviews were conducted with participants individually following the conclusion of the quantitative data collection phases. Thirty minutes was allocated for each interview, which took place onsite at the workplace, in a private meeting room. Interviews were audio recorded on a laptop computer, before being transcribed using the dictate function in the Microsoft Word application. Automated transcriptions were then checked and edited by the researcher (CT) who conducted the interview, before recordings were deleted to protect the anonymity of participants. Two of the participants requested a translator to be present for the interviews, and the same translator was requested in both cases.

Interview questions were framed around participants’ experiences during the interventions and the discussion guide (Appendix 6-C) included questions on the compliance with the intervention, the communication and delivery of the relevant intervention processes, the acceptability of the interventions (for themselves and colleagues), differences observed between job roles or meeting

conditions (depending on the intervention received), any perceived positive or negative effects on wellbeing or PA, any challenges or facilitators to the intervention, and the feasibility of the intervention continuing in the workplace.

Additionally, a reflective researcher dairy was also kept by the embedded researcher (CT). This allowed more casual conversations with employees that took place before, during, and after the interventions to be used for contextual framing of interview data and as input for researcher reflections in the analysis.

6.2.3 Data Processing and Analysis (feasibility testing of measures)

6.2.3.1 Quantitative data

Wellbeing scoring

Scoring for the WHO-5 adapted visual scale was aligned as close as possible to that of the original scale, which has a scale scoring range of 0-5 for each statement on the respondent's feelings and a total range across the five statements of 0-25. In this study, the scoring range of 0-4 (adapted for the visual images) meant that summed total daily scores range from 0-20, with higher scores indicating better wellbeing. To compare changes between experimental and usual work conditions, daily wellbeing scores were used for the within-person analysis of WM, while daily scores from five working days were summed together (scoring range 0-100) for the JR group to assess changes at a weekly level. For the WHO-5 index, a threshold of 50% has been suggested as an indicator of poor mental wellbeing (293). Whilst the scale used in this study is an adaptation and may produce different measurement properties, a total daily score below 10 or a weekly score below 50 would be suggested as an indicator of poor wellbeing.

Accelerometer data processing

Raw accelerometer data was processed using a random forest machine learning model (randomForest package, R software). This is a validated and sensitive method of classifying PA data into activity types (sedentary behaviour, physical active while standing or sitting [labelled stationary+], and walking), with

intensity bands (sedentary (SED), light intensity (LPA), moderate-to-vigorous (MVPA) mapped to each type of PA (194). It also replicates the approach taken to analyse and report accelerometer data in Chapter 3 of this thesis. An inclusion threshold for analysis was set at 360 minutes (6 hours) of wear-time during the study, as this was considered to reasonably account for variation in working hours and capture days when workers arrived late or finished shifts early. Days with less than 360 minutes of wear-time were excluded from analysis rather than imputed to avoid biasing variability estimates.

Job rotation analysis

Daily work-time PA was expressed as two three-part compositions, each expressed in proportional form:

1. **Physical activity type composition**: sedentary behaviour, stationary+ activity, walking activity

2. **Physical activity intensity composition**: sedentary behaviour, LPA, MVPA

Within-week variability in these daily compositions was quantified using a compositional data analysis (CoDA) framework (3,93). For each participant and week, the pairwise log-ratio variances between all behaviour pairs were calculated using the Aitchison variation matrix, implemented via the '*variation*' function in the *compositions* package in R (295). The mean of the upper triangle elements of this matrix was taken as a single scalar summary of overall within-week variability, with higher values indicating greater day-to-day fluctuation in the relative distribution of behaviours. This approach preserves the relative-scale properties of compositional data and avoids spurious correlations inherent in raw-minute metrics (3,91).

In total, five linear mixed-effects models (LMMs) were fitted to assess the effects of the JR intervention on the wellbeing outcome and changes to within-week variation in PA. Initially, a model was fitted to examine changes in wellbeing across the intervention period, with the week of the study (baseline week, intervention week 1, and intervention week 2) entered as a categorical

fixed effect and participant ID included as a random intercept to account for repeated measures within individuals.

Following this, two LMMs were repeated across the PA type and the PA intensity compositions. The first of these models assessed changes in day-to-day (within week) variability of the PA compositions, quantified using Aitchison's mean variation (as described above), again with week of the study as a categorical fixed effect and participant ID as a random intercept. The final PA composition models investigated the association between within week PA variability and wellbeing, with mean variation entered as a continuous predictor, the week of the study included as a categorical covariate, and participant ID specified as a random intercept. Models involving mean variation were fitted using the *bobyqa* optimiser to aid convergence. Baseline week served as the reference category in all models, enabling estimation of mean differences for each intervention week relative to the baseline week. Model assumptions were evaluated through residual diagnostics, and statistical significance was set at $p < 0.05$ with 95% confidence intervals reported.

Walking meetings analysis

Similar to the analysis of the JR intervention, PA data collected during the WM was evaluated following compositional data analyses (CoDA) (92). For the purposes of assessing the intensity of walking, each participant's daily time at work, inclusive of breaks (480 minutes total), was transformed into three separate compositions:

3. **Physical activity type composition**: sedentary behaviour, stationary+ activity, walking activity

1. **Physical activity intensity composition**: sedentary behaviour, LPA, MVPA

2. **Walking-intensity composition**: walking-LPA, walking-MVPA

For interpretability, each composition was modelled separately using the "k – 1" raw-parts approach (3,94). That is, within each composition one part was dropped (sedentary activity for the first two compositions and walking-LPA for

the third) and the remaining two predictors were scaled (mean = 0, SD = 1). This enabled direct interpretation of percent-time effects without compositional transformations.

Three linear mixed-effects models were fitted under restricted maximum likelihood (REML), using Satterthwaite's method for denominator degrees of freedom (lmerTest v3.1-5). In all models, fixed effects were walking meeting (walking meeting day vs. control day, dummy-coded), time (day of study, centred so 0 = average day), and two scaled composition predictors per compositional block.

A random intercept for participant ID captured between-person baseline differences. Multicollinearity was assessed via variance inflation factors (VIFs) using R package *car* (v3.1-1); all VIFs < 2 indicated negligible collinearity among predictors. Variance decomposition (marginal and conditional R^2) was performed to quantify model fit. In addition to variance decomposition, the degree of clustering of repeated wellbeing observations within participants was quantified via the intraclass correlation coefficient (ICC_1), which indicate the proportion of total wellbeing variance attributable to stable individual differences. All quantitative analyses were performed in R version 4.1.3, using the *compositions* and *lme4* packages.

6.2.3.2 Qualitative data

To analyse the qualitative data from the semi-structured interviews, the five stages of the Framework approach to qualitative analysis were followed (296). These five stages are familiarisation with the qualitative data, inductively and deductively identifying themes and sub themes within the data, using these themes to code the data, charting and summarising the data into a matrix, and then interpreting and mapping the data. The process of generating main themes and sub-themes was influenced by the original research objectives and by new concepts generated inductively from the data. Sub-themes developed during the analysis were categorised into facilitators, challenges, perceived benefits, or a combination of these.

6.3 Results

In line with mixed-methods feasibility guidance(289), quantitative assessments of recruitment, data completeness, and outcome variability are reported as feasibility findings, complemented by qualitative findings addressing acceptability, implementation, and contextual fit.

Participant retention, adherence, and demographics

In the JR intervention study, quantitative data was collected for eight participants after two were removed from the JR schedule during the first week of the study. This was due to unexpected demand within the department and a need for their specific skillsets to be assigned to certain job tasks. Participants were mostly male, (female n=3, 37.5%), different ethnicities (37.5% White Scottish, 37.5% other White European, 25.0% other Black), 42.38±14.33 years old with an average BMI of 28.76±3.85.

Of the seven participants that signed up to take part in the WM intervention, all seven engaged in all six days of the study (three control and three experimental). Participants consisted of three females and four males, mainly White Scottish (57.1%) (28.6% other White European,14.3% Asian), 43.86±8.42 years old with an average BMI of 34.41±8.42.

Two of the eight participants who took part in the JR intervention for all 3 weeks, were absent from work during the interview phase. Qualitative data was analysed for ten participants, which comprised of the six available participants from the JR intervention and four senior staff leaders who were responsible for delivering the JR, as well as being participants themselves in the WMs.

6.3.1 Quantitative findings

6.3.1.1 Job rotation intervention

Wellbeing responses and wear time compliance

All participants provided responses to the adapted visual wellbeing scale at the end of each work shift during the study, 15 responses per participant (100%

response rate). One of eight participants missed one day of PA data collection (week 3), as they were running late to work and did not have time to collect their accelerometer. In total 15 days of accelerometer data did not meet the valid working day threshold of 360 minutes and were excluded from the analysis. Mean accelerometer wear time (excluding non-wear days) was 498.2 minutes per day during the study, ranging from 386.2 minutes to 643.3 minutes.

Wellbeing changes between weeks

As shown in Table 6-2, linear mixed-effects modelling indicated no statistically significant differences in total weekly wellbeing scores between the baseline week (Week 1) and the intervention weeks (Weeks 2 and 3). The estimated mean wellbeing score during the baseline week was 85.13 (SE = 5.02). Compared with Week 1, scores were lower by 1.00 points in Week 2 ($p = 0.827$) and higher by 1.75 points in Week 3 ($p = 0.703$). Figure 6-2 shows the temporal changes in daily mean wellbeing across the three weeks.

Table 6-2. Linear mixed-effects model results for wellbeing and PA variability predicted by week, and wellbeing predicted by PA variability and week

Model & Predictor	Estimate	95% CI	p-value
Wellbeing ~ Week			
Intercept (Week 1)	85.13	[74.17, 96.08]	<0.001
Week 2	−1.00	[−10.68, 8.68]	0.827
Week 3	1.75	[−8.93, 12.43]	0.703
PA intensity composition (SED, LPA, MVPA)			
PA intensity variability ~ Week			
Intercept (Week 1)	16.65	[5.07, 28.22]	0.0077
Week 2	−12.24	[−24.99, 0.51]	0.0615
Week 3	−4.60	[−17.35, 8.15]	0.458
Wellbeing ~ PA intensity variability + Week			
Intercept (Week 1)	88.01	[75.64, 100.38]	<0.001
PA intensity variability	−0.17	[−0.55, 0.20]	0.343
Week 2	−3.12	[−14.12, 7.88]	0.547
Week 3	0.95	[−10.72, 12.63]	0.840
PA type composition (sedentary, stationary+, walking)			
PA type variability ~ Week			
Intercept (Week 1)	0.556	[0.27, 0.84]	0.0009
Week 2	−0.278	[−0.68, 0.12]	0.186
Week 3	−0.095	[−0.50, 0.31]	0.645
Wellbeing ~ PA type variability + Week			
Intercept (Week 1)	85.79	[73.99, 97.58]	<0.001
PA type variability	-1.19	[−12.19, 9.82]	0.829
Week 2	-1.33	[−11.48, 8.82]	0.790
Week 3	1.64	[−8.94, 12.22]	0.732

Notes: **Estimates are unstandardised coefficients from linear mixed-effects models fit by restricted maximum likelihood (REML) with random intercepts for participant. 95 % confidence intervals are calculated as Estimate ± 1.96 × SE. Week 1 is the reference category for week contrasts. Variability values represent the mean of the upper-triangle elements of the Aitchison variation matrix for daily compositions within each week.**

Change in within-week variability of physical activity

In the daily PA intensity compositions, the average within-week variability appeared lower in Week 2 compared with Week 1, although this did not reach conventional statistical significance. Variability in Week 3 was also not significantly different from Week 1. For the daily composition of PA types, results were similar to those of the intensity compositions, variability was somewhat reduced in Week 2 and Week 3, but again neither difference was statistically significant (Table 6-2). The random intercept variance for participants was estimated at zero, indicating no detectable between-participant differences in baseline variability.

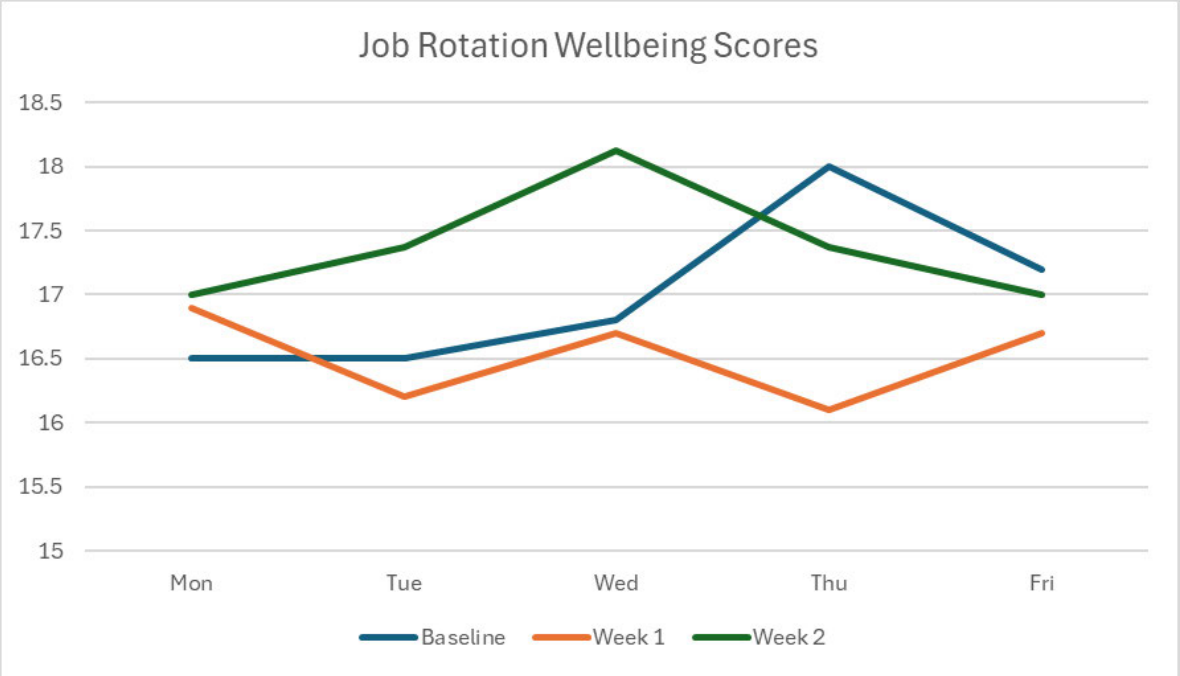

Figure 6-2. Line plots of mean wellbeing scores (range 0-20) across days of the working week in each week of the study

Variability as a predictor of wellbeing

When modelled alongside intervention condition (week), within-week variability was not a significant predictor of wellbeing in either composition of PA intensity or PA type (Table 6-2). The intervention effects remained non-significant in this adjusted model. Figure 6-3 provides a point-range plot of the estimated marginal means (± 95 % CI) for the wellbeing outcome and the variance of both PA compositions each week in the JR study. Values for the y-axis in the within-week variance plots (Figure 6-3) represent the mean log-ratio variance across all pairs of behavioural components. These values are dimensionless and do not correspond to percentages or time-based units. Instead, they quantify how much the relative distribution of behaviours (e.g., sedentary vs. ambulatory activity) fluctuates from day to day. Higher values indicate greater within-week variability in the composition of behaviours, whereas lower values reflect more stable daily patterns. In several PA categories (especially MVPA), between-participant variability was extremely low. As a result, error bars appear very short or visually absent in some panels. This is not a plotting error but reflects the minimal spread in the underlying compositional data.

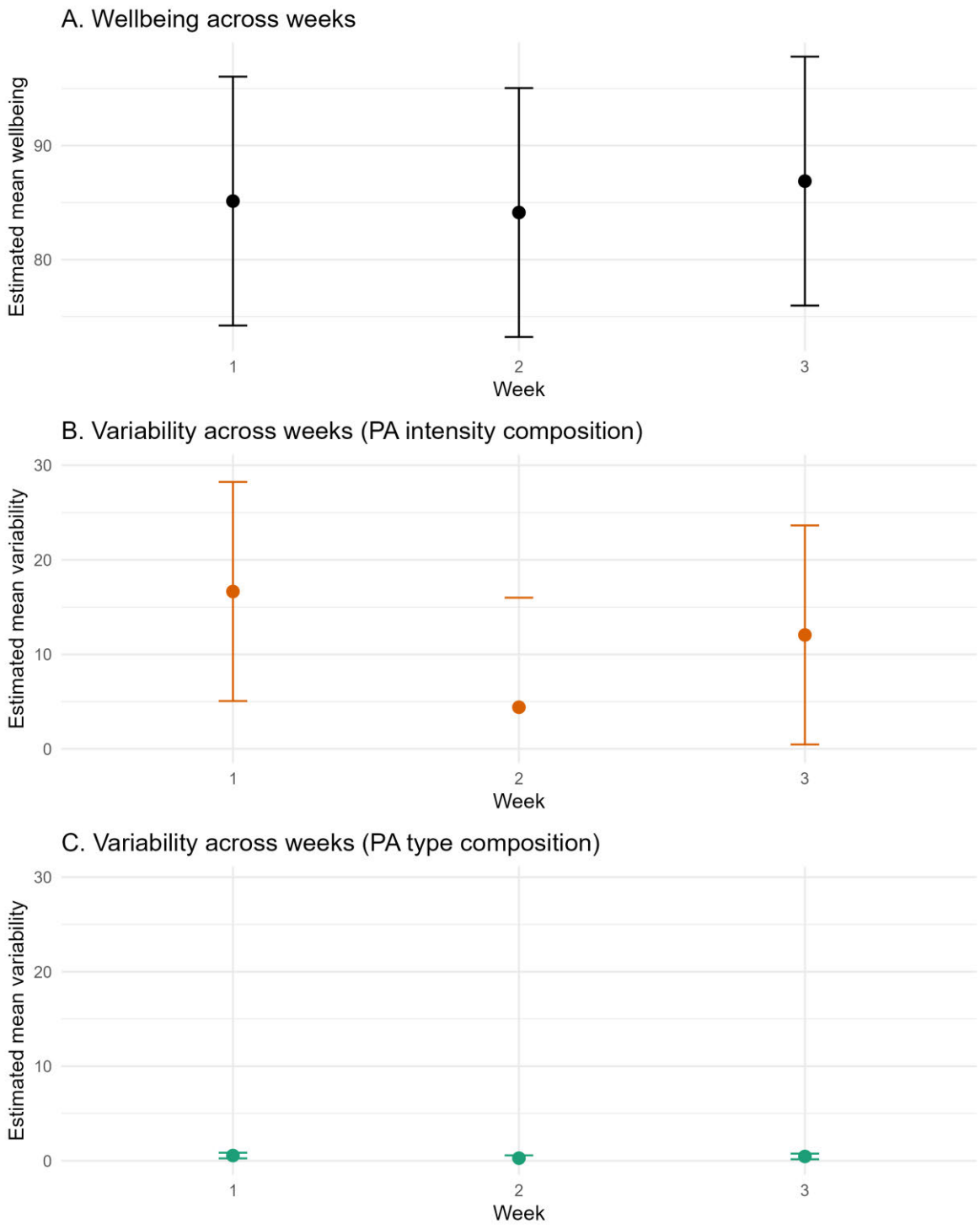

Figure 6-3. (A) Estimated marginal means (± 95 % CI) for wellbeing. (B) Estimated marginal means for within-week variability in PA intensity composition. (C) Estimated marginal means for within-week variability in PA type composition. Panels B and C share the same y-axis scale to allow direct comparison of variability magnitudes. Variability values represent the mean of the upper-triangle elements of the Aitchison variation matrix for daily compositions within each week.

6.3.1.2 Walking meeting intervention

Wellbeing responses and wear time compliance

All seven participants provided responses to the adapted visual wellbeing scale at each of the six time points (100% response rate). Six participants provided PA data at all time points in the study, with one participant forgetting to wear their accelerometer on one of the three experimental days. In total, 41 days of PA data and 42 days of wellbeing data were collected for the within-person analysis of this intervention. Three days of accelerometer data did not meet the valid working day threshold of 360 minutes and were excluded from the analysis. Mean accelerometer wear time (excluding non-wear days) was 585.5 minutes per day during the study, ranging from 295.3 minutes to 887.3 minutes.

Wellbeing changes between days

Results are presented as mean ß-coefficients, that is the associated change in outcome (wellbeing) following a one-standard-deviation increase in the proportion of time spent in a PA behaviour (at the expense of the removed variable and holding the other parts constant). Meaning, ß-coefficients for each predictor within a composition, will represent the magnitude and direction of expected effect on wellbeing following a one standard deviation (SD) increase in %-time (or log-ratio) at the expense of the dropped part of the composition. For example, in the composition of PA intensity (SED, LPA, MVPA), the ß-coefficient related to MVPA represents the predicted change in wellbeing following a 1 SD increase in the proportion of time spent in MVPA at the expense of a 1 SD decrease in SED, with the third part of the composition (LPA) remaining constant.

Table 6-3. Results summary of three linear mixed-effects models

Composition	Walking meetings β (SE, p)	Part 1 β (SE, p)	Part 2 β (SE, p)
PA Type	1.197 (0.482, 0.019)*	Walking: 0.347 (0.312, 0.281)	Stationary+: 0.005 (0.284, 0.985)
PA Intensity	1.203 (0.406, 0.019)*	MVPA: 0.090 (0.407, 0.826)	LPA: 0.232 (0.393, 0.559)
Walking-intensity	1.136 (0.289, 0.026)*	MV Walking: 0.261 (0.289, 0.377)	-

*** Denotes p < .05.**
β = estimated effect on wellbeing score of: a day with a walking meeting vs a day with no walking meeting in the left column; a 1 SD increase in stated PA component at the expense of a 1SD decrease in sedentary time or walking-LPA (walking intensity row) in the middle and right-hand columns.

As seen in Table 6-3, across all three models, walking meetings were associated with a statistically significant point increase in WHO-5 scores (1.14 to 1.20, p < .03). This effect was robust across models and not affected by multicollinearity or the specific composition block. None of the within-composition predictors reached significance (all p > .28). Reallocations of time spent in various PA behaviours did not display detectable effects in this sample. This analysis shows that walking meetings improved wellbeing significantly, but reallocations of PA time did not show any effect.

Figure 6-4. Adapted WHO-5 wellbeing scores (range 0-20) on walking meeting days vs no meeting days

In all models, fixed effects explained approximately 20–21% of wellbeing variance, while including participant-level differences increased total explained variance to ~30–33%. This highlights moderate consistency in composition-related effects and substantial individual variation in baseline wellbeing.

6.3.2 Acceptability, implementation, adaptation (qualitative feasibility findings)

Main themes and sub-themes are presented in tables alongside concise summaries, indicative quotes, and reflective researcher explanations. Summaries of main themes are presented in text.

6.3.2.1 Job rotation intervention

For JR, four main themes and 15 sub-themes were identified and are presented in Table 6-4. This table was used as a source to generate an infographic using Google Notebook LM for Figure 6-5, which shows how each sub-theme maps to a main theme.

Table 6-4. Main themes and sub-themes from thematic analysis of semi-structured interviews with job rotation participants (n=6) and implementors (n=4)

Main theme	**Sub-theme** (challenge, facilitator, or combination)	**Concise Summary**	**Indicative quote**	**Reflective explanation**
Individual capacity for rotation	**Training, skills and job experience** (challenge/facilitator)	Some workstations required specialist skills or long experience, limiting who could be rotated into them; experienced staff could move with minimal disruption.	"…they always come up and say they need a body, but it's hard for me to say aye take a body, because that's putting one person out. So, who do I get to do my spotting? Who do I get then to do my wedding dresses? Because it's easy for everybody else in the factory to take somebody that doesn't need a specific job. But up at my side, my job, is a technical job, it's a professional job." – Team leader 1 " …because I'm in the company 18 years, so I know almost every single station. I'm happy everywhere because I can work in so many places. So, if I were moved right now to the barcode or something or dresses or somewhere. I know exactly what to do and nobody's losing time to explain me how I should work in that place. I'm just going to work." – Employee 1	Skill level and prior experience determined how easily staff could be redeployed, with senior staff concerned about implications for training needs and productivity.

	Perceived Physical capability (challenge)	Physical limitations, pain, or allergies excluded some employees from certain stations.	"Some people do one job all day, but other people I ask to do something else throughout the day. But I don't ask every single person because I know they can't. All the older women or older men. So, we leave some things for younger people." – Team leader 2 "I mean, no, I like the job rotation, but because of my allergy for example, I can't work in the Dry cleaning because of the chemicals." – Employee 5	Physical capacity was a key constraint, with both self-reported and manager-perceived limitations shaping rotation feasibility.
	Temporary staff (challenge)	Short-term agency workers were generally excluded due to training demands.	"We believe we could have something in place that would work for 100% of the workforce, so they all would be part of the job rotation programme, apart from the people that we take on for a short period of time (temporary agency staff). We take them only for the busiest time between May and end of August, so there's no real time to train them." – Manager 1	The seasonal use of temporary staff limited their inclusion in rotation, reducing potential workforce coverage.
	Speaking different languages (challenge)	Communication barriers influenced rotation decisions, with some employees excluded from certain stations or teams.	"Some of the problem is, most of them are Polish and they can't understand. Right. OK, you've got a language barrier in here." – Team leader 1 "Because I don't speak English, there are some places that I don't get asked to work at." – Employee 5	Employees do not all speak the same language, meaning that some teams can be grouped by a common language, at the exclusion of those who do not speak the language.

Resistance to change	**Attachment to a team** (challenge)	Strong identification with close-knit teams created reluctance to release or accept staff from other sections.	"We've got a section that have built their team, and they just keep the same staff, and they weren't sharing the staff with other departments, and they weren't taking anybody in, a more closed section. That's when I had a problem in taking staff out and putting somebody else in instead. And so, it worked for most of the stations, but not for all. " – Manager 1	Some employees and team leaders reported that they feel part of a smaller team within the workforce. Employees and team leaders of these teams had pride in their team culture and work ethics. These teams were viewed with reverence from both a social and productivity perspective, with employees concerned about losing their team bond.
	Current job satisfaction/ wellbeing at work (challenge)	Some employees feared being moved to less desirable or more stressful stations; those with high variety in current roles resisted moves to more monotonous tasks.	"I would say it could work, but I think it would benefit certain people more, because if you're at a station, you're in the one spot all day and it's just doing that same thing. But for me, I like where I work and I'd rather stay at my bit the whole time than get moved, because I'm already doing different stuff... as I get switched off (rotated within the job role). But I would say, definitely if you're doing the station work, I could see why you would want to be moved." – Employee 2	Perceived quality of current work influenced openness to rotation, with concerns about reduced satisfaction or wellbeing.
	Support and encouragement from colleagues and team leaders (facilitator)	Positive social reinforcement eased transitions to new stations.	"When you put in the change, yeah, they look at you and go, 'Really?!'. And then, once they do it a couple of days… (team leader gestures that it's no problem)." – Team leader 1	Social support helped reduce initial apprehension and facilitated adaptation to new roles. Several participants reported support from their colleagues or team leaders as a factor that influenced their willingness to try a new task.

	Rotating within teams, where possible (facilitator)	Internal rotation preserved team cohesion while offering skill development.	"Anytime I would rotate my team within my team, like for instance, I would take maybe one person, say take one of the girls off and say 'right, you're not doing that this week or two days. You're doing machines because you need to learn how to work with them'." – Team leader 1	Within-team rotation was more acceptable to some groups, balancing familiarity with skill diversification.
	Commitment to long-term outcomes (facilitator)	Anticipated benefits encouraged continued engagement.	"Yeah, there's always something to improve, right? And we should still be doing it (job rotation), because there's still some people left to be trained in jobs. So, there's always something to improve and I think it will work." – Team leader 2	Managers, team leaders and employees who anticipated long-term benefits to introducing a job rotation schedule were more optimistic about the effectiveness of the intervention and potential benefits.
Organisational agility	**Top-down decision-making was too slow** (challenge)	Fixed schedules reduced team leaders' flexibility to respond to unplanned demands.	"For the team leaders, I think the fixed job rotation schedule was an obstacle… because they had less flexibility. They had less control, so for them, just because it was a small group of people that had the station assigned, it didn't make it easier for them to plan the work. I believe it made it more difficult." – Manager 2	Team leaders normally act as middle management but a lack of involvement in planning, led to restrictions on their decision making during the job rotation. Under normal working conditions, they have the option to move some staff around to meet operational needs, but during the scheduled job rotation program the staff involved were fixed to a planned schedule by senior management delivering the intervention.

	Diversification of tasks (challenge)	Expanding services increased training needs for new stations, leading managers to rely on familiar staff.	"So before, when we had only menswear, it was easier to plan. People had similar skills and experience. But now there's a lot of new elements, a lot of new specialised tasks. So that's why it's more difficult. There's some variety of tasks, so we tend to pick the same team instead of taking new people for the assignment and explaining again, just more risk for an error." – Manager 1	As the business evolves and offers an increasing number of services, tasks have diversified for the workforce. This leads to an increase in the time necessary for training an individual on a new station.
	Decentralised decision making (facilitator)	Allowing team leaders more input improved responsiveness and flexibility.	"Yes, but I think the second week was different. I felt like I was more involved, because… I could have at least a say in where staff were going or what they were going to do." – Team leader 2 "… once team leaders knew they can act a little bit more, that we can have less communication. We can allow a bit more (freedom), that made it easier." – Manager 2	Managers and team leaders found a solution to the slow top-down decision-making that came with the rigid job rotation schedule implemented in the first week. By delegating some decision-making back to team leaders, task allocation decisions were made more quickly, and staff could cover where needed.
	Seasonal variation to the schedule (challenge/facilitator)	Quieter months allowed more training; busy periods required rotations only between familiar stations.	"I mean in the busy time it's more needed but more difficult to start. Yes, in quieter time, it's easier to do but it's less needed. It's more about the planning." – Manager 1	Seasonal workload patterns offered both opportunities and constraints for rotation scheduling.

Strategic Workforce Versatility	**Increased employee self-efficacy** (facilitator/benefit)	Staff able to work across multiple stations were more confident and felt more valued.	"…even with staff on permanent contracts that do less things we can see that they are less confident, and they possibly don't feel as valued as those that can do many, many more things. So that would be one example of why it needs to be done." – Manager 2 “I like it (job rotation). I'm a flexible person." – Employee 1	There were reports from employees, team leaders and managers of greater self-efficacy in staff who were able to do more tasks. These individuals are more confident in their ability to move between workstations.
	Cover for staff (benefit)	Job rotation can facilitate coverage during absences or turnover.	"We should help each other. If someone is sick or is on holiday, I should go to that station. Help those people." – Employee 5 "We had lots of stuff to add to the system. But many people were on holiday that week. We need people who can cover." – Employee 1	Participants believed that a job rotation schedule would make it easier to cover workstations during staff absence, annual leave or turnover.
	Upskilling of workforce (benefit)	Broader skills can make planning easier and increase operational resilience, despite initial resistance.	So, previously we would rotate some staff, usually every three months, but it could be up to six months. Changing every month, we felt that would be possibly changing too quickly and many people wouldn't like it. And we believed that keeping an employee on a task for more than four or five, six months would be too long. We didn’t keep a schedule. – Manager 1 "So yeah, especially in those people that have moved before, I think they… They felt like this is working better for them, knowing in advance and doing it more frequently." – Manager 2	The job rotation intervention was viewed as a more structured and frequent version of previous ad hoc efforts to rotate staff over longer periods (typically every three months) within the workplace. These longer-term rotations have been perceived as successful in upskilling the workforce, despite challenges in training time and reluctance from some staff.

Theme 1: Individual capacity for rotation

“I tried to do the ironing once, when I’d not long started and I couldn’t do that either because that’s crouching, bending over. There’s no point in me going there and spending all day in pain. I don't want to do that." – Employee 6

Not all employees were able to move to all workstations, and not all workstations were suitable for all employees. Implementation was shaped by differences in employees’ ability to work across multiple stations. Some workstations required specialist skills or long experience in the job, limiting who could be rotated into them, while highly experienced staff could move between stations with minimal disruption. Team leaders often assigned tasks based on perceptions of employees’ physical capability, avoiding rotations that might exacerbate pain, allergies, or other limitations. Short-term agency workers were generally excluded from JR due to the training investment required. Seasonal variation also played a role, with quieter months allowing more training and busy periods requiring rotations only between familiar stations. Language differences influenced rotation decisions, with some employees excluded from certain stations or teams due to communication barriers with English as a second language.

Theme 2: Resistance to change

“Then she was moved, and she says it was a disaster. She hates it. So, she is really happy after being moved permanently." – Employee 4 (through her translator)

Acceptability of the JR program varied among employees and team leaders. While all interviewees stated that they believed that such a program could work, some believed that it would benefit someone else more than themselves. Strong identification with close-knit teams created reluctance to release or accept staff from other sections, with concerns about disrupting established social bonds and work rhythms. Some employees feared being moved to less desirable or more stressful stations, particularly those who already enjoyed high variety or PA in their current role. Positive reinforcement from colleagues and supervisors eased transitions, and internal rotation within a section was sometimes preferred to

cross-section rotations. Anticipated long-term benefits encouraged continued engagement among some managers and team leaders.

Theme 3: Organisational agility

"For me it was, I think managing and assigning the stations. So, before I had a bit more freedom in staff movement, so I could just move them around according to the operational needs. During the intervention, trying to stick to the fixed job rotation schedule made it a bit more difficult to keep the staff at the optimal setting, if I could call it that." - Manager 1 discussing the biggest challenges they faced during implementation of the JR intervention.

The factory's operations depend on the ability to reassign staff quickly in response to fluctuating workloads, new deadlines, and incoming orders. A fixed JR schedule reduced team leaders' flexibility to respond to unplanned demands and was perceived as making daily planning more difficult. Diversification of tasks as the business expanded increased the time needed to train staff for new stations, leading managers to rely on familiar staff for specialised tasks. Allowing team leaders greater input into rotation decisions improved responsiveness and reduced perceived stress, and both managers and team leaders agreed that some flexibility within the JR schedule was essential for operational efficiency.

Theme 4: Strategic Workforce Versatility

"When we have tried to do cross-training in the past… so that it's easier for us to plan [work schedules]. It works. I know people don't like changes, but I think it helped some learn new skills." – Team leader 2

Participants described several perceived benefits of JR on the versatility of the workforce and its resilience to the pressures of staff shortages. Staff who could work across multiple stations were reported to be more confident, adaptable, and felt more valued. Rotation was seen as a practical way to ensure coverage during absences, annual leave, or turnover, reducing disruption to workflow. Both the intervention and prior informal, less frequent rotation efforts were viewed as successful in broadening skills across the workforce, making planning easier and increasing operational resilience, even if initial resistance and training demands were high.

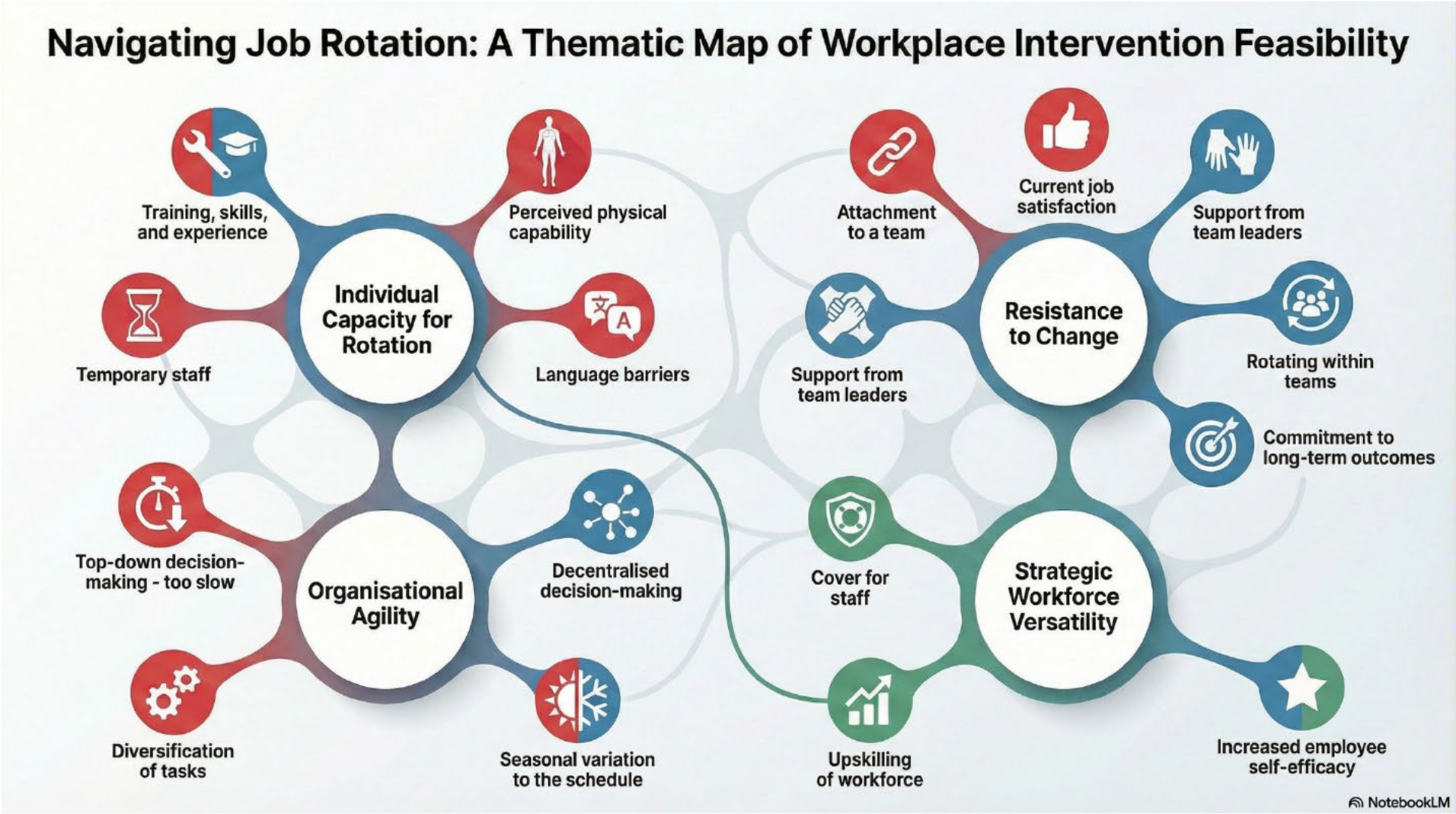

Figure 6-5. A map of the main themes and sub-themes identified through the thematic analysis of semi-structured interviews

6.3.2.2 Walking meetings

Four themes were identified for from the semi-structured interviews that followed walking meetings. These are presented in Table 6-5.

Table 6-5. Framework thematic analysis results identifying four main themes from WM interviews (n = 4)

Main theme (challenge, facilitator, or combination)	**Concise Summary**	**Indicative quote**	**Reflective explanation**
Meeting group size (challenge and facilitator)	Large groups found it difficult to maintain whole-group discussion while walking; conversations split into smaller sub-groups.	"In the first meeting, we found it challenging to have discussions between the entire group while walking. So, we ended up having our discussions in groups of two or three." – Manager 1	During the walking portion of the team meetings, participants found it challenging to communicate clearly with the entire group and found it easier to have smaller break-out group discussions. This may affect the feasibility of walking during meetings with large groups or when presentations are required.
Appropriate environment (challenge and facilitator)	Walking to destinations like cafés was enjoyable but sometimes noisy and distracting. Walking around the worksite created discussion on issues that could be addressed by senior staff.	“In our first walking meeting, we walked to a local café and got coffee. It was great to get out of the boardroom, and I think it had everyone in a great mood.” – Manager 2 “To be honest walking around the warehouse as a group can be beneficial, as it creates discussion points.” – Manager 1	Environmental context shaped the balance between mood benefits and meeting productivity, with the distractions of a local café undermining focus.
Dependency on leadership motivation (challenge and facilitator)	Continuation relied on leaders actively scheduling; meetings reverted to seated format after the intervention ended.	“I’d like to keep it going, but I can see already that we’ve not been keeping up with it since you (the researcher) stopped tracking us. I think we just forget to organise it ahead of time.” – Manager 1	The walks appear to be viewed favourably but without an ongoing commitment to prioritise them from those leading meetings, the meetings returned to the ‘default’ seated option following the end of the study.
Weather (challenge and facilitator)	Good weather encouraged outdoor walking; poor weather led to indoor adaptations.	"The second week, it was raining a little, so we spent some of the meeting walking around the courtyard and the rest walking around the different sections within the department." – Manager 2	Weather played a role in how much time participants wanted to spend outdoors. This led to the organisers deciding to take the meeting inside on a bad weather day and walk between each section within the warehouse

			discussing issues within the workplace.

Theme 1: Meeting group size

“There’s usually seven of us in that meeting, so it was hard to all listen to one person while we’re walking. We’re more used to having one person lead the meeting and only one talking at a time. This was different.” – Team leader 2

Participants described how meeting group size affected communication, with large groups finding it difficult to hold a single, cohesive discussion while walking. Conversations tended to break into smaller sub-groups, which was seen as a barrier when whole-group dialogue or presentations were required.

Theme 2: Appropriate environment

"Going to the café was nice but it was difficult to have a proper meeting, as it was too loud and there were too many distractions. I don’t know if it would be practical in the long-term.” – Team leader 2

The physical environment also shaped experiences: walking to destinations such as a local café was described as enjoyable and mood-enhancing, yet this location introduced noise and distractions that reduced meeting productivity. Participants indicated that as the novelty of the walking meetings wore off, the productive aims would take precedence when deciding on the walking route. Walks around the worksite brought up discussion points that may have otherwise not been part of the meeting but were additive.

Theme 3: Dependency on leadership motivation

“We did enjoy it, but since the trial ended, we haven’t kept it up. I don’t know why. I guess it’s up to the organiser.” – Team leader 2

Continuation of walking meetings was reported to depend on meeting leaders actively scheduling and prioritising them; once researcher oversight ended, sessions often reverted to the default seated format.

Theme 4: Weather conditions

"The weather was really nice, so it was great to get outside for the walk" – Team leader 1

Weather conditions also influenced implementation, with good weather encouraging outdoor walking and poor weather prompting adaptations such as indoor walking routes within the workplace. As with the "appropriate environment" theme, practical adaptations led to a walking route exclusively around the worksite.

6.4 Discussion

This discussion begins with a summary of the key findings before interpreting the combined quantitative and qualitative results and considering how these align with previous research. It then outlines the strengths and limitations of this feasibility study, explores opportunities for future research, and concludes with overarching implications for workplace PA interventions and employee mental health.

6.4.1 Summary of findings

These feasibility trials set out to examine whether two co-designed PA interventions, a JR program and a weekly WM, could be implemented and evaluated in this workplace. Overall, the findings indicate that both interventions were feasible to implement within the organisational context and acceptable to staff and managers. Recruitment and retention were achievable within the targeted departments, with high engagement among those invited to participate, and minimal attrition once interventions commenced. Intervention delivery was largely consistent with planned protocols, although qualitative findings highlighted the need for flexibility and adaptation to accommodate operational demands, particularly for JR. Quantitative data collection procedures, including daily mental wellbeing measurements via visual scale and wrist-worn accelerometer PA monitoring, were acceptable to participants and produced sufficient completeness and variability to support analysis, demonstrating that it is possible to capture both exposure and outcome data in this setting. Qualitative findings further identified key facilitators and challenges

influencing implementation, including individual capacity, team dynamics, organisational agility for JR, and appropriate choice of walking environment, meeting group size, and sustained leadership support for WM, providing important contextual insight into how and why the interventions functioned as they did. While the study was not designed to test effectiveness, exploratory analyses suggested that the outcome measures behaved plausibly and were sensitive to within-person change, supporting the suitability of these methods for use in a future, fully powered evaluation. The collective results demonstrate that progression to further evaluation is justified, while also identifying critical considerations for intervention refinement and study design.

Job rotation

The qualitative findings of this feasibility study show that physical capability, training requirements, and language barriers can limit JR feasibility across an entire manual labour workforce. Some individuals either perceived themselves or were perceived by managers not to be physically capable of certain tasks. While none of the participants involved identified themselves as disabled, one of the eight people involved in the JR intervention discussed chronic pain as a barrier, while another mentioned an allergy to certain chemicals used in cleaning tasks. While JR has been implemented far more often for musculoskeletal complaints than for mental health, the evidence for its effectiveness in this outcome remains weak (262). Mlekus and Maier's (2021) meta-analysis on job and task rotation found that JR was associated with improvements in general mental health (effect size $r = 0.20$, $p = 0.01$) and stress ($r = 0.13$, $p = 0.02$), but musculoskeletal complaints ($r = 0.08$, $p = 0.06$) had smaller and non-significant effects (5). When considered alongside the wider evidence, the theme highlighting the impacts of "individual capacity for rotation" on JR implementation indicates that rotation will unlikely be feasible in all individuals and across all jobs. Assessment of individuals' suitability and opportunities for PA variation should be included in future designs.

The sub-theme "Support and encouragement from colleagues and team leaders" was suggested by some implementors and participants of the JR intervention to be a counter-acting facilitator to "resistance to change". However, Bambra et al's (2007) review of task restructuring interventions in workplaces, found that

workplace social support during these interventions did not influence effects on psychosocial and health outcomes as effectively as anticipated (297). The authors suggested that structural aspects of job design (demands and control) may be more consequential than interpersonal support.

Another potential facilitator to counter the “resistance to change” theme, reported in the thematic analysis, would be to keep rotations between jobs within teams or sub-sections, where possible. However, while rotations within the sub-sections of the department might negate any need for moving employees from their preferred team or surroundings, job tasks rotated within these sections would need to differ enough to make any meaningful difference to PA. A systematic review of 16 studies that implemented a JR intervention found that none measured change in variation of PA exposure (262). Studies more typically measure change in total exposure to PA or physical load, often associating the effectiveness of JR with the extent to which total PA or physical load changes (298). For example, a study that examined female supermarket cashiers before and after the introduction of JR, found no meaningful reductions in stress or pain, and concluded that the lack of beneficial effect was likely associated with a lack of detectable change in muscle load (299). However, meaningful changes to total PA or workload may be difficult to achieve through JR in many workplaces.

One of the exploratory research questions for this feasibility study, was whether a JR would increase PA variability, rather than total PA exposure, for participants working in a department where many physical tasks were deemed repetitive. Interestingly, the within-week variability of the intensity-based composition (SED, LPA, MVPA), showed greater absolute values and wider distributions than found in the PA type (sedentary, stationary+, and walking) composition, suggesting that manual workers’ day-to-day balance of activity intensities fluctuated more than their balance of activity types. This pattern indicates that the intervention had more scope to influence intensity through small changes in posture, pace, or incidental movement, although observed changes did not reach statistical significance. In contrast, within-week variability in PA type composition was consistently low across all three weeks, with narrow distributions for each week. This stability likely reflects the highly structured nature of work tasks and the limited capacity to alter the relative

balance of PA types within existing job roles. The minimal detectable change in PA type-based variability suggests that, in this context, meaningful shifts may require more substantial redesign of tasks or workflows than was feasible within the scope of the present intervention.

Another contextual aspect to consider for the JR design is the seasonal fluctuations that ACS is subject to, with the busiest periods in the summer months. Managers believed that the quieter winter months would allow for more training time, while the busy summer months require more flexibility in staff movement and less training time. This presents a possible solution to the challenge of training, skills and experience needed for rotating employees between workstations. Limiting rotations to workstations that are familiar to employees during busy periods and then to novel workstations, to upskill during quieter periods. The Mlekus and Maier meta-analysis found that “labour flexibility” had the strongest association with job rotation (effect size $r = 0.32$, $p = 0.004$) across a wide range of organisational and employee outcomes, implying that longer implementation of JR can lead to an adaptable workforce (5). Participants in this feasibility study expected that a sustained JR program would lead to benefits of better cover for absent staff and upskilling of the workforce.

The JR was adapted in the second intervention week, as a response to the impact on “organisational agility”. Managers were unable to move staff flexibly and respond to operational demand. Following a discussion, in which the manager leading the intervention sought assurance from the researcher that it would not invalidate this study, it was decided that some flexibility in the schedule would be reintroduced. Senior management were hesitant to adapt the intervention to fit their needs due to context of being observed in an organised study. Parallel insights can be drawn from workplace health promotion studies that have specifically incorporated co-production or co-development principles. Rossi et al. (2022) evaluated the co-production of a workplace health promotion programme in an Italian research institute and found that although co-production broadened the scope of the intervention and encouraged stakeholder engagement, it also introduced contested boundaries, competing priorities, and ongoing negotiation between stakeholders regarding the legitimacy and ownership of health-related initiatives (36). These dynamics are

comparable to the challenges and negotiations encountered in this study, where differing job roles (i.e. team leader vs core staff), operational realities (i.e. individual capacity for rotation), and managerial considerations (top-down vs decentralised decision making) shaped both the feasibility and the perceived legitimacy of this job-specific intervention. Like Rossi et al.'s findings, this study demonstrates that collaborative participatory approaches do not necessarily simplify intervention development; rather, they reveal organisational tensions and power relations that must be navigated in order to produce interventions that are both acceptable and practical. In this feasibility study, the "organisational agility" theme illustrated how rigid schedules can conflict with the need for rapid task reassignment in dynamic manual work environments.

From the qualitative results, there were indicators as to why mean wellbeing did not improve during the JR intervention. For example, the sub-themes of "current job satisfaction and wellbeing at work" and "attachment to a team" highlight that in cases where an employee already has a high level of wellbeing or social connection at work, there may be less beneficial effects of JR on mental health for that individual. Indeed, baseline data showed that this sample had a relatively high average wellbeing before beginning the intervention, which may indicate a ceiling effect (300). However, by not rotating the currently satisfied employee, another employee with lower wellbeing may be excluded from potential beneficial exposures. Psychologists have argued for greater monitoring of unintended consequences and uneven outcomes in organisational interventions, even where interventions result in overall intended improvements (301). Any future studies could target employees with highly repetitive job tasks and perform sub-group analysis on those with lower baseline wellbeing where possible.

Walking meetings

Participants in the WM intervention indicated during the semi-structured interviews that while the new meeting format was perceived as highly acceptable and enjoyable, aspects of the implementation design would need refined to better align with the meeting purpose. Participants reported that the acceptability of walking during meetings was dependent on the number of participants in a meeting or the type of meeting. Larger group sizes or meetings

where there are primary presenters who are engaging with the whole group were less acceptable to the format change, whilst smaller groups or meetings involving break-out discussions in sub-groups of two or three participants were more acceptable. Similar findings have been reported in other small-scale studies. For example, a pilot study that conducted weekly WMs in groups of two or three white-collar workers at a large university, reported that participants found the intervention acceptable, while average weekly MVPA increased from 107±55 to 117±65 minutes across three weeks (272). The results of this feasibility study extend this evidence by showing that, in operational settings with variable group sizes, walking meetings may require tailored formats (e.g., smaller breakout groups) to maintain discussion quality. Future iterations of the WM intervention should be designed and implemented with consideration group size and meeting agenda.

The observed increases in mental wellbeing on WM days may be influenced by the outdoor walking routes in the first two meetings and the café destination of the first meeting. Other walking-based workplace PA interventions have found that the surrounding environment of the walking route, particularly walking outdoors compared with indoors, can play an influential role in the mental health effects (270,302,303). However, while a walk to the local café and back during the first meeting was reported as enjoyable, this option was reported as not acceptable for communication and concentration. Similar to the findings in this study, earlier research has noted that environmental factors, such as noise, weather, and route suitability, can influence both the quality of discussion and the likelihood of adoption (304).

The WM group were given the flexibility in this feasibility trial to adapt and change walking routes to best suit their purposes. The second and third meetings in this study involved walks around the worksite and turned indoors when the weather was worse. This final iteration led to an observation by participants that walking around the worksite, particularly the Operations division where these employees have managerial responsibility, created discussion points for the meeting. Following discussions with the lead researcher, a walking route within the warehouse was planned for future WMs following the study, with the intention of visiting each department while discussing operational matters. The concept was to implement a similar practice to medical doctors' rounds, adding

purpose to the walking component of the meeting by engaging directly with the departments being discussed during meetings. This is a novel adaptation to WM interventions that could increase their productivity value and add further benefit at the organisational level.

The observed wellbeing benefits of WMs align with previous studies reporting improved mood, creativity, and engagement during walking meetings (305). However, the sustainability of the walking component of meetings appeared to be dependent on the motivation of the senior manager responsible for organising each meeting, with reports that WMs were not continued following the intervention study period. The reliance on leadership motivation echoes broader workplace health promotion literature, which consistently identifies managerial support as a key determinant of sustained intervention uptake (126,306). This finding indicates that sustainability of WMs would depend on the extent to which the intervention could become embedded within workplace cultural norms, contain organisational benefits (i.e. better discussion points through warehouse rounds), and be integrated into the role of meeting organisers.

6.4.2 Limitations and Strengths

Limitations

The following strengths and limitations are discussed in light of the primary aim of this study, which was to test the feasibility of two workplace PA interventions during productive work. To this end, it is acknowledged that there was low internal validity in several aspects of the study design in favour of increasing the external validity of the evaluation.

First, it should be acknowledged that job rotations were not designed with an even distribution of task of PA variance among the participants. Rotations were arranged by the department's head manager in consultation with the researcher (CT), but organisational priorities took precedence for the aim of making the intervention as feasible as possible for those implementing the schedule. This resulted in some participants rotating between jobs that were similar and others rotating between jobs that very different. This may have affected the perceived acceptability and impacts of the JR intervention, as well as the detectability of

PA variation between weeks. Additionally, seasonal and workload variations during the JR intervention may have affected feasibility, impact and acceptability outcomes.

Although the control days for the WM evaluation included meetings, these meetings were not with the same group and had different content. Additionally, the days which included WM were always on a Friday and being closer to the weekend may have affected participants' feelings of wellbeing. It is possible that these differences in control days and exposure days affected the outcomes. Finally, while the qualitative sample included a range of roles, some perspectives, such as those of temporary staff, were under-represented.

Interpretability of the quantitative findings, which are from a relatively small sample size and short intervention period and should be considered a proof-of-concept for larger scale studies rather than generalisable to other workplace populations or an indication of longer-term effects. Furthermore, the mental health scale results cannot be compared with population levels, as adaptation to a visual format and daily measurements rather bi-weekly measurements could alter responses. The accelerometer-derived compositional data, while rich, were collected only while participants were at work. This limits the ability to detect shifts in PA behaviour outside of work during the intervention period.

In this study, it was not possible to blind or randomise participants either to condition or timing of exposure, due to the nature of the interventions and workplace demands. In both interventions, participants had to be exposed to the intervention phase at the same time for either the meetings to serve their workplace purpose or for the employees in the job rotation to cover each workstation. In larger workplace trials it may be possible to recruit a control group to compare against an experimental group, but this only controls for bias at a population-level and does not necessarily add to any analysis of within-person effects (307). Furthermore, future studies could assess participants perceptions and liking of PA, to control for motivational effects.

Strengths

The mixed-methods design of this feasibility study was a key strength, which facilitated a deductive approach to evaluation, with qualitative findings providing potential underlying mechanisms for the quantitative outcomes. The use of the Framework Method (163) for thematic analysis allowed systematic comparison across participants and themes, enhancing transparency and rigour. In addition, being an embedded researcher allowed for contextual insights and reflections that would not otherwise be possible and strengthens the interpretation of qualitative findings.

The adaptive and responsive designs of both interventions allowed for workplace implementors to create and find solutions to implementation challenges, increasing the feasibility of both as the study progressed. This approach led to the development of the “organisational agility” theme for JR and the “appropriate environment” theme for WM, both of which can facilitate increased acceptability.

Finally, integration of compositional PA analysis with in-depth qualitative exploration, enabled a nuanced understanding of both behavioural outcomes and implementation processes. From a feasibility perspective, compositional PA analysis provided an important advantage: it allowed the study to test whether the measurement approach itself was workable, sensitive, and appropriate for the population and intervention context. The method provided evidence on whether participants could comply with accelerometer wear-time requirements, whether sufficient valid data could be obtained across repeated days and weeks, and whether meaningful patterns in work time behaviours could be captured. These findings directly informed feasibility by identifying what kinds of PA changes could realistically be measured in future trials.

6.4.3 Potential intervention improvement and future research

For JR, implementation strategies should account for workforce diversity in skills, physical capability, and language. A hybrid scheduling approach, combining structured and regular rotation with daily flexibility for operational demands, may balance skill development with productivity. Training should be timed to align with quieter periods, and communication strategies should address team identity concerns.

For WMs, future iterations should consider formalising the practice within meeting protocols, providing guidance on optimal group sizes, and identifying suitable indoor and outdoor routes to mitigate environmental barriers. Leadership engagement appears critical for sustained adoption and should be supported through alignment with organisational aims and objectives.

Future research could test these interventions over longer periods and in different departments or employees within the workplace. For JR, studies could explore the impact of targeted training and language support on inclusivity. For walking meetings, experimental designs could examine the effects of different formats (e.g., paired vs. group walking) on both productivity and wellbeing.

6.4.4 Conclusion

This feasibility study demonstrates that both JR and WMs are feasible and acceptable interventions for workplaces seeking to influence employee wellbeing, but their success depends on careful alignment with organisational structures, environmental conditions, and workforce characteristics. The mixed-methods approach provided valuable insight into the contextual factors shaping implementation, offering practical guidance for organisations seeking to integrate health promoting practices into everyday operations. Evaluation of mental wellbeing with a brief adapted visual scale was highly acceptable (100% response rate), as was wrist-worn accelerometer measurement of changes in PA.

6.5 Key points of Chapter 6

- The two co-developed workplace physical activity interventions, job rotation and walking meetings, were feasible and acceptable in manual and desk-based workers, respectively.

- Data collection measures, including an adapted visual mental wellbeing scale, wrist-worn accelerometers during working hours, and 30-minute semi-structured interviews were well tolerated. The wellbeing scale, in particular, had a 100% response rate, with workers submitted responses at the end of each work shift.

- Framework thematic analysis of semi-structured interviews revealed four main themes for each intervention: individual capacity for rotation, resistance to change, organisational agility, and strategic workforce versatility for job rotation; and meeting group size, appropriate environment, dependency on leadership, weather for walking meetings.

- The job rotation was adapted to be more flexible on a daily basis, to facilitate “operational agility” for team leaders. While the walking meetings were adapted from a walking route outside of the worksite to a walking route around and inside the worksite, as this was deemed a more “appropriate environment”.

- A positive increase in mental wellbeing was observed for days when WM occurred compared with days with no WM, while there was no detectable difference in mental wellbeing between weeks with job rotation and a week of usual work routines. Change in physical activity did not appear to influence effects in either outcome.

Chapter 7 Final Discussion – Learnings from Developing Workplace-Specific Physical Activity Interventions for Mental Health as an Embedded Researcher

7.1 Introduction

Poor mental health is a global burden that affects individuals and also undermines organisational functioning and productivity, positioning the workplace, where most adults spend much of their waking hours, as a critical yet challenging setting for intervention (8,17,27,28,30,308). Although workplace physical activity (PA) interventions can yield small improvements in activity levels and mental health, their effectiveness is highly variable due to methodological heterogeneity, job-specific demands, limited attention to context, and organisational barriers (19,21). There is a need for approaches that tailor strategies to diverse roles, engage employees, and align with organisational systems and culture.

This PhD aimed to develop a route map for workplaces to follow that would allow them to create their own tailored PA interventions to improve mental health and wellbeing. From the outset, four aims were identified for the project: 1. To systematically review the literature on previous workplace PA interventions effects on mental health; 2. To evaluate the physical health, PA, mental health and productivity of employees at ACS through a mapping process; 3. Based on the evidence from the review and mapping, co-develop with ACS staff, a workplace PA intervention for mental health that is context-sensitive; 4. To run a pilot feasibility trial of the intervention and evaluate the acceptability and effectiveness of the intervention. These four central aims were achieved through the four studies presented in the preceding chapters. This final chapter will:

a) Summarise the key findings from the PhD project and interpret these findings collectively in relation to each other and the wider literature.

b) Discuss the practicalities of developing and implementing a PA intervention for mental health in a complex small-to-medium enterprise

workplace. This includes the methodological considerations and the key learnings from the entire four-year process.

c) Discuss the overall strengths and weaknesses, and what decisions would be made differently in hindsight.

d) Provide concluding statements on the knowledge contributed and recommendations for future research.

7.2 Summary of findings

7.2.1 Three key findings

1. *A combination of subjective and objective data revealed that manual workers had worse mental health, sleep quality, productivity, and work engagement than their desk-based counterparts, despite higher overall levels of PA.*

This first key finding emerged from the Annual Wellbeing Evaluations (AWEs) component of the mapping study in Chapter 3, which collected three years of cross-sectional data from employees at the workplace (ACS). Between the cohorts in years one and two there were no significant differences in any outcomes, while in year three depression, anxiety and stress were significantly worse than in year two. Manual workers had higher levels of depression than desk-based workers in the first two years of AWEs but not in the third, masked perhaps by worse depression across the workforce in year three. Compositional data analysis of PA behaviours showed that PA patterns during work time and at weekends had a meaningful influence on the disparity in mental health and wellbeing between the two job types. However, substantial between-individual heterogeneity in sedentary time, light-intensity PA, and standing PA across job types and timeframes, underscored that narrowly defined PA behavioural patterns are not easily assigned to one job type. Exploratory isotemporal substitutions showed that recovery-oriented weekend and work time substitutions were predicted to improve multiple wellbeing indicators for manual workers specifically.

2. *The systematic review of workplace PA interventions, in Chapter 4, identified low-certainty evidence for improvements in stress, mood or affect, and general wellbeing, alongside inconsistent effects on depression, anxiety, and quality of life.*

No single PA modality emerged as consistently more effective than others, and the diversity of interventions and outcomes precluded the identification of clear patterns of effectiveness across workplace settings or occupational groups. However, post-hoc subgroup analysis of outcome domains revealed patterns within the evidence suggesting interventions involving yoga or related mind-body modalities, and group-based delivery were more favourable for stress and mood/affect, respectively. Additionally, higher PA doses tended to produce more favourable results in anxiety and depression, although these trends remained tentative due to methodological limitations. Reporting of contextual features, particularly employer contributions, implementation factors, and facilitators or barriers to delivery, was sparse, limiting the field's understanding of how workplace structures and organisational support may influence intervention outcomes.

3. *The feasibility trials in Chapter 6 demonstrated that while both PA interventions were implementable in a real-world workplace, their effects and sustainability were shaped strongly by contextual and organisational factors.*

Quantitatively, acceptability was demonstrated through good adherence in both interventions of over 80%. An adapted visual scale of mental wellbeing and wrist-worn accelerometers during work time were acceptable to participants, with high completion rates for both. Qualitatively, job rotation acceptability and feasibility were influenced by employees' skills, physical capability, language differences, team identity, and the organisation's need for agility; rigid schedules reduced operational flexibility, yet participants recognised long-term benefits such as upskilling, improved coverage, and increased self-efficacy. For walking meetings, feasibility depended on practical factors, including group size, meeting environment, weather, and sustained motivation from meeting leaders, with sessions lapsing when not intentionally scheduled. There were no detectable changes in wellbeing during the job rotation intervention, but

walking meetings were associated with significantly higher wellbeing on meeting days. No meaningful changes in the composition or variability of PA were observed during the interventions and PA was not associated with mental wellbeing changes.

7.2.2 Interpretation of the key Findings

Although it is well established that manual workers typically report poorer mental health and wellbeing than desk-based workers (309), previous research has rarely examined whether device-measured PA patterns help explain these disparities. By applying compositional data analysis and context-specific isotemporal substitution to accelerometer-derived PA types, the AWE mapping study in Chapter 3 study provides novel insight into the behavioural mechanisms underlying occupational differences in mental health and identifies specific reallocations of work-time and weekend behaviours that may be most relevant for improving outcomes among manual workers. This key finding aligns with literature describing the “physical activity paradox” theory, whereby occupational physical activity (OPA) may not confer the same health benefits as leisure-time physical activity (LTPA) (108). Conceptual accounts argue that factors such as prolonged exertion, limited recovery, and biomechanical strain may render OPA less beneficial, or in some cases harmful, compared with LTPA (119,286,310). Large cohort studies similarly report opposite and independent associations of OPA and LTPA with mortality and cardiovascular risk, reinforcing the importance of distinguishing PA domains when interpreting workplace wellbeing patterns (115,116,118). The AWE findings should not be interpreted as an indication that occupational PA is a causal mechanism for poor mental health but add to wider evidence cautioning that higher overall PA at work should not be assumed to indicate a health advantage.

Accelerometer data confirmed that manual labour workers spent more time being physically active at work than desk-based workers and PA behaviours outside of work were similar between groups. During this PhD, this pattern was evaluated with more depth because of the integration of accelerometer-derived compositional data with detailed organisational mapping and sustained embedded researcher engagement. Regular informal interactions, field observations, and contextual immersion enabled the identification of

sociocultural groupings, communication patterns, and job design features that are rarely captured in conventional workplace surveys. These contextual insights provided a framing for why manual workers may exhibit poorer wellbeing despite higher absolute PA levels: their PA was predominantly low-intensity, repetitive, and constrained by organisational demands, while opportunities for recovery and autonomy were limited. By combining objective movement behaviour data with rich contextual understanding, this project adds explanatory depth to the physical activity paradox literature and illustrates how domain-specific PA interacts with organisational culture to shape wellbeing.

The systematic review finding in Chapter 4, that workplace PA interventions produce small, inconsistent, and low-certainty effects on mental health outcomes aligns with several previous systematic reviews reporting substantial heterogeneity in intervention design, delivery, and outcome measurement (19,21). Across the literature, improvements in stress, mood, and general wellbeing are typically modest, while effects on depression, anxiety, and quality of life remain inconsistent (21,126). In the current review, no single modality demonstrated clear superiority, reflecting widespread methodological variability and limited theoretical grounding of studies in this area. The subgroup patterns identified, such as more favourable stress outcomes for yoga-based interventions or mood benefits for group-based formats, are consistent with emerging evidence suggesting that mind-body modalities and social connectedness may act as important moderators, although these trends remain under-examined due to inconsistent reporting (16,311).What is contributed through this PhD is a clearer articulation of the structural reasons underpinning the fragmented evidence base. The detailed organisational mapping in Chapter 3 and participatory co-development processes in Chapter 5, provide important of contextual information that is often not reported in studies, such as employer support, workforce characteristics, delivery constraints, and organisational culture, that strongly influence feasibility and outcomes. Because the PhD integrated evidence synthesis with in-depth workplace assessment, it was possible to identify contextual moderators that were key to the design of the interventions. This strengthens calls within the field for more consistent use of developmental and evaluative frameworks, greater transparency in reporting, and the

integration of participatory methods to enhance interpretability and translational potential (159).

The findings reported in Chapter 6 that the co-developed interventions, job rotation and walking meetings, were feasible and acceptable to employees and the organisation, aligns with previous research demonstrating that participatory and context-aligned interventions often achieve high acceptability (151,297). Montano et al. (2014) conducted a systematic review of organisational-level workplace interventions aimed at improving employee health, with a focus on both implementation processes and health-related outcomes (312). The review demonstrated that many intervention designs were feasible to implement and acceptable to employees, yet just under half (19 of 39 included studies) reported significant positive health effects, highlighting a frequent misalignment between implementation success and measurable effectiveness. However, the Dynamic Integrated Evaluation Model (DIEM), developed as a framework for achieving sustainability in organisational interventions, explicitly frames organisational interventions as ongoing, adaptive processes that must be continuously adjusted in response to context, refining content and delivery over time (313). The authors argue that evaluation should occur throughout an intervention's development and implementation cycles, with effectiveness often contingent on multiple refinements. The yearly AWEs from this PhD serve as an example for how wider evaluation and feedback can be sustained beyond intervention feasibility and pilot testing, providing a monitor of outcomes and exposure throughout multiple iterations of development and implementation.

In the present PhD, the feasibility study was not powered to detect change, and the limited effectiveness findings, particularly for job rotation, are best understood in light of the small sample size, short trial duration, and the inherently adaptive nature of the interventions, all of which constrain the ability to detect meaningful changes in wellbeing or PA patterns. These considerations suggest that both interventions represent viable starting points that could yield greater impact if refined and scaled. The vision of this PhD was to develop a route map enabling workplaces to co-create feasible, context sensitive PA interventions for improving mental health. The project achieved this by producing two implementable interventions tailored to distinct occupational

groups. Reflecting on the systematic review in Chapter 4, which found no single modality to be consistently superior, and the Chapter 3 mapping findings demonstrating that higher work-related PA does not equate to better mental health, the results collectively suggest that these interventions should prioritise acceptability, feasibility, and sustainability as foundational criteria over change in outcomes. Effectiveness may then be enhanced iteratively over time, potentially through gradual refinements to movement patterns rather than attempts to increase overall PA volume.

7.3 Contributions to knowledge and the field

1. *Contextual understanding, employee ownership and cultural buy-in should be prioritised as key aspects of intervention development that enhance the sustainability of workplace health promotion efforts.*

Most workplace PA interventions, and particularly those targeting mental health outcomes, follow top-down, deductive approaches that impose predefined activities or programmes onto workers, with limited attention to organisational realities or employee perspectives, a pattern clearly reflected in the systematic review conducted as part of this PhD (Chapter 4). These interventions, whilst sometimes effective in the short-term, are often challenging to sustain and highly vulnerable to organisational disruption (314,315). My observations as an embedded researcher at ACS Clothing during this PhD project reinforce these concerns. Despite a highly supportive organisational culture, the company underwent restructuring, redundancies, and a change in ownership; events typical in small-to-medium enterprises (SMEs) and likely to destabilise health promotion efforts. That engagement with the project continued despite these challenges underscores both the value of sustained stakeholder involvement and the vulnerability of health initiatives that rely on managerial or organisational stability. For this reason, if PA interventions are to be impactful, they must first be robust to these challenges and sustainable in the longer-term. Creating organisational buy-in, establishing employee ownership and governance, and embedding changes into roles rather than individuals are all essential aims for sustainability.

2. *This PhD provided valuable and novel insights into the differences in wellbeing, productivity, and PA patterns between desk-based and manual labour workers within the same workforce. Establishing the feasibility of developing job-specific PA interventions for these groups within the same workplace setting.*

The development and implementation of the PA interventions took place in a workplace with both manual workers who predominantly stand or walk to complete their work tasks and desk-based workers who spend most of their time at work seated. With this mix of job types comes a range of required skills, experience and education, and in turn differences in job types are often reflected in employee salaries and other confounding factors. Indeed, ACS participants in both the AWEs and pilot interventions ranged from upper management to cleaners. This mix of occupational PA profiles and heterogeneity in socioeconomic demographics within one workplace is rarely the target population for PA interventions. In the studies in our systematic review (Chapter 4) interventions were delivered to desk-based workers in most cases, hybrid (i.e. healthcare) or manual workers (i.e. manufacturing) in a few cases, but in no study was an intervention or multiple interventions delivered to a mixed population of manual and desk-based workers. This dearth of evidence is understandable given the complexities of implementing and evaluating PA interventions in mixed-profile workplaces. Therefore, this project provides novel insights into the heterogeneity of PA patterns and mental health, and PA intervention development and implementation within a mixed-profile workplace.

3. *Each phase of the PhD added to the development of a route map for other workplaces to follow when creating PA interventions for mental health.*

Many SMEs in technology, textiles, manufacturing, and healthcare have a range of job types within a relatively small workforce. This means that in many workplaces PA interventions that are specifically designed for one type of occupational PA profile will only be applicable to a small proportion of the workforce. While attempting to generalise the effectiveness of any PA intervention to all workers is clearly an imprecise strategy, testing specific intervention designs, delivery, and components for every conceivable specific

workplace setting and population is an unfathomable task. This PhD project did not set out to identify a one-size fits all solution or specific solution for mixed profile workforces, instead the key contribution here is the route map of processes that led to the development of feasible interventions that met the needs of the ACS workplace. As shown in Table 7-1, this route map is an iterative process of mapping, evidence-informed collaborative development, small-scale testing and feedback. The route map goes beyond the steps followed in this PhD and incorporates the key learnings from the intervention development processes reported in this thesis. Each iteration can lead a workplace towards more refined and sustainable PA interventions. The transformation of the AWEs from measurement tool to measurement and multi-level feedback tool is an example component of this iterative process allowing individuals, the organisation, and researchers to observe the longer-term effects of PA interventions as the scale and reach increases.

When situated within the existing evidence base, this project stands out for its integration of multiple methodological traditions (occupational health, movement behaviour science, public health systems thinking, and participatory co-design) within a real-world mixed-profile workforce. Few workplace PA intervention studies have applied such a comprehensive and iterative process (24), and fewer still have deliberately tailored interventions to both manual and desk-based workers within the same organisation. The findings therefore both affirm key themes in the complex intervention literature (namely the importance of contextual alignment and employee involvement) and extend this field by demonstrating, through empirical data, how job role heterogeneity, organisational structures, and psychosocial mechanisms can enhance the contextual sensitivity and rigour of workplace PA intervention development.

Table 7-1. A route map for develop a workplace physical activity intervention for mental health

Intervention Development Phase	*Recommended aims for each phase*	*Key components*
PHASE 1: Engagement & Set-Up	Secure organisational buy-in	Leadership commitment Identify a "champion" (replacing embedded researcher role)
	Establish governance	Create a steering group Include: management, employees (different roles), and delivery staff (e.g. for AWEs)
PHASE 2: Understand the Workplace (Mapping)	Conduct workplace mapping	Collect data on: • Physical activity levels (by job type) • Mental health & wellbeing • Productivity / work patterns • Environmental + organisational context
PHASE 3: Feedback & Sense-Making	Rapid feedback to individuals and organisation	Share results with employees (individual) + managers (organisational)
	Facilitated interpretation	Provide support for understanding the results: "What does this mean for us?"

PHASE 4: Co-Creation & Option Development	Co-create solutions	Workshops with staff + managers (2 steps)
		1. Inform with:
		  ○ Mapping results
		  ○ Evidence from literature
		2. Identify feasible intervention options, while considering:

		○ Job type differences (job demands + worker profiles) ○ Past initiatives ○ Barriers/facilitators
PHASE 5: Intervention Design	Select and design intervention(s)	Refine ideas into: • Clear components • Delivery methods • Target groups
PHASE 6: Implementation	Build delivery into roles	Train staff Embed into job roles, not individuals Ensure organisational ownership
	Deliver the intervention	On a scale that fits with targeted groups and evaluation plan Allow for and monitor adaptations during intervention delivery
PHASE 7: Evaluation & Iteration	Run testing cycle (feasibility)	Assess: • Acceptability • Feasibility • Early outcomes
	Iterate and adapt	Feedback evaluation results to co-creators and stakeholders Modify intervention(s) based on feedback and data
PHASE 8: Sustainability	Embed and scale	Integrate into policies, roles, and culture Maintain steering group or similar structure Seek to scale interventions to other teams/employees through each iteration

7.4 Methodological considerations and key learnings from the PhD

Adaptive processes and alignment with established frameworks

When considered as a whole, the findings of this project align with and extend a growing but still underdeveloped body of research advocating for workplace health promotion approaches that combine evidence synthesis, organisational mapping, and participatory co-development (159). While several of the 54 workplace PA intervention studies included in the systematic review in Chapter 4 acknowledge the importance of contextual relevance when interpreting results, none reported following a structured process that integrates systematic review evidence with in-depth workplace assessment and co-creation with employees. These findings align with wider evidence indicating that PA research frequently underuses structured frameworks, particularly in evaluation. A review by Fynn et al. (2020) found that just 69 (23%) of 292 PA intervention evaluations reported employing an evaluation framework, with substantial inconsistency in reporting quality (316). The authors pointed out that this underutilisation is problematic because studies that do employ systematic frameworks, tend to show clearer specification of determinants, mechanisms, and delivery strategies, which in turn enhances feasibility, contextual fit, and transparency in reporting. Where frameworks have been applied, often in fields such as public health, implementation science, and co-design research, studies report improvements in feasibility, acceptability, and contextual fit (317,318). A recent systematic review of co-design in public health identified rapid growth in studies using collaborative, multi-stage design frameworks, but also highlighted significant inconsistency in how co-design processes are applied and reported, calling for clearer conceptualisation and methodological transparency to improve their effectiveness and replicability (239).

This PhD project was primarily guided by the UK Medical Research Council (MRC) Framework for developing and evaluating complex interventions, which advocates for consideration of context, programme theory, stakeholder engagement, key uncertainties, refinement, and economic impact during four phases of: intervention development, feasibility assessment, evaluation, and implementation (159). The framework clarifies that these four phases of

intervention development and evaluation should not necessarily be linear, a principle that fit very well with this PhD project. By prioritising engagement with staff and managers (stakeholders) and including these key stakeholders in reporting of the mapping study, the AWEs became a participant engagement tool and a prompt for action both at the individual and organisational level. Additionally, the unorthodox decision to delay the full analysis and reporting of the systematic review (Chapter 4) in this PhD project was taken to focus on maintaining stakeholder and organisational engagement with the project, whilst gaining insights from the synthesis of the literature to contribute to the planning of the co-development workshops. Taking an adaptable approach allowed for such pivots and non-traditional timelines. Such an approach follows the examples set in wider health promoting disciplines that have a stronger focus on real-world effectiveness than PA centred research often does (319), due to in part to the latter's roots in sports science and lab-based physiology.

Benefits of an embedded research design

Being an embedded researcher provided opportunities to engage with ACS employees on a more frequent and consistent basis than would have been possible otherwise. Casual conversations in the cafeteria and in the offices, as well as observations during walks around the warehouse, made me far more aware of the physical, social, and cultural environment of this workplace. As none of these interactions were to be formally recorded (consent was not sought to collect as data), I kept field notes of my reflections, which became a valuable source for my decision making. For example, I was made aware that employees wanted faster feedback from their AWEs, because individuals would ask me directly and on a weekly basis when they could expect this. These interactions led to the development of the Employee Wellbeing Assessment Portal (EWAP), an online platform designed to streamline the testing to feedback process. Additionally, I learned of redundancies and departmental restructuring, and the effects of these events through workplace conversations. This information allowed me to adapt throughout the project, for example, changing who would be recruited to the walking meeting feasibility study, as some departments came under increased work pressure. Discussions with management around the company takeover discussed in Chapter 3 also helped to reframe feedback and reporting to the organisation in the final year of the PhD. By emphasising the

relationship between mental health and productivity to new board members, it was made more apparent that the interventions and AWEs could be additive on an organisational level. It is unlikely that the change in the sampling for the feasibility study or the strategy of communication to owners would have been made, if I had not been an embedded researcher.

Perhaps the most impactful observation from the embedded research at ACS was one that took a little longer to identify. After months of conversations with employees from a wide range of roles, I could recognise distinct sociocultural groups within in the organisation, some of which aligned with departments and others which did not:

- More senior managers and most of the office staff were engaged with the objectives of the business and were in turn more often motivated to engage with this project for the benefits of the workplace as a whole. This group would participate in all aspects of the project but their social detachment from lower-level employees made the participation less visible.

- Core staff working in manual labour roles in the warehouse were more often willing to engage with the project for personal reasons. However, these individuals would mostly allude to feeling disjointed from the aims of the business and complained of not being well informed (a theme that surfaced in the co-development workshops).

- Middle management or supervisors held a gate keeping role. They felt more informed about the aims of the business but often prioritised their own or their team's productivity output beyond any wider outcomes, a reflection of the expectations they perceived the business to have of them. This led some supervisors to "protect" their team from what they perceived as unnecessary distractions, such as health promotion initiatives.

- Satellite teams or individuals, who are able to operate with a low frequency of daily interactions with other employees or teams, were the most challenging to engage with the project. These workers often

> protected their isolation and did not seek to engage with other employees or the wider organisation. These individuals desired to be left to do their job and drew distinct lines between work and personal domains.

Understanding these employee groups made it easier to tailor interactions with each and address their needs and motivations more effectively. Such differentiation between stakeholder groups is well-established in organisational intervention research, where scholars have shown that individuals and groups vary in their motivations for engaging with interventions, shaped by distinct "push" and "pull" factors that influence their willingness and degree of participation (320). However, without the regular communication and accessibility that comes with embedded research, it would have been difficult to identify which employees were most aligned to each group in this setting. Each workplace will have its own distinct groups and sociocultural environment, and while recognising that theoretically is fundamental to developing tailored workplace interventions, addressing this challenge in practice requires a commitment to sustained engagement that many research projects do not have the time or resources for.

Reflections on the approaches taken and what I would do differently

With the benefit of hindsight, the non-linear and adaptive approach taken in this PhD created a continual negotiation between the fast-moving expectations of a real-world workplace and the slower, more deliberate pace required for rigorous academic analysis and reporting. Workplace momentum often encouraged rapid progression to the next visible phase of the project, particularly when new insights emerged or organisational opportunities arose. In contrast, academic work demands periods of sustained reflection, systematic analysis, and careful documentation, processes that unfold on a fundamentally different timescale. This mismatch meant that activities such as planning, data collection, stakeholder engagement, and analysis did not always follow a traditional research sequence. For example, after synthesising the initial literature and mapping findings, I moved quickly into planning the co-creation workshops to maintain organisational engagement, even though this delayed the deeper academic interrogation of the review. This experience illustrates how embedded

and participatory research requires deliberate strategies to balance these competing temporal rhythms, including building structured pauses for analysis during quieter periods of workplace activity. Ultimately, navigating the differing speeds and expectations of academic and workplace environments became a central methodological consideration of the project. A full breakdown of research activities and the project timeline is available in Appendix 7-A: PhD research activities timeline.

Another reflection from this project was that the AWEs became a central feature of the PhD and a primary way of connecting with employees. A component that began as a means of iterative mapping, baselining, and with a view to a time-series analysis, pivoted into a primary means of engaging employees with the PhD project and its aims. The AWEs became an unanticipated mechanism for behaviour change at the individual and organisational levels. It was my observation that employees valued the reports generated from these testing periods more than the prospect of a potential PA intervention, possibly because benefits were more immediate. Despite long waits for individual reports, caused in part by delays in the analysis of hair cortisol samples, recruitment rates were sustained in years two and three. This was a reflection of the pivots made to the design of AWEs and a reduced participation burden, brought about by direct feedback from employees. Similar projects would be well advised to consider the experience of participants when designing repeated data collection in small populations. A balance should be struck between data minimisation, speed of feedback, and continued engagement.

7.5 Strengths and Limitations of the Project

7.5.1 Limitations of the Project

There are overarching limits that must be acknowledged within this PhD. Firstly, the mapping study was observational, so differences between job types cannot be interpreted causally. The AWEs from the mapping study were conducted at approximately the same time of year on all three occasions, limiting the ability to detect seasonal changes in mental health, PA and organisational demands throughout the project. Furthermore, the AWEs were initially designed to capture wider temporal changes in mental health and PA, as the part of the

evaluation of further refinement and scaling of the iterative intervention development. However, as previously acknowledged, time did not allow for further refinement and scaling during the research period of the PhD. Therefore, while the AWE results serve as a rich observational study of a workplace with mixed activity profiles and job roles, the provisional aim to capture the workplace-wide impact of multiple iterations of PA intervention implementation was not possible.

The pilot trials in Chapter 6 lacked control groups, meaning improvements (in walking meetings) cannot be attributed solely to the intervention. These feasibility trials were necessarily short, limiting the ability to detect changes in mental health outcomes, which often require longer exposure periods. Time constraints meant that further refinement, embedding, and scaling of the workplace PA interventions, which is recommended by the UK MRC framework (159), could not be conducted during the PhD project.

While the advantages of embedded research have been discussed, the limitations of this aspect of the design must also be acknowledged. As an embedded researcher, I became a visible and socially meaningful presence in the organisation. Employees are aware that someone is there to record their data and attempting to make them healthier, which pertains to the much-debated Hawthorne effect (206,208). The dual role of researcher and informal facilitator may have blurred boundaries, shaping how employees interpreted the purpose of the AWEs, workshops, and trials. This likely influenced participation, responses, and even organisational decision-making. Additionally, the embedded design can lead to the emphasis of certain voices, from those more willing to engage informally, potentially biasing the co-development process. The results from the AWEs, co-development process, and feasibility trials therefore cannot be considered independent of my presence as a researcher at ACS. Furthermore, it was not within the scope of this PhD to include an evaluation of the effects of the embedded researcher leaving the workplace.

Finally, the co-development process produced interventions that were feasible, but not necessarily those with the strongest theoretical or empirical basis for improving mental health. Furthermore, the PhD did not include a formal process

evaluation of the co-development workshops themselves, limiting insight into how decisions were made and whose perspectives dominated.

7.5.2 Strengths of the Project

This PhD project demonstrated several methodological and conceptual strengths that enhanced the robustness and relevance of its findings. First, the project employed a multi-method design that integrated organisational mapping, objective movement-behaviour measurement, systematic evidence synthesis, and qualitative inquiry. This combination allowed for a comprehensive understanding of workplace PA and mental health patterns, enabling triangulation across data sources and improving the explanatory depth of the analyses.

Second, the use of embedded research practices provided access to rich, real-time contextual information about the workplace environment, culture, and employee experiences. Informal interactions, observations, and sustained presence enabled a level of contextual immersion that would not have been achievable through episodic data collection alone. This facilitated more sensitive identification of sociocultural groupings within the organisation, informed sampling and recruitment decisions, and improved the alignment of intervention components with the realities of everyday work processes. To further engage with stakeholders, participatory co-development methods were applied to design two workplace interventions tailored to the distinct needs of manual and desk-based employees. Engaging staff directly in generating and refining intervention ideas enhanced acceptability and feasibility, ensured that proposed activities aligned with operational constraints, and provided insights into the organisational and interpersonal factors shaping implementation. The mixed-methods feasibility trials further strengthened the project by evaluating both quantitative trends and qualitative experiences, offering a nuanced understanding of how organisational context influenced the delivery and perceived impact of each intervention.

Finally, the PhD contributed strength through its layered assessment of PA behaviours. The integration of accelerometer-derived compositional data with contextual organisational insights helped identify potential mechanisms

underpinning differences in wellbeing across job roles. Furthermore, by using accelerometery and compositional data analysis, the research was able to examine how different activity intensities and reallocations of time were associated with wellbeing outcomes across job roles. This rigorous assessment of movement patterns strengthened the evidence base concerning occupational PA and its relationship with mental health and wellbeing, particularly within manual work contexts, and enabled the project to test whether intervention effects could be attributed to changes in PA behaviour rather than perceptions alone.

7.6 Recommendations and directions for future research

While this PhD developed PA interventions for a specific workplace, the route map that guided the development of these interventions can be generalisable to other workplaces. There is an opportunity to test this route map in other SMEs with different organisational cultures, compare outcomes from single-profile workforces against mixed-profile workforces, and conduct cross-sector comparative studies to identify common contextual determinants. Future work should conduct longer-term feasibility and optimisation studies, allowing interventions to evolve through repeated cycles of testing and adaptation. Moreover, interventions that are embedded into job roles and practices should be evaluated for robustness against changes in personnel. Applying evaluation methods, such as the MRC complex intervention framework used in this project or similar models (159), will allow intervention developers to track how interventions change over time and how organisational shifts influence their delivery.

In this PhD project, AWE reports became an integral participant engagement tool, but employees communicated that they wanted their individual reports on much shorter timescales than data processing could allow. The initial inclusion of hair cortisol sampling meant that external lab analysis was implemented for this component. This slowed the process of testing to analysis to feedback, and created tension where employees expected a faster turnaround in their individual reports. To better maintain continuous stakeholder engagement, future projects should consider the balance between academic rigour and the value of speed when sharing findings with key stakeholders. Digital toolkits, such as the Employee Wellbeing Assessment Portal (EWAP), can accelerate the

process of data collection for researchers and increase engagement with employees simultaneously.

Embedded researchers or practitioners should accept their influential role within any workplace intervention implementation and evaluation. This role needs to be acknowledged as a component within the design and planning should include evaluation of the sustainability of interventions following the exit of embedded facilitators. Furthermore, not every workplace will benefit from an embedded facilitator or be willing to accommodate one, whether researcher or internal employee. Future intervention designers should consider the strengths and limitations of this position, then decide whether there is an overall benefit to be gained from this level of engagement with a workplace.

More PA intervention trials are needed in mixed-profile workplaces, to further evaluate differences in effects on mental and physical health outcomes between job types within the same setting. Furthermore, the exploratory isotemporal substitutions in the compositional analysis of accelerometer-measured PA data reported in Chapter 3, have the potential to provide a predictive model for prescribing more effective shifts in PA behaviour. A growing movement within movement-behaviour research emphasises that daily behaviours, sleep, sedentary time, light-intensity PA, and MVPA, are parts of a finite 24-hour composition; therefore, increasing one behaviour necessarily reduces time in another (3,95,96,321). Compositional isotemporal substitution analyses model these dependencies and help estimate how reallocating time from one behaviour to another relates to health outcomes (321). A scoping review of over 100 compositional studies suggests that reallocations toward MVPA are frequently, though not uniformly, associated with favourable outcomes, while reallocations away from MVPA tend to be unfavourable (322). However, associations for reallocating time between sedentary behaviour, light-intensity PA, and sleep are more variable, and longitudinal evidence remains limited, warranting cautious interpretation. As many manual labour jobs involve long periods of light-intensity PA and relatively little time in MVPA (323,324), as was the case in the AWE samples, there is a need for more evidence on the effects of reallocating time between PA behaviours that are applicable to real-world cases.

7.7 Final Conclusions

This PhD project mapped workplace PA and wellbeing, synthesised existing evidence, and co-developed and piloted two context-sensitive workplace PA interventions for mental health. The findings revealed substantial differences in wellbeing across job roles and demonstrated how organisational context shapes the feasibility of workplace PA initiatives. The processes followed during the project provide a route map that is grounded in established frameworks and addresses the issues of contextual sensitivity. Future projects can adopt this route map to develop context-sensitive PA interventions across a wide range of other workplace settings.

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Appendices

Appendix 3-A: Ethics approval for Annual Wellbeing Evaluations (AWEs): A workplace mapping study

University of Glasgow

Dr Gemma Ryde

MVLS College Ethics Committee

Developing a workplace wide physical activity intervention for mental health 200210186

The College Ethics Committee has reviewed your application and has agreed that there is no objection on ethical grounds to the proposed study. We are happy therefore to approve the project, subject to the following conditions

- Project end date as stipulated in original application.
- The data should be held securely for a period of ten years after the completion of the research project, or for longer if specified by the research funder or sponsor, in accordance with the University's Code of Good Practice in Research: (http://www.gla.ac.uk/media/media_227599_en.pdf)
- The research should be carried out only on the sites, and/or groups defined in the application.
- Any proposed changes in the protocol should be submitted for reassessment, except when it is necessary to change the protocol to eliminate hazard to the subjects or where the change involves only the administrative aspects of the project. The Ethics Committee should be informed of any such changes.
- For projects requiring the use of an online questionnaire, the University has an Online Surveys account for research. To request access, see the University's application procedure at https://www.gla.ac.uk/research/strategy/ourpolicies/useofonlinesurveystoolforresearch/.
- You should submit a short end of study report within 3 months of completion.

Yours sincerely

Dr Terry Quinn

Terry Quinn
FWSO, FESO, MD, FRCP, BSc (hons), MBChB (hons)
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The University of Glasgow, charity number SC004401

Appendix 3-B: Participant consent form for AWE mapping and co-creation studies

Project Number:
200210186

Participant Identification Number for this study:

Title of Project: Developing a Workplace Wide Physical Activity Intervention for Mental Health

Name of Researcher(s): Craig Tumblety, Dr. Gemma Ryde

CONSENT FORM

	Please initial box
I confirm that I have read and understood the Participant Information Sheet version 3 dated 09/08/2022.	☐
I confirm that I have read and understood the Privacy Notice version 3 dated 09/08/2022.	☐
I have had the opportunity to think about the information and ask questions and understand the answers I have been given.	☐
I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my legal rights being affected.	☐
I confirm that I agree to the way my data will be collected and processed and that data will be stored for up to 10 years in University archiving facilities in accordance with relevant Data Protection policies and regulations.	☐
I understand that all data and information I provide will be kept confidential and will be seen only by study researchers and regulators whose job it is to check the work of researchers.	☐
I agree that my name, contact details and data described in the information sheet will be kept for the purposes of this research project.	☐
I understand that if I withdraw from the study, my data collected up to that point will be retained and used for the remainder of the study.	☐
I agree to any workshop group I attend being recorded via anonymous post-its and researcher notes.	☐

I understand that the information recorded during workshops will be stored for up to 10 years in University archiving facilities in accordance with Data Protection policies and regulations. ☐

I agree to be contacted by the research team in around 12 months' time about taking part in another Annual Wellbeing Evaluation or workshop. ☐

I agree for the data I provide to be anonymously archived in the UK data archive or other approved archiving facilities, and that other researchers can have access to this data only if they have scientific and ethical approval, and agree to preserve the confidentiality of this information as set out in this form. ☐

I understand that the research team will not be making any clinical interpretations of the data I provide during this study and that it is my responsibility to act on any abnormal results from my data. ☐

I understand and agree with how my collected samples will be processed and handled for purposes of this study. ☐

I agree to take part in the study. ☐

Name of participant	Date	Signature
Name of Person taking consent (if different from researcher)	Date	Signature
Researcher	Date	Signature

(1 copy for participant; 1 copy for researcher)

Appendix 3-C: Influential confounders for AWE survey outcomes

Outcome	Influential Confounders
Anxiety-Stress Score	Extenuating circumstances, Quintile, BMI, Age at AWE, Sex, Education
DASS-10 Total	Extenuating circumstances, Quintile, BMI, Age at AWE, Sex, Education, Years worked at ACS
Depression Score	Extenuating circumstances, Quintile, BMI, Age at AWE, Years worked at ACS
HPQ_Absolute_Presenteeism_percentage	Extenuating circumstances, BMI, Age at AWE, Education
HPQ_Absolute_absenteeism	Extenuating circumstances, Education
HPQ_Combined_Productivity	Extenuating circumstances, Quintile, Age at AWE, Education
HPQ_Relative_Absenteeism	Extenuating circumstances, Education
HPQ_Relative_Hours_of_Work	Extenuating circumstances, Education
HPQ_Relative_Presenteeism	Extenuating circumstances, Quintile, BMI, Age at AWE, Education
HWQ_Concentration	Extenuating circumstances, Quintile, BMI, Age at AWE, Sex, Education, Years worked at ACS
HWQ_Impatience	Quintile, BMI, Age at AWE, Education, Years worked at ACS
HWQ_Nonwork_Satisfaction	Extenuating circumstances, BMI, Age at AWE, Education, Years worked at ACS
HWQ_Own_Productivity	Extenuating circumstances, Age at AWE, Education, Years worked at ACS
HWQ_Productivity	Extenuating circumstances, BMI, Age at AWE, Education, Years worked at ACS
HWQ_Productivity_Other	Extenuating circumstances, BMI, Age at AWE, Years worked at ACS
HWQ_Supervisor_Relationship	Extenuating circumstances, Education
HWQ_Total	Extenuating circumstances, Quintile, BMI, Age at AWE, Education, Years worked at ACS
HWQ_Work_Satisfaction	Extenuating circumstances, Quintile, Age at AWE, Education
PSQI	Extenuating circumstances, Age at AWE
PSS	Extenuating circumstances, Quintile, BMI, Age at AWE, Education
Total UWES	Extenuating circumstances, Age at AWE, Education, Years worked at ACS
UWES_Mean_Absorption	Extenuating circumstances, Age at AWE, Education, Years worked at ACS
UWES_Mean_Dedication	Age at AWE, Education, Years worked at ACS
UWES_Mean_Vigour	Age at AWE, Years worked at ACS
WEMWBS	Extenuating circumstances, Age at AWE, Education, Years worked at ACS

Appendix 3-D: Checklist of Health Promotion Environments at Worksites (CHEW)

CHECKLIST OF HEALTH PROMOTION ENVIRONMENTS AT WORKSITES (CHEW)
VERSION:25 AUGUST,1995

OBSERVATION

Worksite: _____ACS Clothing Ltd, Eurocentral site_____

Building/Address: _____Eurocentral Scotland, Centralpoint Logistics Park, 6 Dovecote Rd, Motherwell_____

Date: _____20/09/2022_____ Time: ____10:00____ Observer: _____CT_____

BUILDING ASSESSMENT

Number of buildings at the worksite — No. = ___1____

Number of floors — No. = ____3___

Worksite is on how many floors? — No. = ____3____

Freestanding or connected to other buildings?
1. Freestanding
2. Connected

Is worksite all or part of building?
1. All
2. Part

Number of bicycles seen stored inside building:
Tally: _____I_____ Total No. = ___1___

Number of male changing rooms
Tally: _____II_____ Total No. = ___2___

Number of female changing rooms
Tally: _____II_____ Total No. = ____2__

Number of unisex changing rooms
Tally: _____ Total No. = ___0___

Number of male showers
Tally: _____I_____ Total No. = ____1__

Number of female showers

Tally: _____I_____ Total No. = ___1___

Number of unisex showers
Tally: _____ Total No. = ___0___

SIGNS AND BULLETIN BOARDS (the information environment)

Number of bulletin boards at the worksite
Tally: _____IIII IIII I_____ Total No. = __9____

Physical Activity:

Number of signs or posters generally encouraging physical activity (other than related to stairs)
Tally: _____ Total No. = ___0___

Number of notices about onsite exercise classes
Tally: _____ Total No. = ___0___

Number of notices about offsite physical activity/sports sponsored by the specific worksite
Tally: _____ Total No. = ___0___

Number of notices about offsite physical activity/sports sponsored by other organisations (this can include the parent company)
Tally: _____ Total No. = ___0___

Number of other notices about physical activity/sports
Tally: _____ Total No. = ___0___

Sedentary behaviour:

Number of signs or posters generally encouraging people to sit less (other than related to stairs)
Tally: _____ Total No. = __0____

Number of signs, posters or notices about the risks of sitting
Tally: _____ Total No. = __0____

Number of signs, posters or notices promoting standing in meetings
Tally: _____ Total No. = __0____

Number of signs, posters or notices promoting active breaks in meetings
Tally: _____ Total No. = __0____

Number of signs, posters or notices promoting walking meetings
Tally: _____ Total No. = ___0___

Nutrition:

Number of signs/posters encouraging dietary fat reduction or promoting programs
Tally: _____ Total No. = __0____

Number of signs/posters encouraging more fruits and vegetables or promoting programs
Tally: _____ Total No. = __0____

Number of notices on bulletin board about dietary information
Tally: ____II_____ Total No. = __2____

Number of notices on bulletin board about weight loss
Tally: _____ Total No. = ___0___

Smoking:

Number of entrances to building
Tally: ___IIII_____ Total No. = ___4___

Number of signs about smoking restrictions on or around entrance doors
Tally: _____ Total No. = ___0___

Number of notices on bulletin board about smoking cessation programs or smoking policies
Tally: _____ Total No. = ___0___

Number of signs/posters about smoking
Tally: _____ Total No. = __0____

Alcohol:
Number of signs/posters about responsible drinking
Tally: _____ Total No. = __0____

Number of notices on bulletin boards about responsible drinking or alcohol policies
Tally: _____ Total No. = ___0___

Health Promotion:
Number of bulletin boards dedicated to health promotion
Tally: _____II_____ Total No. = ___2___

Number of postings related to combination of diet, physical activity, smoking, or alcohol
Tally: _____ Total No. = __0____

ELEVATOR CHECKLIST

(tick if yes or present)	Entrance 1	Entrance 2	Entrance 3
Elevator (or sign) visible from major employee entrance	☐	☐	☐
Sign encouraging use of stairs at elevators	☐	☐	☐

Total number of elevators Total No. = ___0____

STAIR CHECKLIST

(tick if yes or present)	Stairwell Number 1	2	3	4	5	6
Staircase not enclosed in stairwell	☑	☑	☑	☑	☐	☐
Able to see stairs from entrance	☐	☐	☐	☐	☐	☐
✓						
Carpeted	☐	☐	☐	☐	☐	☐
Painted/decorated/finished walls	☐	☐	☐	☐	☑ ✓	☐

Utilities <u>not</u> visible in stairwell	☑	☑	☐	☐	☑	☐
(eg. gas pipes, elec wires)						
Door is ajar on most or all floors	☐	☐	☐	☐	☐	☐
Door is unlocked on most floors	☐	☐	☐	☐	☑	☐
Door marked "stairs" (not just exit)	☐	☐	☐	☐	☐	☐
No warnings or cautions on door	☐	☐	☐	☐	☐	☐
Floor number labelled inside of stairway	☐	☐	☐	☐	☐	☐
No restricted exit (locked from inside)	☑	☑	☑	☑	☑	☐
Signs encouraging use of stairs	☐	☐	☐	☐	☐	☐

FITNESS CENTRE ASSESSMENT – N/A

	Workout Room 1	Workout Room 2
In worksite	☐	☐
In grounds	☐	☐
Area for aerobics /dance/other activities	1. <u>No area</u> 2. Part time 3. Permanent	1. <u>No area</u> 2. Part time 3. Permanent
Size of workout area: _____m	_____m X _____m	_____m X _____m
Treadmills	No. = _____	No. = _____
Bikes	No. = _____	No. = _____
Rowing Machines	No. = _____	No. = _____
Stepper Machines	No. = _____	No. = _____
Free Weights	No. = _____	No. = _____
Resistance Equipment	No. = _____	No. = _____
Other Machines	No. = _____	No. = _____
TV in workout area	☐	☐
Music in workout area	☐	☐

Other Facilities: (tick if present)

Table Tennis Tables	In worksite or on grounds?	1. Worksite 2. Grounds
Billiard Tables	In worksite or on grounds?	1. Worksite 2. Grounds
Sauna	In worksite or on grounds?	1. Worksite 2. Grounds
Spa	In worksite or on grounds?	1. Worksite 2. Grounds
TV Lounge	In worksite or on grounds?	1. Worksite 2. Grounds

ASSESSMENT OF THE SEDENTARY BEHAVIOUR ENVIRONMENT AT WORK

Standing desks No. = ____10____

Standing desks actively in use No. = ___8_____

Activity permissive workstations (pedal bikes, treadmill desks) No. = ____0____

Standing meeting rooms No. = ___0_____

Standing room in common areas No. = ____1____

ASSESSMENT OF THE NUTRITION ENVIRONMENT AT WORK

Canteen assessment - Canteen 1

In worksite or on grounds? 1. Worksite
2. Grounds

(For the following tick if present)
Fresh fruit ☐
Green salads ☐
Lowfat milk or yogurt ☐

Number of other low/reduced fat items on menu or on notices No. = __1____

Number of NHF ticks displayed or other labelling of lowfat items No. = _____

Number of items with easily visible nutrition information signs (fat grams, cals) No. = __5____

Number of signs/prompts to choose low fat items No. = ___0___

Number of signs/prompts to choose fruits and vegetables No. = ___0___

Canteen assessment - Canteen 2

In worksite or on grounds? 1. Worksite
2. Grounds

(For the following tick if present)
Fresh fruit ☐

Green salads
Lowfat milk or yogurt

Number of other low/reduced fat items on menu or notices No. = _____

Number of NHF ticks displayed or other labelling of lowfat items No. = _____

Number of items with easily visible nutrition information signs (fat grams, cals) No. = _____

Number of signs/prompts to choose low fat items No. = _____

Number of signs/prompts to choose fruits and vegetables No. = _____

Vending Machine Assessment

Vending Machine Number

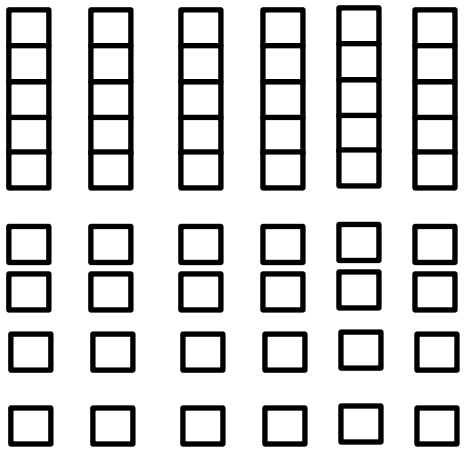
	1	2	3	4	5	6
In worksite						
On grounds						
Type of machine:						
Please tick if snack machine	✓					
Please tick if soft drink machine	✓					
Please tick if hot drink machine		✓				
(Please write NA if not applicable)						
Total number of items that machine holds	56					
Number of slots with low fat/sugar snacks						
Number of slots with fresh fruit						
Number of slots with fresh green salads						
Number of slots with items with heart tick						
Number of slots with fruit juice or mineral water (can be mineral water with some fruit juice)						
Number of slots with diet soft drink	2					
Number of slots with coffee/tea with no milk and no sugar		2				
Please tick if there is an option for using lowfat milk for coffee/tea						
Please tick if there is a sign encouraging selection of lowfat items						

Vending Machine Assessment

Vending Machine Number

	7	8	9	10	11	12
In worksite						
On grounds						
Type of machine:						
Please tick if snack machine						
Please tick if soft drink machine						
Please tick if hot drink machine						
(Please write NA if not applicable)						

Total number of items that machine holds
Number of slots with low fat/sugar snacks
Number of slots with fresh fruit
Number of slots with fresh green salads
Number of slots with items with heart tick
Number of slots with fruit juice or mineral water (can be mineral water with some fruit juice)
Number of slots with diet soft drink
Number of slots with coffee/tea with no milk and no sugar
Please tick if there is an option for using lowfat milk for coffee/tea
Please tick if there is a sign encouraging selection of lowfat items



Lunch Room Assessment - Lunch Room 1
In worksite or on grounds? 1. Worksite
2. Grounds

Number of signs/posters encouraging dietary fat reduction Total No. = __0____

Number of signs/posters encouraging more fruits and vegetables Total No. = __0____

Number of notices about dietary information or weight loss Total No. = __0____

(For the following tick if present)
Microwave ☑
Other oven or toaster ☐
Fridge ☑
Seating in or near food preparation area ☑

Lunch Room Assessment - Lunch Room 2
In worksite or on grounds? 1. Worksite
2. Grounds

Number of signs/posters encouraging dietary fat reduction Total No. = _____

Number of signs/posters encouraging more fruits and vegetables Total No. = _____

Number of notices about dietary information or weight loss Total No. = _____

(For the following tick if present)
Microwave ☐
Other oven or toaster ☐
Fridge ☐
Seating in or near food preparation area ☐

ASSESSMENT OF THE SMOKING ENVIRONMENT AT WORK
Number of cigarette vending machines in the building
Tally: _____ Total No. = __0____

ASSESSMENT OF THE ALCOHOL ENVIRONMENT AT WORK
Is there an observed area where alcohol is served? (tick if yes) ☐

PARKING ASSESSMENT

Number of signs in parking lot encouraging drivers to park farther Total No. = __0____

Number of bike rack spaces on grounds
Tally: _____ Total No. = __0____

Number of bikes parked outside
Tally: _____ Total No. = ___0___

Number of bike lockers Total No. = ___0___

Other lock up facilities for bikes (tick if yes) ☑

GROUNDS ASSESSMENT

Are grounds exclusive for target worksite or shared?
1. Exclusive
2. Shared

(For the following tick if present)

Volleyball court	☐
Basketball goal	☐
Walking path on or adjacent to grounds	☑
Open space/grassy area large enough for physical activity	☐

Size of open space/grassy areas _____m X _____m

Other outdoor fitness or sport facilities (tick if yes)

Please specify:_____

_____

NEIGHBOURHOOD ASSESSMENT (**)

Nearest access road(s): Road 1 _____Dovecote Rd___ Road 2_____

(For the following tick if yes or present)

Level of traffic:	light ☑	light ☐
	medium ☐	medium ☐
	heavy ☐	heavy ☐
Sidewalk adjacent to road	☑	☐
Sidewalk separated from road (more than 3 m)	☐	☐
Bike lanes on road	☐	☐
Bike lanes separate from road (more than 3 m)	☐	☐

(For the following please tick if yes)

Is a fitness facility visible from worksite grounds?	☐
Is a park/open space visible from worksite grounds?	☐
Is the park/open space large enough for physical activity?	☐
Is a pool visible from worksite grounds?	☐
Are tennis courts visible from worksite grounds?	☐
Are squash courts visible from worksite grounds?	☐
Is a major shopping centre visible from worksite grounds?	☐
Are shops that sell cigarettes visible from worksite?	☐
Is pub or bar visible from worksite grounds?	☐
Is liquor/beer store visible from worksite grounds?	☐

Food Shops Visible From Grounds

	Food shop 1	Food shop 2	Food shop 3
Name of shop	_____	_____	_____
Type of shop	_____	_____	_____

(The following questions are optional)

Number of signs about low fat items	☐	☐	☐
Visible nutrition labelling of items (fat grams, cals)	☐	☐	☐
Fresh fruit	☐	☐	☐
Fresh green salads	☐	☐	☐

Limits of Workplace Grounds
Front car park borders to perimeter fencing were defined as the limits.

Name and title of employee who accompanied you on tour of the worksite:
_____AM – Sustainability manager_____
Other comments:
_____
_____
_____
_____

Appendix 3-E: Summary statistics of AWE physical activity type compositions (relative proportions)

YEAR	JOB TYPE	TIMEFRAME	PART	MEAN	SD	INTERQUARTILE RANGE	N
1	Desk	Non-Work Time	Ambulatory	0.072	0.031	0.032	13
1	Desk	Non-Work Time	Sedentary	0.441	0.102	0.082	13
1	Desk	Non-Work Time	Stationary+	0.487	0.102	0.069	13
1	Desk	Weekend	Ambulatory	0.038	0.021	0.032	13
1	Desk	Weekend	Sedentary	0.311	0.091	0.106	13
1	Desk	Weekend	Sleep	0.379	0.093	0.125	13
1	Desk	Weekend	Stationary+	0.272	0.070	0.090	13
1	Desk	Whole Workday	Ambulatory	0.060	0.023	0.036	13
1	Desk	Whole Workday	Sedentary	0.295	0.084	0.056	13
1	Desk	Whole Workday	Sleep	0.308	0.072	0.080	13
1	Desk	Whole Workday	Stationary+	0.337	0.065	0.105	13
1	Desk	Work Time	Ambulatory	0.093	0.045	0.050	13
1	Desk	Work Time	Sedentary	0.402	0.112	0.143	13
1	Desk	Work Time	Stationary+	0.506	0.083	0.063	13
1	Manual	Non-Work Time	Ambulatory	0.054	0.029	0.038	43
1	Manual	Non-Work Time	Sedentary	0.502	0.092	0.148	43
1	Manual	Non-Work Time	Stationary+	0.444	0.078	0.110	43
1	Manual	Weekend	Ambulatory	0.033	0.018	0.025	43
1	Manual	Weekend	Sedentary	0.327	0.070	0.087	43
1	Manual	Weekend	Sleep	0.385	0.075	0.093	43
1	Manual	Weekend	Stationary+	0.255	0.055	0.090	43
1	Manual	Whole Workday	Ambulatory	0.056	0.029	0.043	43
1	Manual	Whole Workday	Sedentary	0.254	0.077	0.112	43
1	Manual	Whole Workday	Sleep	0.252	0.060	0.059	43
1	Manual	Whole Workday	Stationary+	0.438	0.086	0.122	43
1	Manual	Work Time	Ambulatory	0.094	0.059	0.095	43
1	Manual	Work Time	Sedentary	0.170	0.137	0.168	43
1	Manual	Work Time	Stationary+	0.736	0.172	0.255	43
2	Desk	Non-Work Time	Ambulatory	0.062	0.036	0.040	10
2	Desk	Non-Work Time	Sedentary	0.453	0.081	0.110	10
2	Desk	Non-Work Time	Stationary+	0.485	0.082	0.089	10
2	Desk	Weekend	Ambulatory	0.070	0.035	0.056	10
2	Desk	Weekend	Sedentary	0.276	0.079	0.101	10
2	Desk	Weekend	Sleep	0.355	0.107	0.075	10
2	Desk	Weekend	Stationary+	0.299	0.088	0.138	10
2	Desk	Whole Workday	Ambulatory	0.055	0.026	0.038	10
2	Desk	Whole Workday	Sedentary	0.268	0.059	0.076	10
2	Desk	Whole Workday	Sleep	0.302	0.049	0.084	10
2	Desk	Whole Workday	Stationary+	0.374	0.074	0.092	10
2	Desk	Work Time	Ambulatory	0.086	0.047	0.063	10
2	Desk	Work Time	Sedentary	0.326	0.120	0.150	10
2	Desk	Work Time	Stationary+	0.588	0.119	0.090	10
2	Manual	Non-Work Time	Ambulatory	0.059	0.026	0.038	32
2	Manual	Non-Work Time	Sedentary	0.467	0.106	0.143	32
2	Manual	Non-Work Time	Stationary+	0.473	0.104	0.138	32

2	Manual	Weekend	Ambulatory	0.037	0.022	0.019	32
2	Manual	Weekend	Sedentary	0.328	0.101	0.129	32
2	Manual	Weekend	Sleep	0.375	0.098	0.130	32
2	Manual	Weekend	Stationary+	0.261	0.073	0.062	32
2	Manual	Whole Workday	Ambulatory	0.058	0.031	0.030	32
2	Manual	Whole Workday	Sedentary	0.220	0.062	0.092	32
2	Manual	Whole Workday	Sleep	0.240	0.055	0.054	32
2	Manual	Whole Workday	Stationary+	0.482	0.061	0.069	32
2	Manual	Work Time	Ambulatory	0.086	0.060	0.051	32
2	Manual	Work Time	Sedentary	0.106	0.057	0.056	32
2	Manual	Work Time	Stationary+	0.809	0.091	0.112	32
3	Desk	Non-Work Time	Ambulatory	0.083	0.030	0.028	11
3	Desk	Non-Work Time	Sedentary	0.517	0.071	0.104	11
3	Desk	Non-Work Time	Stationary+	0.400	0.076	0.056	11
3	Desk	Weekend	Ambulatory	0.049	0.024	0.031	11
3	Desk	Weekend	Sedentary	0.299	0.095	0.135	11
3	Desk	Weekend	Sleep	0.410	0.135	0.062	11
3	Desk	Weekend	Stationary+	0.243	0.103	0.157	11
3	Desk	Whole Workday	Ambulatory	0.073	0.027	0.022	11
3	Desk	Whole Workday	Sedentary	0.381	0.078	0.082	11
3	Desk	Whole Workday	Sleep	0.256	0.049	0.067	11
3	Desk	Whole Workday	Stationary+	0.291	0.066	0.084	11
3	Desk	Work Time	Ambulatory	0.111	0.042	0.046	11
3	Desk	Work Time	Sedentary	0.497	0.149	0.262	11
3	Desk	Work Time	Stationary+	0.392	0.119	0.182	11
3	Manual	Non-Work Time	Ambulatory	0.060	0.031	0.038	33
3	Manual	Non-Work Time	Sedentary	0.539	0.121	0.145	33
3	Manual	Non-Work Time	Stationary+	0.401	0.109	0.150	33
3	Manual	Weekend	Ambulatory	0.034	0.029	0.033	33
3	Manual	Weekend	Sedentary	0.386	0.114	0.128	33
3	Manual	Weekend	Sleep	0.357	0.136	0.161	33
3	Manual	Weekend	Stationary+	0.223	0.076	0.119	33
3	Manual	Whole Workday	Ambulatory	0.053	0.033	0.037	33
3	Manual	Whole Workday	Sedentary	0.282	0.075	0.076	33
3	Manual	Whole Workday	Sleep	0.245	0.065	0.060	33
3	Manual	Whole Workday	Stationary+	0.419	0.086	0.108	33
3	Manual	Work Time	Ambulatory	0.081	0.061	0.069	33
3	Manual	Work Time	Sedentary	0.162	0.108	0.100	33
3	Manual	Work Time	Stationary+	0.757	0.126	0.149	33

Appendix 3-F: Summary statistics of AWE physical activity intensity compositions (relative proportions)

YEAR	JOB TYPE	TIMEFRAME	PART	MEAN	SD	INTERQUARTILE RANGE	N
1	Desk	Non-Work Time	LPA	0.543	0.099	0.068	13
1	Desk	Non-Work Time	MVPA	0.016	0.016	0.025	13
1	Desk	Non-Work Time	Sedentary	0.441	0.102	0.082	13
1	Desk	Weekend	LPA	0.305	0.084	0.114	13
1	Desk	Weekend	MVPA	0.005	0.005	0.005	13
1	Desk	Weekend	Sedentary	0.311	0.091	0.106	13
1	Desk	Weekend	Sleep	0.379	0.093	0.125	13
1	Desk	Whole Workday	LPA	0.389	0.073	0.120	13
1	Desk	Whole Workday	MVPA	0.009	0.007	0.007	13
1	Desk	Whole Workday	Sedentary	0.295	0.084	0.056	13
1	Desk	Whole Workday	Sleep	0.308	0.072	0.080	13
1	Desk	Work Time	LPA	0.593	0.110	0.137	13
1	Desk	Work Time	MVPA	0.005	0.005	0.005	13
1	Desk	Work Time	Sedentary	0.402	0.112	0.143	13
1	Manual	Non-Work Time	LPA	0.486	0.086	0.134	43
1	Manual	Non-Work Time	MVPA	0.011	0.014	0.013	43
1	Manual	Non-Work Time	Sedentary	0.502	0.092	0.148	43
1	Manual	Weekend	LPA	0.283	0.062	0.086	43
1	Manual	Weekend	MVPA	0.004	0.006	0.006	43
1	Manual	Weekend	Sedentary	0.327	0.070	0.087	43
1	Manual	Weekend	Sleep	0.385	0.075	0.093	43
1	Manual	Whole Workday	LPA	0.485	0.078	0.116	43
1	Manual	Whole Workday	MVPA	0.010	0.008	0.011	43
1	Manual	Whole Workday	Sedentary	0.254	0.077	0.112	43
1	Manual	Whole Workday	Sleep	0.252	0.060	0.059	43
1	Manual	Work Time	LPA	0.817	0.145	0.180	43
1	Manual	Work Time	MVPA	0.013	0.014	0.019	43
1	Manual	Work Time	Sedentary	0.170	0.137	0.168	43
2	Desk	Non-Work Time	LPA	0.527	0.078	0.093	10
2	Desk	Non-Work Time	MVPA	0.020	0.025	0.029	10
2	Desk	Non-Work Time	Sedentary	0.453	0.081	0.110	10
2	Desk	Weekend	LPA	0.339	0.092	0.153	10
2	Desk	Weekend	MVPA	0.029	0.024	0.038	10
2	Desk	Weekend	Sedentary	0.276	0.079	0.101	10
2	Desk	Weekend	Sleep	0.355	0.107	0.075	10
2	Desk	Whole Workday	LPA	0.415	0.074	0.081	10
2	Desk	Whole Workday	MVPA	0.015	0.014	0.009	10
2	Desk	Whole Workday	Sedentary	0.268	0.059	0.076	10
2	Desk	Whole Workday	Sleep	0.302	0.049	0.084	10
2	Desk	Work Time	LPA	0.654	0.118	0.125	10
2	Desk	Work Time	MVPA	0.020	0.024	0.002	10
2	Desk	Work Time	Sedentary	0.326	0.120	0.150	10
2	Manual	Non-Work Time	LPA	0.515	0.108	0.149	32
2	Manual	Non-Work Time	MVPA	0.017	0.015	0.018	32
2	Manual	Non-Work Time	Sedentary	0.467	0.106	0.143	32

2	Manual	Weekend	LPA	0.288	0.080	0.077	32
2	Manual	Weekend	MVPA	0.009	0.009	0.011	32
2	Manual	Weekend	Sedentary	0.328	0.101	0.129	32
2	Manual	Weekend	Sleep	0.375	0.098	0.130	32
2	Manual	Whole Workday	LPA	0.517	0.057	0.075	32
2	Manual	Whole Workday	MVPA	0.023	0.021	0.015	32
2	Manual	Whole Workday	Sedentary	0.220	0.062	0.092	32
2	Manual	Whole Workday	Sleep	0.240	0.055	0.054	32
2	Manual	Work Time	LPA	0.858	0.069	0.075	32
2	Manual	Work Time	MVPA	0.036	0.039	0.024	32
2	Manual	Work Time	Sedentary	0.106	0.057	0.056	32
3	Desk	Non-Work Time	LPA	0.446	0.079	0.089	11
3	Desk	Non-Work Time	MVPA	0.037	0.027	0.040	11
3	Desk	Non-Work Time	Sedentary	0.517	0.071	0.104	11
3	Desk	Weekend	LPA	0.277	0.116	0.167	11
3	Desk	Weekend	MVPA	0.014	0.009	0.016	11
3	Desk	Weekend	Sedentary	0.299	0.095	0.135	11
3	Desk	Weekend	Sleep	0.410	0.135	0.062	11
3	Desk	Whole Workday	LPA	0.339	0.077	0.118	11
3	Desk	Whole Workday	MVPA	0.025	0.013	0.020	11
3	Desk	Whole Workday	Sedentary	0.381	0.078	0.082	11
3	Desk	Whole Workday	Sleep	0.256	0.049	0.067	11
3	Desk	Work Time	LPA	0.478	0.141	0.236	11
3	Desk	Work Time	MVPA	0.025	0.021	0.017	11
3	Desk	Work Time	Sedentary	0.497	0.149	0.262	11
3	Manual	Non-Work Time	LPA	0.437	0.115	0.157	33
3	Manual	Non-Work Time	MVPA	0.024	0.023	0.026	33
3	Manual	Non-Work Time	Sedentary	0.539	0.121	0.145	33
3	Manual	Weekend	LPA	0.244	0.086	0.124	33
3	Manual	Weekend	MVPA	0.012	0.019	0.008	33
3	Manual	Weekend	Sedentary	0.386	0.114	0.128	33
3	Manual	Weekend	Sleep	0.357	0.136	0.161	33
3	Manual	Whole Workday	LPA	0.449	0.086	0.097	33
3	Manual	Whole Workday	MVPA	0.023	0.022	0.022	33
3	Manual	Whole Workday	Sedentary	0.282	0.075	0.076	33
3	Manual	Whole Workday	Sleep	0.245	0.065	0.060	33
3	Manual	Work Time	LPA	0.800	0.114	0.116	33
3	Manual	Work Time	MVPA	0.038	0.041	0.032	33
3	Manual	Work Time	Sedentary	0.162	0.108	0.100	33

Appendix 3-G: Meaningfully influential compositions (year-to-year contrasts)

Outcome	composition ID	composition	any ilr sig	minimum p-value	delta of AIC	delta of BIC	adjR2_change	n of composition
Anxiety_Str	intensity_n	Intensity co	FALSE	0.495826	221.2452	220.6846	0.018725	100
Anxiety_Str	type_nonw	Type comp	FALSE	0.525204	221.1812	220.6206	0.018359	100
Anxiety_Str	type_work	Type comp	FALSE	0.064561	154.3555	151.8295	0.033903	114
Anxiety_Str	intensity_w	Intensity co	FALSE	0.174374	151.4696	148.9437	0.019615	114
Anxiety_Str	intensity_w	Intensity co	FALSE	0.19212	143.6459	138.5247	0.006389	113
Anxiety_Str	type_week	Type comp	FALSE	0.228273	142.4701	137.3489	2.72E-04	113
Anxiety_Str	type_whole	Type comp	FALSE	0.244846	118.1922	112.3783	-0.00503	118
Anxiety_Str	intensity_w	Intensity co	FALSE	0.222204	118.0528	112.2388	-0.00573	118
DASS10_To	type_nonw	Type comp	FALSE	0.670152	278.0189	277.816	0.048099	100
DASS10_To	intensity_n	Intensity co	FALSE	0.859229	277.8456	277.6427	0.047204	100
DASS10_To	type_work	Type comp	FALSE	0.069122	191.6915	189.3922	0.055944	114
DASS10_To	intensity_w	Intensity co	FALSE	0.501498	188.4608	186.1615	0.041336	114
DASS10_To	intensity_w	Intensity co	FALSE	0.156644	178.6798	173.794	0.025733	113
DASS10_To	type_week	Type comp	FALSE	0.2265	177.5892	172.7034	0.020512	113
DASS10_To	type_whole	Type comp	FALSE	0.232361	148.4712	142.8494	0.013402	118
DASS10_To	intensity_w	Intensity co	FALSE	0.222594	148.0892	142.4674	0.011616	118
Depressio	**type_work**	**Type comp**	**TRUE**	**0.013473**	**171.3847**	**167.8057**	**0.082242**	**126**
Depressio	**type_whol**	**Type comp**	**TRUE**	**0.02694**	**136.6494**	**129.8592**	**0.051298**	**130**
Depressio	**intensity_v**	**Intensity c**	**TRUE**	**0.021341**	**136.1908**	**129.4005**	**0.049325**	**130**
Depressior	intensity_n	Intensity co	FALSE	0.249798	250.0991	248.0139	0.039883	110
Depressior	type_nonw	Type comp	FALSE	0.343883	249.7208	247.6357	0.03792	110
Depressior	intensity_w	Intensity co	FALSE	0.15019	165.2147	161.6358	0.055767	126
Depressior	intensity_w	Intensity co	FALSE	0.128911	156.2688	149.9492	0.042572	125
Depressior	type_week	Type comp	FALSE	0.140168	153.5375	147.2178	0.030042	125

Appendix 3-H: Meaningfully influential compositions (Job type contrasts)

Outcome	Year	Job type	composition ID	composition	any ilr significant	minimum ilr p-value	delta_AIC	delta_BIC	adjR2_change	n_base	n_comp
Depressior	1	Manual	intensity_w	Intensity co	TRUE	0.005122	44.54611	40.86153	0.164482	47	39
Depressior	1	Manual	type_week	Type comp	TRUE	0.006041	42.96558	39.281	0.128719	47	39
Depressior	1	Manual	type_work	Type comp	TRUE	0.0446	24.74135	22.05336	0.028955	47	42
Depressior	1	Desk	intensity_w	Intensity co	FALSE	0.301168	27.14367	26.76801	0.863297	14	12
Depressior	1	Desk	intensity_w	Intensity co	FALSE	0.091579	13.25504	13.36428	0.344037	14	12
Depressior	1	Desk	type_whole	Type comp	FALSE	0.221153	12.62677	12.2511	0.191696	14	12
HPQ_Relat	1	Desk	type_work	Type comp	FALSE	0.107094	54.00513	55.27778	1.355606	13	11
HPQ_Relat	1	Manual	type_work	Type comp	FALSE	0.075321	30.31438	28.19354	0.160964	44	39
HPQ_Relat	1	Manual	intensity_w	Intensity co	FALSE	0.213478	29.55245	26.8086	0.188632	44	36
HPQ_Relat	1	Desk	intensity_w	Intensity co	FALSE	0.605895	18.44744	19.72008	0.792809	13	11
HWQ_Impa	1	Manual	type_work	Type comp	TRUE	0.036158	20.24752	18.12668	0.145567	44	39
HWQ_Impa	1	Manual	intensity_w	Intensity co	TRUE	0.036441	19.25889	17.13805	0.122932	44	39
HWQ_Impa	1	Desk	intensity_w	Intensity co	FALSE	0.083946	44.53503	45.80767	0.435849	13	11
PSQI	2	Manual	type_work	Type comp	TRUE	0.037824	41.65892	40.69604	0.189662	34	24
PSQI	2	Manual	intensity_w	Intensity co	TRUE	0.043168	41.39228	40.42939	0.180461	34	24
UWES_Mea	1	Manual	type_week	Type comp	TRUE	0.002031	38.83889	35.89437	0.299328	44	36
UWES_Mea	1	Manual	intensity_w	Intensity co	TRUE	0.00273	37.73666	34.79214	0.275839	44	36
UWES_Mea	1	Desk	intensity_w	Intensity co	FALSE	0.512368	19.92539	21.30006	0.242531	14	11
UWES_Mea	1	Desk	type_work	Type comp	FALSE	0.071291	14.86371	15.76616	0.441325	14	12
UWES_Mea	1	Desk	intensity_w	Intensity co	FALSE	0.384483	9.087027	9.989476	0.180178	14	12
UWES_Mea	1	Manual	type_week	Type comp	TRUE	0.006987	38.95232	35.80713	0.252364	44	36
UWES_Mea	1	Manual	intensity_w	Intensity co	TRUE	0.010732	37.54091	34.39572	0.222392	44	36
UWES_Mea	1	Desk	type_work	Type comp	FALSE	0.054844	14.24131	14.98961	0.49247	14	12

Appendix 3-I: Isotemporal substitution matrix

OUTCOME	JOB TYPE	YEAR	TIMEFRAME	FROM	5-MINUTE SUBSTITUTION	TO	PREDICTED CHANGE IN SCORE
PSQI (SLEEP QUALITY)	Manual	1	Work	LPA	→	Sedentary	-10.63
DEPRESSION	Manual	1	Weekend	MVPA	→	Sedentary	-8.98
UWES ABSORPTION	Manual	1	Weekend	Sedentary	→	LPA	7.75
HWQ IMPATIENCE	Manual	1	Work	Sedentary	→	MVPA	-6.42
UWES DEDICATION	Manual	1	Weekend	Ambulatory	→	Sleep	5.69
HPQ RELATIVE PRESENTEEISM	Manual	1	Work	Sedentary	→	Ambulatory	-2.35
HPQ RELATIVE PRESENTEEISM	Manual	2	Weekend	MVPA	→	Sedentary	-0.56

Appendix 4-A: Systematic review search strategies

Search strategies

Source: MEDLINE(R) and In-Process & Other Non-Indexed Citations

Interface: OvidSP

Database coverage dates: 1946 to 20 June 2024

Search date: 20 June 2024

Retrieved records: 3952

Search Strategy:

1 exp work/

2 exp Occupational Groups/

3 (Occupation$ or organi#ation or employ$ or worker? or workplace or worksite).tw.

4 or/1-3

5 exp Exercise/

6 exp Exercise Test/

7 "Physical Education and Training"/

8 exp Physical Fitness/

9 exp Sports/

10 stress, physiological/ or running/ or swimming/ or walking/ or muscle fatigue/ or muscle strength/ or exp physical endurance/ or physical exertion/ or exercise tolerance/ or exp physical fitness/ or exp postural balance/

11 (physical adj2 (activ$ or condition$ or education or therap$ or train$ or fit$)).tw.

12 (exercis$ or aerobic or anaerobic or endurance$ or kinesiotherapy or resistance or strength$ or stamina or treadmill).tw.

13 (step counter or accelorometer or Actigraph or ActivPal or Fitbit or fit*adj2 device).tw.

14 (active tra* or ai chi or bad ragaz or baseball or basketball or bicycl* or boxing or chi kung or climbing* or cricket or cycling or football or golf or gym* or halliwick or hockey or jog* or martial or mind body or mountaineering or pilates or calisthenic* or pole danc* or qigong or racquet or recreation* or rowing or rugby or run* or skating or skiing or soccer or sport* or squash or swim* or tai chi or tai ji or tennis or track or volleyball or walk* or (water adj1 sport*) or weight lifting or wrestling or yoga).tw.

15 or/5-14

16 Randomized Controlled Trials as Topic/

17 randomized controlled trial/

18 Random allocation/

19 Single Blind Method/

20 controlled trial.pt.

21 randomized controlled trial.pt.

22 (allocated adj2 random$).tw.

23 (intervention or randomized or randomly allocated or mixed method* or pre?post or quasi?experiment*).tw.

24 cluster random$.mp.

25 controlled before-after studies/

26 multicenter study.pt.

27 or/16-26

28 animal/

29 human/

30 29 not 28

31 Comment/

32 Letter/

33 Editorial/

34 Historical article/

35 or/31-34

36 30 not 35

37 Mental Health/ or mental health.mp.

38 (Mental$ adj3 (health or well$)).mp.

39 Stress, Psychological/

40 psychological health.mp.

41 Resilience, Psychological/ or psychological resilience.mp.

42 (well being or well?being).mp.

43 (stress or coping or mood or self?esteem).tw.

44 or/37-43

45 4 and 15 and 27 and 36 and 44

46 limit 45 to english language

Search history link:

https://ovidsp.ovid.com/ovidweb.cgi?T=JS&NEWS=N&PAGE=main&SHAREDSEARCHID=2pzLZ361IOY16MrlwaZlf6u6oQdi314PaMavOeGGfKENhATQM8qlb15z8xBSbUaaG

Source: EMBASE

Interface: OvidSP

Database coverage dates: 1947 to 20th June 2024

Search date: 20th June 2024

Retrieved records: 6344

Search Strategy:

1. exp work/, (471692)
2. exp employee/, (30168)
3. (Occupation$ or organi#ation or employ$ or worker? or workplace or worksite).tw. (1960388)
4. 1 or 2 or 3 (2283425)
5. exp exercise/ (484228)
6. exp physical activity/ (584696)
7. exp exercise test/ (126230)
8. *physical education/ (7661)
9. exp sport/ (232700)
10. exp muscle strength/ (90595)
11. *muscle fatigue/ep, pc, rh, si, th [Epidemiology, Prevention, Rehabilitation, Side Effect, Therapy] (234)
12. exp muscle stretching/ (6217)
13. (physical adj2 (activ$ or condition$ or education or therap$ or train$ or fit$)).tw. (310876)
14. (exercis$ or aerobic or anaerobic or endurance$ or kinesiotherapy or resistance or strength$ or stamina or treadmill).tw. (2492711)
15. (step counter or accelorometer or Actigraph or ActivPal or Fitbit or fit*adj2 device).tw., (8503)
16. (active tra* or ai chi or bad ragaz or baseball or basketball or bicycl* or boxing or chi kung or climbing* or cricket or cycling or football or golf or gym* or halliwick or hockey or jog* or martial or mind body or mountaineering or pilates or calisthenic* or pole danc* or qigong or racquet or recreation* or rowing or rugby or run* or skating or skiing or soccer or sport* or squash or swim* or tai chi or tai ji or tennis or track or volleyball or walk* or (water adj1 sport*) or weight lifting or wrestling or yoga).tw., (1093463)
17. 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 (3926855)
18. randomized controlled trial/ (829441)
19. "randomized controlled trial (topic)"/ (275495)
20. randomization/ (99703)
21. single blind procedure/ (55125)
22. pretest posttest design/ (10412)
23. controlled trial.pt. (0)
24. randomized controlled trial.pt. (0)
25. (allocated adj2 random$).tw. (52816)
26. (intervention or randomized or randomly allocated or mixed method* or pre?post or quasi?experiment*).tw. (2154520)
27. cluster random$.mp. (24403)
28. multicenter study.pt. (0)
29. or/18-28 (2626815)
30. animal/ (2162886)
31. human/, (27867779)
32. 31 not 30, (27343606)
33. letter/ or editorial/ or note/, (2943225)
34. 32 not 33, (25055626)
35. mental health/, (235612)
36. mental health.mp., (447786)
37. (Mental$ adj3 (health or well$)).mp., (464601)
38. mental stress/, (106125)
39. psychological health.mp. (11323)
40. psychological resilience/ or psychological resilience.mp. (12356)
41. (well being or well?being).mp. (239392)
42. (stress or coping or mood or self?esteem).tw. (1465202)

43. 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 (2062869)
44. 4 and 17 and 29 and 34 and 43 (6464)
45. limit 44 to english language (6344)

Search history link:

https://ovidsp.ovid.com/ovidweb.cgi?T=JS&NEWS=N&PAGE=main&SHAREDSEARCHID=6AAe6gBslN2Yi5fWQOpWmMFHcsSQBsnVYGymc1RDme1TcjDwIzm6Oh3RVpbeBPXNC

Source: EMBASE, PubMed, CT.gov, ICTRP & CINAHL

Interface: Cochrane Library

Database coverage dates: All years

Search date: 20th June 2024

Retrieved records: 4101 (in English)

Search Strategy:

1. MeSH descriptor: [Workplace] explode all trees
2. MeSH descriptor: [Occupational Groups] explode all trees
3. (occupation* or organi#ation or employ* or worker* or workplace or worksite):ti,ab
4. {or #1-#3}
5. MeSH descriptor: [Exercise] explode all trees
6. MeSH descriptor: [Exercise Test] this term only
7. MeSH descriptor: [Accelerometry] explode all trees
8. MeSH descriptor: [Health Promotion] explode all trees
9. MeSH descriptor: [Sports] explode all trees
10. MeSH descriptor: [Muscle Strength] explode all trees
11. MeSH descriptor: [Exercise Therapy] explode all trees
12. MeSH descriptor: [Muscle Fatigue] explode all trees
13. MeSH descriptor: [Physical Fitness] explode all trees
14. MeSH descriptor: [Physical Endurance] explode all trees
15. (physical near/2 (activ* or condition* or education or therap* or train* or fit*)):ti,ab
16. (exercis* or aerobic or anaerobic or endurance or kinesiotherapy or resistance or strength* or stamina or treadmill):ti,ab
17. (step counter or accelorometer or Actigraph or ActivPal or Fitbit or fit* near/2 device):ti,ab
18. (active tra* or ai chi or bad ragaz or baseball or basketball or bicycl* or boxing or chi kung or climbing* or cricket or cycling or football or golf or gym* or halliwick or hockey or jog* or martial or mind body or mountaineering or pilates or calisthenic* or pole danc* or qigong or racquet or recreation* or rowing or rugby or run* or skating or skiing or soccer or sport* or squash or swim* or tai chi or tai ji or tennis or track or volleyball or walk* or (water near/1 sport*) or weight lifting or wrestling or yoga):ti,ab
19. {or #5-#18}
20. MeSH descriptor: [Mental Health] this term only
21. (mental health):kw
22. (Mental* near/3 (health or well*)):kw
23. MeSH descriptor: [Stress, Psychological] explode all trees
24. MeSH descriptor: [Resilience, Psychological] explode all trees
25. MeSH descriptor: [Quality of Life] explode all trees
26. MeSH descriptor: [Work-Life Balance] explode all trees
27. (psychological health or well being or well-being or wellbeing):kw
28. (stress or coping or mood or self?esteem):ti,ab
29. psychological resilience:kw
30. {or #20-#29}

31. #4 and #19 and #30 in Trials

Search history link:

https://www.cochranelibrary.com/advanced-search/search-manager?search=7466718

Appendix 4-B: Characteristics of studies included in the systematic review

Author and year of publication	Workplace/sector, job type and Country	Study design	Intervention duration	Participants	Target outcome/s and *(Measure/s)*	Description of PA intervention
Bastug 2021 (325)	University - Office Workers, Turkey	NRCT	Not reported	Experimental: n = 40. Control: n = 57. Total sample: mean age 41.6±9.5 years.	Job stress and Life satisfaction *(Job Stress Scale; The Satisfaction with Life Scale)*	Stretching and mobility exercises, seated and standing stretches (very light intensity) 15-20 minutes on 3 days/week.
Biman et al., 2021 (326)	Industrial - Diamond cutting, India	RCT	3 months	Experimental: n = 79, 41 females 38 males, mean age 38.2±7.1 years. Control: n = 76, 44 females 32 males,	Stress and QoL *(Perceived Stress Scale (PSS); WHO Quality of Life Instrument (WHOQOL))*	Structured, supervised yoga sessions (1 hour each) 4 times / week including asanas (yoga postures), pranayama (yogic breathing techniques), relaxation techniques, and meditation.

				mean age 36.8±7.9 years.		
Brandt et al., 2024 (327)	University - Predominantly sitting military and civilian staff, Germany	NRCT	12 months	Experimental: n = 55, 31 females, 26 males, mean age 38.2±12.1 years, BMI 25.4±3.9 kg/m^2. Control: n = 34, 20 females, 14 males, mean age 36.7±11.4 years, BMI 27.3±5.3 kg/m^2.	Wellbeing *(WHO-5)*	CrossFit delivered by CrossFit certified coaches. Employees were given 90 minutes per week to train during working hours. Wide range of additional facilities and classes provided free of charge.
Buuck et al., 2023 (328)	Commercial - Consumer technology, Germany	RCT	8 weeks	Experimental: n = 36, 18 females, 18 males, mean age 42.4±11.1 years. Control: n = 31, 17 females, 14	Mood/affect *(Positive and Negative Affect Schedule (PANAS))*	One group received motor-cognitive coordination training which included exercises such as walking on the spot, clapping, jumping, juggling, balancing, and often combined with cognitive tasks, the other received relaxation and

				males, mean age 40.0±10.4 years.		mobility training with aspects of yoga as an active work break. Both met for 15 minutes 3x per week.
Cheema et al., 2013 (329)	University - Academic, general staff and post-graduate students, Australia	RCT	10 weeks	Experimental: n = 18, 14 females, 4 males, mean age 37±12 years. Control: n = 19, 16 females, 3 males, mean age 39±13 years.	Anxiety and mental health *(Short Form Health Survey (SF-36); State-Trait Anxiety Inventory (STAI))*	Hatha Yoga 3x pw, 50 minutes per session, led by external qualified instructor. Started at beginner level and progressed. Classes delivered during lunch hour.
Chen et al., 2016 (330)	Hospital - nurses, Taiwan	RCT	24 weeks	Experimental: n = 50 females, mean age 33.3±2.9 years. Control: n = 49 females, mean	Anxiety *(Beck Anxiety Inventory (BAI); Visual Analogue Scale for Anxiety (VASAS)*	Supervised releasing exercise program (warm-up exercises, muscle tension-releasing exercises, and mood adjustments) 50 minutes, 3 x per week. Provided lunchtime and dinner time options at employee activity centre.

				age 33.6±7.0 years.		
Chhugani et al., 2018 (331)	Residential care - caregivers, India	NRCT	1 month	Experimental: n = 18 females, age 22-55 years. Control: n = 18 females, age 22-55 years.	Depression, anxiety and stress *(*Depression, anxiety and stress *Scale (DASS-21))*	Supervised yoga, Asanas, pranayama, meditation, and relaxation techniques every day for 6 days per week. Yoga session lasted for 1 hour.
de Freitas-Swerts et al., 2014 (332)	University - administrative staff, Brazil	PP	10 weeks	Experimental: n = 30, 17 females, 13 males, mean age 41.7±8.8 years.	Work-related stress *(Workplace Stress Scale)*	Compensatory Workplace Exercise program, known as "workplace gym" to encourage active breaks which included postural exercises, segmental stabilization, and muscular chain stretching 2 x / week for 15 minutes.
Diaz-Benito et al., 2022 (333)	Office workers, Spain	RCT - Double-blind pilot	12 weeks	Experimental: n = 40, 21 females, 19	Wellbeing and QoL	Group based, supervised aerobic and strength training

				males, mean age 37.6±12.4 years. Control: n = 27, 13 females, 14 males, mean age 31.0±11.9 years.	*(Short Form Health Survey (SF-36 v2); Health questionnaire for QoL)*	PRODET®, conducted two days/week for 50 minutes
Diaz-Silveira et al., 2020 (334)	Telecommunications - professional team leaders, Spain	RCT	5 weeks	Experimental: n = 30, 18 females, 12 males, mean age 47.8±5.2 years. Control: n = 30, 23 females, 7 males, mean age 47.4±3.8 years.	Stress and mental health *(Perceived Stress Questionnaire (PSQ), General Health Questionnaire (GHQ), Salivary Immunoglobulin A (sIgA))*	30 mins of Mindfulness, meditation and physical exercise, practised as daily recovery activities during lunch breaks.
Eather et al., 2020 (335)	University employees, Australia	RCT	8 weeks	Experimental: n=25. Control: n =23.	Well-being at work and anxiety *(Short questionnaire to measure wellbeing at work (Short-SWELL); Brief*	Supervised High Intensity Interval Training (HIIT) 2-3 x/week (minimum of 2) for 10 minutes (2 minute warm up and 8-minute session. Exercises included aerobic and resistance

				Total sample: 48, 41 female, 7 male, mean age 43.0±10.7 years.	*measure for assessing generalized anxiety disorder (GAD-7)*	either individual or with a partner.
Fang and Li, 2015 (336)	Hospital - nurses, China	RCT	6 months	Experimental: n = 54 female nurses, mean age 35.1±11.0 years. Control: n = 51 female nurses, mean age 36.1±9.9 years.	Work related stress *(Questionnaire on Medical workers Stress)*	Yoga, including included physical postures, loosening exercises, supervised 2x/week for 50-60 minutes after work hours.
Genin et al., 2018 (337)	Service industry, France	PP	10 months	Experimental: n = 244, 162 females, 60 males, mean age 43.8±10 years, BMI 24±3.7 kg/m^2.	Anxiety, depression, overall wellbeing *(Worksite Well-being and Quality of Life questionnaire; The hospital anxiety and depression scale)*	Two sessions per week, from a choice of 18 different activities (one strength & one aerobic session) supervised, lasting 45 minutes at onsite facilities with access any time of the day.

Gerodimos 2022 (338)	Hospital - Health professionals (doctors, nurses, physiotherapists), Greece	RCT	6 weeks	Experimental: n = 25, 18 females, 7 males, mean age 44.4±6.2 years, BMI 26.9±5.4 kg/m^2. Control: n = 25, 17 females, 8 males, mean age 44.3±5.7 years, BMI 26.9±5.4 kg/m^2.	Life satisfaction *(Cantril's ladder)*	Daily, supervised, group based chair-based strength, stretching, balance and aerobic exercise 5 days a week, for 30-40 minutes per day
Griffith et al., 2008 (339)	Hospital - Medical and social work staff, USA	RCT	6 weeks	Experimental: n = 16, 12 females, 4 males, mean age 52±9 years. Control: n = 21, 17 females, 5 males, mean age 50±10 years.	Stress and mental health *(Perceived Stress Scale (PSS); Short Form Health Survey (SF-36))*	Qigong exercises 'The Basic Eight' © delivered during supervised, group class sessions, with specific breathing patterns 1 hr, 2 x / week at noon. Independent practice 30 minutes on non-class days with the aid of a DVD.

Hargreaves et al., 2023 (340)	University - Academic, professional and administrative employees, New Zealand	PP (Interrupted time series)	12 weeks	Experimental: n = 52, 40 females, 12 males, mean age 43.6±9.6 years.	Mood/affect *(Positive and Negative Affect Schedule (PANAS)*	30-minute individual behaviour change consultation delivered by trained Move More @ Work coaches including self-monitoring and action planning. Weekly support emails were provided.
Hartfiel et al., 2011 (341)	University, UK	RCT	6 weeks	Experimental: n = 24, 17 females, 7 males, mean age 40.6±11.4 years. Control: n = 20, 19 females 1 male, mean age 38.0±9.6 years.	Mood/affect and psychological Wellbeing *(Profile of Mood States Bipolar (POMS-Bi); Inventory of Positive Psychological Attitudes (IPPA))*	1 x 60-minute class Dru Yoga per week by a certified Dru Yoga instructor at lunchtime. Dru Yoga DVD, which included a guided 35-minute home practice session. Both included breathing and relaxation.
Hartfiel et al., 2012 (342)	Local government, – Local authority officers, health/education/social care professionals, managers, admin staff, UK	RCT	8 weeks	Experimental: n = 33, 29 females, 4 males, mean age 46.1±11.5 years.	Stress and mood/affect *(Perceived Stress Scale (PSS); Positive and*	1 x 50 min instructed Dru yoga classes per week plus 2 x 20 min DVD guided yoga sessions at home. Both with directed

				Control: n = 26, 24 females, 2 males, mean age 43.6±11.5 years.	*Negative Affect Schedule (PANAS-X))*	breathing and relaxation techniques.
Hinman 1997 (343)	University – Desk-based/office workers, USA	RCT	8 weeks	Experimental: n = 24 females, mean age 36 years. Control: n = 26 females, mean age 39.3 years.	Stress *(Personal Strain Questionnaire (PSQ))*	Exercises directed by "Exercise Break" software, 2x per day, for 15 mins per session focusing on various body areas and included relaxation and circulation exercises.
Holzgreve et al., 2020 (344)	Automotive company, Germany	NRCT	12 weeks	Experimental: n = 158, 56 females, 102 males, mean age 44.94±10.56 years, BMI 25.0±3.9 kg/m^2. Control: n = 95, 59 females, 36 males, mean age 40.83±11.92	Mental health *(Short Form Health Survey (SF-36)*	Static stretching 2x/week for 10 minutes using 'five-Business' program and stretching equipment.

				years, BMI 23.6±3.4 kg/m^2.		
Jakobsen et al., 2017 (345)	Hospital – Healthcare professionals, Denmark	CRCT - Two-armed parallel-group	10 weeks	Experimental: n = 111 females, mean age 40±12 years, BMI 23.8±4 kg/m^2. Control: n = 89 females, mean age 44±10 years, BMI 24.4±4 kg/m^2.	Mental health, and psychosocial work perceptions *(Short Form Health Survey (SF-36); Copenhagen Psychological Questionnaire (COPSOQ))*	At work exercise - group-based and supervised strength training, during working hours at the hospital for 10mins 5x/week, using elastic bands, kettlebells and swiss balls in designated room.
Larisch et al., 2024 (280)	Retail and Finance companies – Predominantly office workers, Sweden	CRCT	6 months	Experimental: n = 69. *49 females 11 males, mean age 41±9 years. Control: n = 74.	Stress, anxiety, depression, and wellbeing *(Hospital Anxiety and Depression Scale (HADS); WHO-5; single-item stress question)*	Two groups focused on either increasing MVPA or reducing SB in work time based on aspects of the social ecological model including managers as role models, joint exercise session, lunch walks, standing walking meetings and individual and group counselling.

				*46 females 17 males 17, mean age 45±7 years.		
Lennefer et al., 2020 (346)	Mobility enterprise company – Office workers, Germany	RCT	3 weeks	Experimental: n = 59. Control: n = 57. Total sample: 53 females, 63 males, mean age 43.0±12.7 years, BMI 27.2±4.7 kg/m^2.	Burnout, and health perception (including mental health) (Shirom–Melamed Burnout Measure)	Behavioural approach using activity trackers and a cognitive approach with an online coach providing advice on health behaviour change (goal-setting tools and coping plans)
Lin et al., 2015 (347)	Hospital, Taiwan	RCT	12 weeks	Experimental: n = 30, 26 females, 4 males, mean age 32.1±7.5 years. Control: n = 30, 22 females, 8 males,	Work-related stress, stress adaptation *(Work-related stress scale; Stress Adaptation Scale; Heart Rate Variability (V1.89))*	60-minute supervised yoga sessions, once a week including breathing and relaxation.

				mean age 29.8±6.9 years.		
Mandal et al., 2021 (348)	Hospital – Nursing, India	RCT	12 weeks	Experimental: n = 58, 50 females, 8 males, mean age 35.0±7.9 years. Control: n = 52, 30 females, 22 males, mean age 32.5±6.8 years.	Stress (perceived and physiological) and QoL *(Perceived Stress Scale (PSS); Serum cortisol; English Professional Quality of Life (ProQOL))*	2 x yoga supervised sessions per week for 50 minutes each, including deep relaxation delivered before or after working hours. Text message/email reminders sent before sessions.
Matsugaki et al., 2017 (349)	Hospital – Nurses, Japan	RCT	12 weeks	Experimental: n = 15 females, mean age 25.3±3.4 years, BMI 19.3±1.9 kg/m^2. Control: n = 14 females, mean age 24.7±3.7	Depression and Mood *(Beck Depression Inventory (BDI-II); Profile of Mood States (POMS))*	Resistance exercise (10 x 3 sets) and aerobic (20 minutes) 2 x per week under supervision of a personal trainer but in an induvial setting in a specific training room on site.

				years, BMI 19.9±2.5 kg/m^2.		
Melville et al., 2012 (350)	University, Australia	RCT - Within-subjects crossover	15 minutes	Experimental: n = 20, 12 females, 8 males, mean age 39.6±9.5 years, BMI range 19.8-44.1 kg/m^2. Control: Crossover design.	Stress *(Perceived stress - 100 mm visual analogue scale)*	Seated yoga for 15 mins including deep breathing -one session only.
Michishita et al., 2017 (351)	Commercial – White collar workers, Japan	CRCT	10 weeks	Experimental: n = 29, 10 females, 19 males, mean age 40.8±9.8 years, BMI 23.1±3.2 kg/m^2. Control: n = 30, 9 females, 21 males, mean age 41.1±8.6 years,	Mood/affect and Job-related stress *(Profile of Mood States (POMS); Brief Job Stress Questionnaire (BJSQ))*	Stretching, cognitive functional training, aerobic exercise, body weight resistance training 10 minutes lunch fitness program 3 times per week in a dedicated room under supervision.

				BMI 22.5±2.5 kg/m^2.		
Mohebbi et al., 2019 (352)	Hospital – Nurses, Iran	RCT	8 weeks	Experimental: n = 27 females. Control: n = 30 females. Total sample: mean age 33±2.7 years.	Occupational stress *(Health and Safety Executive questionnaire (HSE))*	Aerobic exercise with some stretching 3 x 1 hr per week with brief relaxation period.
Mulla et al., 2018 (353)	Car company – Office employees, Canada	RCT	12 weeks	Experimental: n = 21, 12 females, 9 males, mean age 44.1±10.5 years, BMI 28.7±5.5 kg/m^2. Control: n = 22, 15 females, 7 males, mean age 43.3±10.4 years,	Depression *(Centre for Epidemiological Studies Depression Scale (CES-D))*	Resistance exercise supervised classes specifically for lower body 45 minutes 3 x per week at onsite fitness centre (a choice of 7 class times)

				BMI 27.3±4.7 kg/m^2.		
Nurminen et al., 2002 (354)	Laundry company – Laundry workers, Finland	RCT	8 months	Experimental: 133 females, mean age 40.7 years. Control: 127 females, mean age 39.1 years.	Stress and life satisfaction *(Modified version of the Standard Nordic Questionnaire)*	Feedback on a physical capacity test, exercise prescription, counselling to increase leisure time PA, group worksite 60-minute exercise sessions, once per week, during work hours involving muscle strengthening, cardiovascular exercise, and stretching.
Odhiambo et al., 2023 (355)	University – Administrative staff, USA	RCT - crossover design x2	8 weeks	Experimental: n = 36 females, mean age 44.4±10.6 years, BMI 32.6±8.5 kg/m^2. Control: n = 38 females, mean age 44±11.6 years, BMI 30±8.5 kg/m^2.	Mood/affect *(Modified version Exercise-induced Feeling Inventory (EFI))*	Desk bikes used at employees' discretion with an informational handout provided on its benefits and usage.

Opdenacker and Boen, 2008 (356)	University, Belgium	PP	3 months	Experimental (face-to-face group): n = 33, mean age 38.8±11.4 years, BMI 23.8±3.6 kg/m^2. Experimental (telephone group): n = 33, mean age 39.9±9.9 years, BMI 25.7±4.9 kg/m^2.	Trait Anxiety and self-efficacy *(Spielberger State-Trait Anxiety Inventory (STAI); Self-efficacy questionnaire; social support items)*	Coaching programme with introductory face to face session, brochure on how to become active with additional in person coaching support.
Patel et al., 2022 (357)	University – Administrative offices, India	CRCT	4 weeks	Experimental: n = 29, 17 females, 12 males, mean age 38.4±12.3 years. Control: n = 19, 10 females, 9 males, mean age 36.3±17.3 years.	Wellbeing *(Workplace Wellbeing Questionnaire (WWQ))*	Manual provided with the risks of sitting, guidelines on break schedules, exercise to perform during breaks from sitting and encouraging walking bouts 5x30 per week.

Puig-Ribera et al., 2008 (358)	University – Academic and administrative staff, Spain	RCT	9 weeks	Experimental: n = 44, Control: n = 26 Total sample: n = 70, 49 females (BMI 23.6±3.82 kg/m^2), 21 men (BMI 25.1±2.3 kg/m^2).	QoL *(Short Form Health Survey (SF-12))*	Two walking groups, one focused on walking routes and 15 mins of continuous walking per day and the other walking while working focusing on steps in the office.
Puig-Ribera et al., 2017 (359)	University, Spain	CRCT	19 Weeks	Experimental: n = 129, 87 females, 42 males, mean age 41±9 years. Control: n = 135, 84 females, 51 males, mean age 42±10 years.	Mental health *(Warwick Edinburgh (WEMWBS))*	Web based walking programme with tips on how to increase movement with weekly guidance and reinforcing emails.

Roessler et al., 2013 (360)	Industrial production – Laboratory technicians, Denmark	CRCT	20-weeks	Experimental: 199, 177 females, 22 males, mean age 42±11 years, BMI 25±4 kg/m^2. Experimental: 228, 182 females, 46 males, mean age 42±10 years, BMI 25±5 kg/m^2.	Mental health (time pressure, influence at work) *(Copenhagen Psychological Questionnaire (COPSOQ))*	Resistance exercise 1 h per week divided into three sessions of 20 min during work hours in dedicated rooms onsite (storage rooms, corridors) Experienced instructors introduced the program in small groups of approximately 5-15 colleagues. After 2 x introduction sessions the subjects were allowed to train on individual basis or in self-organised groups.
Rostami and Ghodsbin, 2019 (361)	Hospital – ICU nurses, Iran	RCT	2 months	Experimental: n = 35, mean age 30.5±5.1 years. Control: n = 35, mean age 29.3±5.1 years.	QoL *(WHO-QOL)*	Supervised yoga classes 2/3x per week (at least 30 minutes), focusing on mind control, breathe control, and slow body movements and mindfulness.

Ryde et al., 2022 (271)	Multiple workplaces – Mainly office based, UK	PP	4 weeks	Experimental: n = 246, 204 females, 42 males, mean age 42.5±11.1 years.	Stress *(Perceived Stress Scale (PSS))*	Online step count challenge in workplace teams of five with online tracking of steps and leader boards at a national level.
Saavedra et al., 2021 (362)	Healthy office workers, Iceland	NRCT	12 weeks	Experimental (circuit training): n = 18, 16 females, 2 males, mean age 44.8±15 years, BMI 29.7±5.7 kg/m^2. Experimental (brisk walk): n = 18, 15 females, 3 males, mean age 45.6±9.4 years, BMI 28.6±4.1 kg/m^2. Control: n = 11, 6 females, 5 males, mean age	Depression, anxiety and stress *(Depression Anxiety Stress Scale (DASS))*	Two groups, one brisk walking group with cadence >100 strides and the other a circuit training group. 3 sessions per week x 30 mins in the middle of the workday with an extra 15 mins of the lunchtime on training days.

				43.2±12.1 years, BMI 27.4±3.7 kg/m^2.		
Schellewald, Kleinert and Ellegast, 2018 (363)	Telecommunications - Office workers, Germany	PP	12 weeks	Experimental: n = 36, 19 females, 17 males, mean age 41±10.7 years, BMI 25.2±5 kg/m^2.	Psychological wellbeing *(Modified Eigenzustandsskala (EZ-scale))*	8 desk bikes provided by the company and stored in "borrowing stations" for employees to use when desired. Information session provided before the intervention began.
Sianoja et al., 2018 (364)	Multiple workplaces (including public administration, education, health care, media, engineering, and finance) – Office work, Finland	RCT	2 weeks	Experimental: n =51. Control: n = 46. Total sample: 89 females, 8 males, mean age 46.8±9.6 years.	Stress - called *strain* in the survey but asks about stress *(Finnish version of the Recovery Experience Questionnaire; multiple adapted questionnaires)*	15-minute park walks close to participant's place of work during lunch break for 10 consecutive days. Participants were instructed to walk the predetermined route at a slow pace and focus on the natural surroundings alone or in a group but advised not to talk.

Sjogren et al., 2006 (365)	Local government – Office workers, Finland	CRCT – crossover design	15 weeks	Experimental (treatment group 1): n = 55, 46 females, 9 males. Experimental (treatment group 2): n = 35, 20 females, 15 males. Total sample: n = 90, 66 females, 24 males, mean age 45.7±8.5 years.	Wellbeing and life satisfaction *(Descriptive visual rating scales)*	Light intensity resistance exercise using air resistance equipment onsite for 6/8 min/working day. 3 Physio led group education sessions (3x20mins) also provided.
Smith-McLallen et	Two manufacturing & one office-based worksite, USA	CRCT	40 weeks	Experimental: n = 234,	Mood/affect and stress	Online tool kit to encourage walking with some groups receiving add ons such as

al., 2017 (366)				144 females, 90 males, mean age 48.6±11.4 years. Control: n = 225, 115 females, 110 males, mean age 50.4±11.1 years.	*(Positive and negative affect Schedule (PANAS); Perceived Stress Questionnaire)*	walking challenges, feedback on miles walked, rewards and monthly seminars.
Stone et al., 2023 (367)	Multiple workplaces -Office workers, Australia	PP	4 months	Experimental: n = 422, 245 females, 177 males, mean age 41 years.	Stress - Psychological distress *(Kessler Psychological Distress Scale (K-10))*	The Global Corporate Challenge® website. Logging step count, team challenges against others in their company with online visualisation of distance covered. Weekly encouragement newsletters sent via email.
Tamim et al., 2009 (368)	University – Computer based jobs, Canada	PP	12 weeks	Experimental: n = 52 females, mean age 46.1 ±10.7 years.	Stress *(Perceived Stress Scale (PSS))*	Two x 50-minute supervised Tai Chi classes per week in lunchtime at onsite fitness centre.

Taylor et al.,2020 (369)	Hospital – Junior doctors, Australia	RCT	8 weeks	Experimental: n = 11, 10 females, 1 male, mean age 30±5 years. Control: n = 10, 6 females, 4 males, mean age 30±4 years.	QoL, burnout (traumatic stress reported but only a component of another scale) *(Professional Quality of Life (ProQoL); Maslach Burnout Inventory; MBI Human Services Survey for Medical Personnel (MBI-HSS (MP))*	1-hour private yoga sessions, once a week including relaxation and breathing techniques. A 4- hour workshop/retreat, two eHealth video classes, and audio-guided breathing and relaxation was also provided. Participants were asked to log 2 hours of homework. Active control included interval and 'box fit' training 45-60mins 1x/week plus 2.5hrs 'homework' (unclear if homework was exercise).
Thogersen-Ntoumani et al., 2015 (370)	University, UK	RCT	16 weeks	Experimental: n = 26. Control: n = 30. Total sample: n = 56, 52 females, 4	Mood/affect *(Job Affect Scale; Trait version of the Positive and Negative Affect Schedule (PANAS))*	Three 30-min group-led walks during lunchtime per week, and two walks during the weekends which were independently organized. The following 6 weeks were independently organized by the participants.

				males, mean age 47.7± 10.3 years.		Maps and step counters provided.
Tveito and Eriksen, 2009 (371)	Residential care – various employee roles, Norway	RCT -Pilot	9 months	Experimental: n = 19 females. Control: n = 21 females.	Coping, health-related QoL (job stress reported but only a component of another scale) *(Subjective Health Complaints Inventory; Short Form Health Survey (SF-36); Instrumental Mastery Oriented Coping Factor (CODE); Demand/Control Model)*	Group based, supervised, aerobic dance exercise one hour three times a week including relaxation. Education on stress management and 15 hours of Health and lifestyle information sessions.
Vainre et al., 2024 (372)	Multiple workplaces - Desk-based workplaces, UK	Randomised Comparison Trial - Feasibility	4 weeks	Experimental (light exercise): n = 119, 99 females, 20 males, mean age 45±10.2 years.	Stress, anxiety, depression, mindfulness, ability to work affected by mental health *(Perceived Stress Scale (PSS); The Patient Health Questionnaire (PHQ-9);*	Pre-recorded and fully automated online light physical exercise programme aimed to enhance mobility (such as joint rotation and stretching). 10-12 minutes daily.

				Comparison (mindfulness): n = 122, 105 females, 17 males, mean age 44.2±11.1 years.	*The Generalized Anxiety Disorder (GAD-7); The Experiences scale measured decentring; The Mindful Attention Awareness Scale (MAAS))*	
Van Rhenen et al., 2005 (373)	Telecommunication company, The Netherlands	RCT	8 weeks	Experimental: n = 39 Control: n = 36 Total sample demographics (only pre-intervention data provided): n = 130, 13 females, 117 males, mean age 44.2±7.4 years.	Distress, depression, anxiety, somatisation and burnout *(The Four-Dimensional Symptom Questionnaire (4DSQ); Utrecht Burnout Scale (UBOS); Maslach Burnout Inventory-General Survey (MBI-GS))*	Four training sessions, each lasting for 1 h every 2nd week, during working hours. Every session consisted of four main parts: education on health topic, warming up and physical exercise, relaxation exercise and an assignment.

Vert et al., 2020 (374)	Biomedical Research Park, Spain	RCT – Crossover design	3 weeks x 2	Experimental: n = 59, 41 females, 18 males, mean age 29 years (range 19-49 years), BMI 22.6 kg/m^2 (range 17.1 – 35.1 kg/m^2). Control: Crossover design.	Wellbeing and mood *(WHO-5; Profile of Mood States (POMS); Short Form Health Survey (SF-36); Other items developed from questionnaire developed by the UK's Office of National Statistics)*	Strict controlled timing of set walking routes to assess blue versus urban route. 20 minutes a day Monday to Thursday.
Wolever et al., 2012 (230)	Insurance, USA	RCT	12 weeks	Experimental: n = 90, 66 females, 24 males, mean age 41.6±10.1 years. Control: n = 53, 43 females, 10 males, mean age 42.7±9.7 years.	Stress and depression *(Perceived Stress Scale (PSS); The Centre for Epidemiological Studies Depression Scale (CES-D))*	Weekly 1 hr therapeutic Vini yoga class with trained teachers delivering sessions at worksite. Instructional handouts provided to educate participants on a home practice and shorter "yoga breaks". Half of the participants received a DVD to support home practice.

Yancey et al., 2004 (375)	Multiple worksites Local government, USA	RCT - post-test only	10 weeks	Experimental: n = 189, 139 females, 50 males, median age 41 years (range 17-79 years. Control: n = 260.	Mood/affective state *(Instrument developed at the Stanford University Center for Research in Disease Prevention and Health Promotion)*	Exercise breaks of 10 minutes during 1 hour+ meetings (simple aerobic dance/calisthenics movements). Delivered in-person by nursing and health education staff, and others trained by these staff.

Appendix 6-A: Ethics approval for feasibility trial of two co-designed workplace physical activity interventions for mental health

University of Glasgow

Dr Gemma Ryde

MVLS College Ethics Committee

Developing a Workplace Wide Physical Activity Intervention for Mental Health 200230360

The College Ethics Committee has reviewed your application and has agreed that there is no objection on ethical grounds to the proposed study.

We are happy therefore to approve the project, subject to the following conditions

- Project end date as stipulated in original application.
- The data should be held securely for a period of ten years after the completion of the research project, or for longer if specified by the research funder or sponsor, in accordance with the University's Code of Good Practice in Research: (http://www.gla.ac.uk/media/media_227599_en.pdf)
- The research should be carried out only on the sites, and/or groups or datasets as defined in the application.
- Any proposed changes in the protocol should be submitted for reassessment, except when it is necessary to change the protocol to eliminate hazard to the subjects or where the change involves only the administrative aspects of the project. The Ethics Committee should be informed of any such changes.
- For projects requiring the use of an online questionnaire, the University has an Online Surveys account for research. To request access, see the University's application procedure at https://www.gla.ac.uk/research/strategy/ourpolicies/useofonlinesurveystoolforresearch/.
- You should submit a short end of study report within 3 months of completion.

Yours sincerely

[redacted]

Dr Terry Quinn

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FWSO, FESO, MD, FRCP, BSc (hons), MBChB (hons)

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Appendix 6-B: Consent form for measurements and interviews during workplace implemented intervention trials

VERSION 2
01/03/2024

Project Number:
200230360

Participant Identification Number for this study:

Title of Project: Developing a Workplace Wide Physical Activity Intervention for Mental Health

Name of Researcher(s): Craig Tumblety, Dr. Gemma Ryde

CONSENT FORM

	Please initial box
I confirm that I have read and understood the Participant Information Sheet dated 01/03/2024.	☐
I confirm that I have read and understood the Privacy Notice dated 01/03/2024.	☐
I have had the opportunity to think about the information and ask questions and understand the answers I have been given.	☐
I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my legal rights being affected.	☐
I confirm that I agree to the way my data will be collected and processed, and that data will be stored for up to 10 years in University archiving facilities in accordance with relevant Data Protection policies and regulations.	☐
I understand that all data and information I provide will be kept confidential and will be seen only by study researchers and regulators whose job it is to check the work of researchers.	☐
I agree that my name, contact details and data described in the information sheet will be kept for the purposes of this research project.	☐
I understand that I own my data and that as my data will be held under GDPR rules, I have the right to free access to it at any time, including the right to ask for it to be restricted, corrected or erased.	☐

I agree to any interview I attend being audio recorded. ☐

I understand that the information recorded during interviews will be stored for up to 10 years in University archiving facilities in accordance with Data Protection policies and regulations. ☐

I understand that my information and things that I say in an interview may be quoted in reports and articles that are published about the study, but my name or anything else that could tell people who I am will not be revealed. ☐

I understand the limits of confidentiality during the interview component of this study, and that any disclosure of illegality, professional misconduct or at-risk status must be reported to the ACS HR department or an appropriate member of the company's management. ☐

I agree to be contacted by the research team within the next 4 months regarding repeats of this data collection. ☐

I agree for the data I provide to be anonymously archived in the UK data archive or other approved archiving facilities, and that other researchers can have access to this data only if they have scientific and ethical approval, and agree to preserve the confidentiality of this information as set out in this form. ☐

I agree to take part in the study. ☐

Name of participant	Date	Signature
Name of Person taking consent (if different from researcher)	Date	Signature
Researcher	Date	Signature

(1 copy for participant; 1 copy for researcher)

Appendix 6-C: Semi-structured interview discussion guide

Topics		Prompts
Introductions	A refresher on the study and it's purposes.	Participant information document available in appropriate language.
	Reminder of participant's right to withdraw at any time.	Privacy notice available, with a reminder of what will happen to their responses during interview.
Review of workplace interventions	Which changes affected the participant?	Was your job changed at all during the trial period? In what way?
	What was their recollection of the events?	What do you remember about the changes and how were these tasks/events different to a normal working week?
Implementation	What role did the participant play in the implementation of any changes?	What was your role(s) in the changes? What did this involve?
	Were there any difficulties or challenges expected or unexpected in implementation?	What challenges or barriers did you experience during this time? Were you expecting to face these challenges?
	Reponses to changes.	How did your colleagues react to these changes?
Outcomes	Was there any change to productivity?	Did you notice any difference any work rate or productivity between weeks? Did you notice any change in your energy at work?
	Was there any change to wellbeing?	Did you notice any difference in your moods and emotions between weeks? Did you leave work with more or less energy than the control week?
	Was there any change to job satisfaction?	Did you notice any difference in your attitude to work between weeks? Did you leave feeling any more or less invigorated?
	Was there any change to physical activity during or outside of work time?	Were there any differences that you noticed in your physical activity during the trial, compared to a normal week?
Sustainability	Could this change be established over 6 months?	Do you believe this intervention could become a permanent fixture at ACS? Yes, as is or yes, with adaptation, or no, it can't work.

Appendix 7-A: PhD research activities timeline