University of Bedfordshire

Title: **Development and evaluation of a tailored workplace intervention to reduce and break up sitting time in office workers**

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Development and evaluation of a tailored workplace intervention to reduce and break up sitting time in office workers

by

Samson Oluseye Ojo

A thesis submitted to the University of Bedfordshire in partial fulfilment of the requirements for the degree of Doctor of Philosophy

Institute for Health Research

January 2019

ACADEMIC THESIS: DECLARATION OF AUTHORSHIP

I, **Samson Oluseye Ojo** declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

Development and evaluation of a tailored workplace intervention to reduce and break up sitting time in office workers

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ABSTRACT

There is a growing body of evidence linking high volumes of sitting with adverse health risks, including cardiovascular disease and mental health problems. The workplace is a major contributor to excessive sitting, particularly for desk-based workers who spend more than two-thirds of working time sitting. Although the workplace contributes to prolonged sitting, it has also been identified as an ideal setting to combat sedentary behaviour (SB). A wide range of studies have sought to break up and reduce sitting time in the workplace using strategies like prompts to stand, environmental restructuring such as walking meetings and the use of active workstations. Although some of these strategies have been successful in decreasing workplace sitting time, results are inconclusive, with problems of compliance in some interventions. One reason for low compliance could be that few studies take views of employees into consideration when designing interventions. In addition, management might be reluctant to implement interventions if productivity is negatively affected. Finally, there is evidence that interventions developed to change behaviour should be informed by theoretical, evidence-based frameworks. Accordingly, the aim of this thesis was to design an appropriate intervention to break up and reduce workplace sitting time in desk-based office workers, then to test the efficacy of the intervention on employees' productivity, cardiometabolic risks, and wellbeing.

A multi-phase mixed-method study was employed covering the first two stages of the Medical Research Council framework for complex interventions. The first three phases covered the development of the subsequent intervention. Firstly, a systematic review found no acute effect of active workstations on productivity, although there were concerns regarding study designs and the tools used to assess productivity. Secondly, a cross-sectional study of self-

reported sitting time found no differences between age, gender, and ethnic groups, suggesting that interventions to reduce workplace sitting should be targeted at all desk-based employees irrespective of age, gender, or ethnicity, although this need to be confirmed in a fully powered study. The final stage of the intervention development was a qualitative study of desk-based employees who had high volumes of sitting time. This study identified barriers and facilitators to breaking up sitting and reducing sitting time using the COM-B (Capability and Opportunity and Motivation) model, with Psychological Capability, Reflective Motivation, Automatic Motivation, Social Opportunity, and Physical Opportunity found to be predictors of workplace sitting behaviour. The Behaviour Change Wheel guide was followed, leading to the identification of 39 behaviour change techniques as active ingredients for intervention development.

The final phase of the PhD was a pilot cluster-randomised controlled trial to test the efficacy of a multicomponent intervention including education, computer-prompt software and height-adjustable workstations, as well as managerial support. The intervention decreased sitting time and increased standing time in the workplace, with most participants meeting the two-hour minimum recommendation for standing up. The intervention also improved productivity but had no effect on cardiometabolic biomarkers or mental wellbeing outcomes.

This study could serve as evidence for workplace managers on the benefits of such interventions and provides evidence to strengthen the need to tailor workplace interventions to employees' needs to improve adherence.

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This great feat would not have been possible without the unending support of my supervisory team. I am particularly thankful to my Director of Studies, Professor David Hewson, for your support, guidance, mentorship and friendship throughout the course of this thesis. Your positivity even in the face of uncertainty is admirable. To my second supervisor, Dr. Daniel Bailey: your advice, constructive criticism, perfectionism and guidance during the course of this PhD have been invaluable. I would like to extend my unalloyed appreciation to Dr. Angel Chater who stepped in as my advisor when the complexity of my research dawned on me. Your expertise in behaviour change, unwavering enthusiasm and guidance are appreciated. Special thanks to Marsha Brierley for her assistance during the BCT coding phase.

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I would like to thank Ergotron Inc. for donating the height-adjustable workstations for the pilot intervention reported in this thesis

To my amazing family and friends, thank you all so much, your immense and unwavering support and sacrifices over the years have been a source of strength for me. I am blessed to have you all in my life!

Lastly, special thanks to all the individuals who took part in the studies in this thesis. You were all amazing and I hope you benefit from the outcomes of this thesis.

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- Ojo, S.O., Bailey, D.P., Hewson, D.J., and Chater, A.C. (2019). 'Perceived barriers and facilitators to breaking up sitting time among desk-based office workers: A Qualitative Investigation Using the TDF and COM-B', *International Journal of Environmental Research and Public Health* 16 (16), 2903.
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TABLE OF CONTENTS

ACADEMIC THESIS: DECLARATION OF AUTHORSHIP I

ABSTRACT II

ACKNOWLEDGEMENTS IV

PUBLICATIONS TO DATE VI

TABLE OF CONTENTS VII

LIST OF TABLES XIII

LIST OF FIGURES XV

GLOSSARY XVI

CHAPTER 1 INTRODUCTION 1

1.1 RESEARCH AIM AND OBJECTIVES 7

1.2 THESIS ORGANISATION 10

CHAPTER 2 LITERATURE REVIEW 13

2.1 CHAPTER OVERVIEW 13

2.2 SECTION ONE: PHYSICAL ACTIVITY AND SEDENTARY BEHAVIOUR 14

2.2.1 Definition of terms 14

2.2.1 Physical activity guidelines 17

2.2.2 Sedentary behaviour guidelines 18

2.2.3 Strategies for measuring physical activity and sedentary behaviour 20

2.2.4 Sedentary behaviour and health 31

2.3 SECTION TWO: WORKPLACE SEDENTARY BEHAVIOUR 41

2.3.1 Sitting in the workplace 41

2.3.2 Workplace Sitting and Health 42

2.3.3 The effects of breaking up prolonged sitting time 43

2.3.4 Factors that may influence prolonged workplace sitting time 45

2.3.5 The effect of age, gender and ethnicity on sitting time 52

2.3.6 Strategies to break up sitting time in the workplace 55

2.3.7 Measuring productivity and performance 67

2.4 SECTION THREE: DEVELOPING COMPLEX INTERVENTIONS 70

2.4.1 The Medical Research Council guidance on complex interventions design 70

2.4.2 Theoretical foundations for behaviour change 71

CHAPTER 3 METHODOLOGICAL APPROACH AND DESIGN 87

3.1 CHAPTER OVERVIEW 87

3.2 PHILOSOPHICAL FRAMEWORK AND RESEARCH APPROACH 87

3.3 RESEARCH DESIGN 89

CHAPTER 4 THE IMPACT OF ACTIVE WORKSTATIONS ON WORKPLACE PRODUCTIVITY AND PERFORMANCE: A SYSTEMATIC REVIEW 92

4.1 INTRODUCTION 92

4.2 MATERIALS AND METHODS 95

4.2.1 Data sources and study selection 95

4.2.2 Quality appraisal 97

4.2.3 Extraction and management of data 97

4.3 RESULTS 98

4.3.1 Article selection 98

4.3.2 Study Characteristics 100

4.3.3 Cognitive performance: a measure of productivity 103

4.3.4 Work-related performance 107

4.3.5 Effects of active workstations on productivity 108

4.4 DISCUSSION 110

4.5 CONCLUSION 115

CHAPTER 5 THE EFFECT OF AGE, GENDER, AND ETHNICITY ON SELF-REPORTED SITTING TIME AND PHYSICAL ACTIVITY IN DESK-BASED WORKERS 116

5.1 INTRODUCTION 116

5.2 METHODS 119

5.2.1 Participants 119

5.2.2 Study design and procedures 119

5.2.3 Statistical Analysis 121

5.3 RESULTS 122

5.3.1 Participant Characteristics 122

5.3.2 Sitting time 123

5.3.3 Physical activity 124

5.4 DISCUSSION 125

5.5 CONCLUSION 133

CHAPTER 6 IDENTIFYING INTERVENTIONS TO REDUCE AND BREAK UP WORKPLACE SITTING TIME USING THE BEHAVIOUR CHANGE WHEEL 134

6.1 INTRODUCTION 134

6.2 THEORETICAL FRAMEWORK UNDERPINNING THE INTERVENTION DESIGN 135

6.3 METHOD 138

6.3.1 Design 141

6.4 RESULTS 148

6.4.1 Demographics of interview participants 148

6.4.2 Core Themes—Determinants of Breaking Up and Reducing Sitting Time in the Workplace (COM-B Behavioural Diagnosis) 150

6.4.3 Identification of intervention functions and policy categories 164

6.4.4 Identification of behaviour change techniques 178

6.4.5 Mode of delivery 179

6.5 DISCUSSION 179

6.5.1 Strengths of the study 184

6.5.2 Limitations of the study 185

6.6 CONCLUSION 186

CHAPTER 7 CONTEXTUALISING A TAILORED WORKPLACE INTERVENTION TO BREAK UP AND REDUCE SITTING TIME 188

7.1 INTRODUCTION 188

7.2 SCREENING WITH THE APEASE CRITERIA 189

7.3 IDENTIFICATION OF CONTEXT-BASED INTERVENTION FUNCTIONS 191

7.4 IDENTIFICATION OF CONTEXT-BASED POLICY CATEGORIES 193

7.5 IDENTIFICATION OF CONTEXT-BASED BEHAVIOUR CHANGE TECHNIQUES 193

7.6 DISCUSSION 207

CHAPTER 8 WORKPLACE INTERVENTION FOR REDUCING SITTING TIME IN SEDENTARY WORKERS: A PILOT STUDY 209

8.1 INTRODUCTION 209

8.2 METHOD 211

8.2.1 Study Design 211

8.2.2 Participant selection 212

8.2.3 Eligibility 212

8.2.4 Sample size 212

8.2.5 Randomisation 213

8.2.6 Outcome measures 214

8.2.7 Statistical data analysis 222

8.3 RESULTS 223

8.4 DISCUSSION 237

8.5 CONCLUSION 251

CHAPTER 9 SUMMARY AND CONTRIBUTION OF THE THESIS 252

9.1 CHAPTER OVERVIEW 252

9.1 THESIS SUMMARY 252

9.2 SIGNIFICANCE OF THE THESIS FINDINGS 257

9.3 LIMITATIONS OF THE PHD 259

9.4 FUTURE DIRECTIONS FOR WORKPLACE SEDENTARY BEHAVIOUR RESEARCH 260

REFERENCES 264

LIST OF APPENDICES 333

LIST OF TABLES

Table 1: Inclusion and exclusion criteria 96

Table 2: Characteristics of the selected articles 101

Table 3: Effect of active workstation use on attention 105

Table 4: Effect of active workstation use on memory 106

Table 5: Effect of active workstation use on reasoning and reaction time 106

Table 6: Effect of active workstation use on work-related performance tasks 107

Table 7: Effect of active workstation use on work-related productivity tasks 109

Table 8: The effect of gender and ethnicity on sitting time 124

Table 9: Physical activity levels for the total sample 124

Table 10: Physical activity level classification for the study sample 125

Table 11: Correlation matrix of sitting time and physical activity levels 125

Table 12: Capability, Opportunity, and Motivation to Behaviour system (COM-B)/Theoretical Domains Framework (TDF)-informed interview schedule 144

Table 13: Participant demographics 149

Table 14: Combined link between COM-B model, TDF domains, intervention functions, policy categories and BCT 166

Table 15: APEASE criteria as a screening tool 190

Table 16: Selection of intervention functions to cause a change in office workers' sitting behaviour 192

Table 17: Screening and identification of policy categories to support the delivery of intervention 192

Table 18: Screening of the possible behaviour change techniques with APEASE criteria 197

Table 19: Intervention content specified by behaviour change techniques and mapped onto components of TDF and COM-B model 201

Table 20: EMA productivity questions 218

Table 21: Baseline characteristics of study participants 226

Table 22: Changes in workplace sitting time 227

Table 23: Changes in workplace siting and activity outcomes at follow-up 228

Table 24: Changes in daily sitting and activity outcomes at follow-up 229

Table 25: Changes in daily physical activity outcomes at follow up by randomisation group 230

Table 26: Changes in absenteeism and presenteeism 231

Table 27: Changes in EMA outcomes when sitting 232

Table 28: Changes in EMA outcomes when standing 233

Table 29: Changes in EMA outcomes between sitting and standing for the intervention follow-up 234

Table 30: Changes in cardiometabolic risk outcomes 235

Table 31: Changes in stress and wellbeing outcomes 236

LIST OF FIGURES

Figure 1: Thesis structure versus the Medical Research Council framework 9

Figure 2: Sedentary behaviour and physical activity as distinct constructs 16

Figure 3: Perceived influences on breaking up workplace sitting 47

Figure 4: The MRC framework for developing and evaluating complex interventions 71

Figure 5: The COM-B system: A framework for understanding behaviour 81

Figure 6: The Behaviour Change Wheel 81

Figure 7: Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) flow chart of study selection 99

Figure 8: Stages involved in the development of an intervention using the BCW 138

Figure 9: COM-B adapted determinants of workplace sedentary behaviour 151

Figure 10: CONSORT diagram of progression of participants through the study 225

GLOSSARY

ACSM	American College of Sports Medicine
APEASE	Affordability, Practicability, Effectiveness and Cost-effectiveness, Acceptability, Side effects/safety and Equity
BAME	Black, Asian, and Minority Ethnic
BCa	Bias-corrected and accelerated
BCT	Behaviour Change Technique
BCTTv1	Behaviour Change Technique Taxonomy version 1
BCW	Behaviour Change Wheel
BMI	Body Mass Index
CI	Confidence interval
COM-B	Capability, Opportunity, Motivation -Behaviour
CVD	Cardiovascular disease
EMA	Ecological Momentary assessment
HBM	Health Belief Model
HDL	High Density Lipoprotein
HEPA	Health-enhancing physical activity
ICC	Intraclass Correlation Coefficient
IMU	Inertial Measurement Unit

IPAQ	International Physical Activity Questionnaire
LPL	Lipoprotein Lipase
MEETING	Recommended Guidelines
MET	Metabolic equivalent
MINIMAL	Minimal Guidelines
MMR	Mixed Methods Research
MRC	Medical Research Council
MVPA	Moderate-to-Vigorous Physical Activity
NICE	National Institute for Health and Care Excellence
ONS	Office for National Statistics
OSPAQ	Occupational Sitting and Physical Activity Questionnaire
PA	Physical activity
PANAS	Positive Affect, Negative Affect Schedule
PI	Physical inactivity
PICOT	Population, Intervention, Comparison, Outcomes, and Trial design
PoC	Point-of-Choice
PSS	Cohen Perceived Stress Scale
RCT	Randomised Controlled Trial
SB	Sedentary behaviour
SCT	Social Cognitive Theory

SMArT	Stand More At Work
SMD	Standardized Mean Difference
T2D	Type 2 Diabetes
T2DM	Type 2 Diabetes Mellitus
TDF	Theoretical Domain Framework
TPB	The Theory of Planned Behaviour
TTM	Transtheoretical Model
WEMWBS	Warwick-Edinburgh Mental Well-Being Scale
WHO	World Health Organisation
WHWI	Workplace Health and Wellbeing Intervention
WLQ	Work Limitations Questionnaire
WPAI	Work Productivity and Activity Impairment Questionnaire
WSQ	Workforce Sitting Questionnaire

CHAPTER 1 INTRODUCTION

The study of sedentary behaviour (SB) is an important component of physical activity (PA) research in its own right (Hamar *et al.,* 2010). SB has often been confused with physical inactivity (PI), although the two concepts are different (Barnes *et al.,* 2012; Hamar *et al.,* 2010). SB refers to any waking behaviour that results in an energy expenditure of ≤ 1.5 metabolic equivalents (METs), while sitting, reclining or lying down (Tremblay *et al.*, 2017). In contrast, PI can be described as a state in which recommended guidelines for PA are not met (Barnes *et al.,* 2012; British Heart Foundation National Centre, 2013). It is clear, therefore, that SB should be treated as a separate construct to PI (van der Ploeg and Hillsdon, 2017).

SB has been identified as a public health concern that is an independent predictor of a wide range of negative health outcomes (Biswas *et al.,* 2015). Accordingly, SB has been the focus of both research and media attention (Stamatakis *et al.,* 2018). SB has both medium and long term detrimental effects on health (Magnon, Vallet and Auxiette, 2018), regardless of the amount of time spent on moderate to vigorous PA (Katzmarzyk *et al.,* 2009). Some of the negative health consequences of SB include obesity, type 2 diabetes (T2D), cancer, stress, cardiovascular disease, all-cause mortality, and mental health problems, such as depression and anxiety (Dunstan *et al.,* 2010; Gibson *et al.,* 2017; Healy *et al.,* 2011b; Petersen *et al.,* 2014; Teychenne, Costigan and Parker, 2015; Thorp *et al.,* 2012; Warburton, Nicol and Bredin, 2006; Wilmot *et al.,* 2012). Emerging evidence suggests that the risks of SB can be attenuated by high levels of moderate-to-vigorous physical activity (MVPA) (Ekelund *et al.,* 2016; Pulsford *et al.,* 2017). However, the amount of MVPA (60-75 minutes every day) required to eliminate these risks from a public health point of view is often impracticable (van der Ploeg and

Hillsdon, 2017). The majority of the population do not engage in such high volumes of MVPA (Colley *et al.,* 2011; Troiano and Berrigan, 2008). For those who are unable to achieve these high levels of MVPA, the workplace could be a potential intervention environment to reduce excess sitting (Mache *et al.,* 2015; Quintiliani, Sattelmair and Sorensen, 2008; Strickland *et al.,* 2015). It is reported that 73% of the UK population aged 16-64 is currently in employment (Hall *et al.,* 2015; ONS, 2015).

Long periods of SB occur in multiple domains, including transportation, leisure time, and in the workplace (Bennie *et al.,* 2015; Davis *et al.,* 2011; Mensah *et al.,* 2016; Owen *et al.,* 2010a; Owen *et al.,* 2011). One commonly-cited reason for the increase in SB in recent decades has been technological advancement (Church *et al.,* 2011; Katzmarzyk, 2010). Although the time spent watching television has plateaued in the last two decades (Marshall, Gorely and Biddle, 2006), an increased use of other devices, such as desktop computers, electronic games and smart mobile devices has contributed to an increase in overall sedentary time (Katzmarzyk, 2010; Owen *et al.,* 2010b; Straker, Levine and Campbell, 2009). The effect of technological advancement is also evident in the workplace, which is the biggest contributor to total daily sitting time (Bennie *et al.,* 2015). In one study, employees were shown to spend more than 80% of their working time sitting (Hall *et al.,* 2015). Other evidence shows that about two-thirds of employees' time at work is spent in a sitting posture and their sitting bouts typically last at least 30 minutes (Evans *et al.,* 2012; Parry and Straker, 2013; Ryan *et al.,* 2011; Thorp *et al.,* 2012), which is referred to as prolonged sitting bout (Henson *et al.,* 2016a). These findings are because many people are in job roles that require little or no physical movement, and thereby directly or indirectly promote prolonged sitting time (Church *et al.,* 2011; Katzmarzyk, 2010). Therefore, intervention studies should target the workplace, as it is a focal

site for SB and a place to target multiple levels of influence on behaviour (Mache *et al.,* 2015; Quintiliani, Sattelmair and Sorensen, 2008; Strickland *et al.,* 2015).

A wide range of studies have sought to break up and reduce sitting time and increase PA in the workplace, with several different strategies used. These have included the use of prompts (Owen, 2012; Swartz, Squires and Strath, 2011), face-to-face communication, rather than intranet or email, and environmental restructuring in the form of walking meetings and restricting access to printers (Hadgraft *et al.,* 2016a; Smith *et al.,* 2016). Other interventions have included the use of active workstations, such as adjustable desks, cycling or treadmill workstations and portal pedal machines (Carr *et al.,* 2013; Carr, Walaska and Marcus, 2012; Duvivier *et al.,* 2013; Elmer and Martin, 2014; Healy *et al.,* 2013; Larson *et al.,* 2015a; Neuhaus *et al.,* 2014b; Straker *et al.,* 2013; Thompson *et al.,* 2008). Some complex interventions have incorporated multiple components simultaneously (Healy *et al.,* 2013). The effectiveness of these interventions on sitting time reduction has been well documented (Ben-Ner *et al.,* 2014; Donath *et al.,* 2015; Koepp *et al.,* 2013; Manini *et al.,* 2015; Maylor *et al.,* 2018). For instance, in a one-year prospective trial, treadmill desks were found to significantly decrease sedentary time by close to 90 minutes after six-months, with the total reduction at the end of the 12-month intervention of just over 40 minutes (Koepp *et al.,* 2013). Similarly, through the use of a height-adjustable workstation, a one-week pilot intervention reported a 143-minute reduction in sitting time in comparison with control subjects (Alkhajah *et al.,* 2012). Moreover, the use of prompts has been reported to reduce sitting time by more than 30 minutes in five-day objective randomised controlled trials (Evans *et al.,* 2012). In addition, after four weeks, a non-randomised multicomponent intervention was reported to decrease sitting time by an average of 122 min (Healy *et al.,* 2013). Although these interventions appear

promising, management of organisations might be reluctant to implement them if productivity is negatively affected (Ben-Ner *et al.,* 2014). Thus, it was necessary to acquire further evidence, such as from a systematic review, to determine the effect of these active workstations on worker productivity.

While some of the strategies outlined above appear to be effective in decreasing workplace sitting time (Alkhajah *et al.,* 2012; Evans *et al.,* 2012; Koepp *et al.,* 2013), evidence has been inconsistent and tends to be from lower quality research, with no indication of its use long-term (Shrestha *et al.,* 2016). Therefore, additional evidence from better quality research such as randomised controlled trials is warranted. In addition to issues of effectiveness in long-term interventions (defined as intervention carried out for more one year (Shrestha *et al.,* 2016)), non-adherence is also a barrier to a successful uptake and implementation of workplace intervention to breaking up sitting time, as access to an intervention does not translate to compliance. According to one study, among different companies in Sweden, only 60% of the employees who had recently received height-adjustable workstations reported using the desks only once a month or less (Wilks, Mortimer and Nylen, 2006), suggesting that having access to height-adjustable workstations does not guarantee its use. One reason for this could be because few studies have taken the views of employees into consideration during the development of interventions to break up sitting time in the workplace (De Cocker *et al.,* 2015b; Gilson, Straker and Parry, 2012). It is paramount for employees to be consulted prior to the design of any intervention to reduce workplace sitting time to ensure their specific needs are addressed, which in turn may lead to improved adherence (Straker *et al.,* 2004). Finally, it is worth noting that many studies have tailored workplace PA interventions according to age, gender, and ethnicity (Bhatnagar *et al.*, 2016; Celis-Morales *et al.*, 2012;

Wallmann-Sperlich *et al.*, 2014), after recommendations on the need to determine how employee characteristics such as age, gender and ethnicity influence the effectiveness of workplace PA (National Institute for Health and Care Excellence, 2008). However, no evidence of the effectiveness of workplace SB interventions targeted at specific populations based on age, gender and ethnicity is available. It has been recommended that, in order for occupational sitting time to be reduced successfully, strategies that cater for the preferences of individual workers should be adopted (Gilson, Straker and Parry, 2012). Although such strategies might conceivably vary with age, gender and ethnicity, before ascertaining that a preliminary study is needed to determine whether sitting time in desk-based employees differs according to age, gender, and ethnicity.

Growing evidence has revealed that interventions being developed to change behaviour should be informed by theoretical, evidence-based frameworks. The Medical Research Council (MRC) (2000; 2006) recommends that complex interventions must pass through four stages, namely development, feasibility / piloting, evaluation, and implementation. The MRC Framework is shown in Figure 1, along with the study plan for this PhD. The focus of this thesis is limited to development and piloting stages, with the development stage further broken down into theory and modelling phases (Craig *et al.,* 2008; Medical Research Council, 2000; Michie *et al.,* 2008). In addition to the MRC Framework, this thesis uses appropriate behaviour change theory to develop individually-tailored interventions that consider specific preferences, work practices and settings (Cole, Tully and Cupples, 2015). Such an approach is necessary as it ensures that participants are part of the processes involved in making decisions to change behaviour (McGuckin, Sealey and Barnett, 2017). Researchers have a wide range of theoretical models of behaviour to choose from when developing an intervention,

including the Theory of Planned Behaviour (Ajzen, 1991), the Health Belief Model (Rosenstock, 1966), and the Socio-Cognitive Theory (1986). However, these theories are limited as they are only able to understand or predict behaviour (Kok *et al.,* 2004), but not to understand behaviour change (Brug, Oenema and Ferreira, 2005). In contrast, the Behaviour Change Wheel (BCW), which is a hybrid of 19 different frameworks, and has been successfully used to understand behaviour change in different contexts, such as sexual counselling (Mc Sharry, Murphy and Byrne, 2016), medication management (Jackson *et al.,* 2014; Sinnott *et al.,* 2015), auditory rehabilitation (Barker, de Lusignan and Cooke, 2018), and PA (Webb, Foster and Poulter, 2016). Research applying the BCW to develop interventions to reduce workplace sitting is still at the infancy stage, with only one SMArT study published in which an intervention targeting hospital office workers was reported (Munir *et al.,* 2018). Munir *et al.* (2018) identified ten behaviour change techniques that could be used to target individual, environmental and organisation level barriers to reducing sitting. The SMArT study decreased workplace sitting time by 50.6 min at three months and by 64 min and 83 min at six and 12 months respectively, and with evidence of sustainable long-term effects on job performance (Edwardson *et al.*, 2018b). Future interventions should thus consider using a similar approach to maximise effectiveness.

1.1 Research aim and objectives

The principle aim of this thesis was to design an appropriate intervention to break up and reduce workplace sitting time in desk-based office workers. The secondary aims were to test the efficacy of the developed intervention on employees' productivity, cardiometabolic risks, and wellbeing.

To achieve these aims, the outlined main objectives were met:

- To systematically examine the acute and chronic effect of active workstations on workplace productivity and performance.

Study 1: The Impact of Active Workstations on Workplace Productivity and Performance: A Systematic Review.

- To identify a specific population with high levels of sitting that would be selected for interviews to gain an insight into factors influencing workplace sitting time.

- To identify magnitudes of differences in sitting time between ages, gender and ethnic groups for a future study that would be powered to detect changes.

Study 2: The effect of age, gender, and ethnicity on self-reported sitting time and physical activity in desk-based workers.

- To develop through qualitative interviews a tailored intervention package using the BCW that could be used in future breaking up and reducing workplace sitting interventions with desk-based employees.

Study 3: Identifying interventions to break up and reduce workplace sitting time using the Behaviour Change Wheel: A qualitative study.

- To develop a context-based workplace intervention for breaking up or reducing siting time in office workers

Study 4: Contextualising a tailored workplace intervention to break up and reduce sitting time

- To conduct a pilot study to test the efficacy of the selected intervention package on overall workplace sitting time, productivity, cardiometabolic risk, and wellbeing.

Study 5: Workplace intervention for reducing sitting time in sedentary workers: protocol for a pilot study.

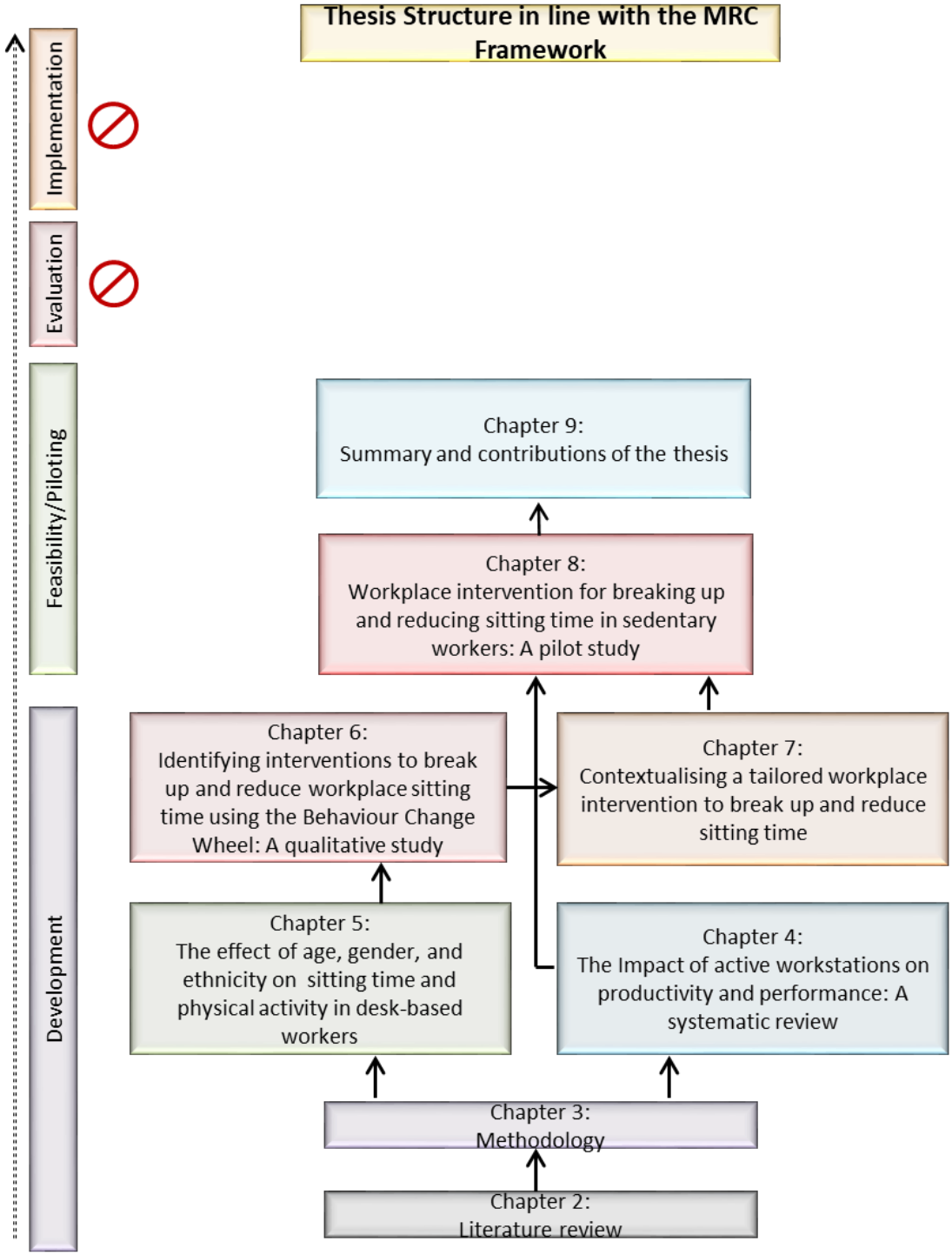

Figure 1: Thesis structure versus the Medical Research Council framework

Chapters 2- 7 addressed the development stage of the Medical Research Council framework, while Chapters 8-9 addressed the piloting stage.

1.2 Thesis Organisation

The research presented in this thesis follows a mixed methods approach with some of the findings having been disseminated in research publications. Full details of the published works arising from this thesis are listed in the section Publications to Date of this thesis (page *vii*). The thesis is organised in nine chapters, including the present one, with the details of the remaining chapters described below.

Chapter Two is a review of literature on the topics that led to the identification of the gap in the available evidence with respect to reducing sitting in the workplace. These studies were then used to inform the rationale for the thesis, leading to its aims and objectives. This chapter reviews the links between SB and health outcomes, the guidelines for PA and SB, as well as strategies for measuring PA and SB. It also reviews the need to target the workplace, the determinants of prolonged workplace sitting, and strategies that can be used to interrupt sitting. Lastly, it provides information regarding the development of complex interventions based on both the Medical Research Council guidelines on complex interventions and the Behaviour Change Wheel.

Chapter Three provides details of the research approach, design, and the methods that were used to develop a tailored intervention to decrease sitting in the workplace. It also details the philosophical stance taken by the researcher.

Chapter Four is a systematic review examining the acute and chronic effect of active workstations on workplace productivity and performance. This was an important component of the PhD because several studies have recommended the use of active workstations in the workplace to reduce excessive sitting. Due to the lack of information on the effect of active

workstations on productivity, employers have shown reluctance towards such interventions, possibly due to a belief that it would decrease employees' productivity and performance. This chapter also evaluates measures of productivity in the workplace, which informed the productivity assessment measures for the pilot study presented in Chapter Eight of this PhD.

Chapter Five presents details of an investigation into workplace sitting in which magnitudes of differences in sitting time of office workers was compared between ages, genders, and ethnicity for a future study that would be powered to detect changes. This study is important as it helps to purposively identify and target a specific population for the subsequent intervention study of this PhD. The population identified in this study were subsequently recruited for the studies presented in Chapters Six to Nine.

Chapter Six is a qualitative study that followed a systematic approach to identify the components of a workplace sitting reduction intervention. This involved closely following the stages of the Behaviour Change Wheel, then using the Behaviour Change Technique Taxonomy (v1) to identify generic behaviour change techniques.

Chapter Seven contextualises the intervention and provides details of the context-based decisions in relation to the selected intervention components, policy categories and behaviour change techniques.

Chapter Eight is a pilot study, which describes the procedures used for experimental testing of the intervention. It also contains the results of the pilot study, as well as an accompanying discussion. Details are provided of the outcomes obtained, and lessons learned from the pilot intervention that could be used in a wider implantation of the intervention.

Chapter Nine is a summary and contribution of thesis chapter and includes a linkage between all the studies presented in the different chapters, as well as a comparison with existing evidence. This chapter also discusses the strengths and weaknesses of the thesis, as well as providing recommendations for the direction of future research.

CHAPTER 2 LITERATURE REVIEW

2.1 Chapter overview

A number of topics that informed the rationale for this thesis are reviewed in this chapter, which is divided into three different sections. The first section focuses on PA and SB, and reviews guidelines and recommendations for PA and SB, and health problems associated with PA and SB, and finally measurement methodologies for PA and SB. Definitions of the main terminologies used in this study are also provided. Section two focuses on workplace SB, and covers topics such as workplace sitting and health, influences on prolonged sitting, and strategies for breaking up sitting. The final section focuses on the development of complex interventions, including the Medical Research Council guidelines and several behaviour change models including the Behaviour Change Wheel.

2.2 Section One: Physical Activity and Sedentary Behaviour

2.2.1 Definition of terms

Physical activity: can be defined as "any movement of the body that is produced by skeletal muscles, and subsequently results in energy expenditure" (Caspersen, Powell and Christenson, 1985). PA can be categorised based on the type, duration, frequency and intensity of activity (Ainsworth *et al.,* 2000; McArdle, Katch and Katch, 2007; Welk, 2002). Usually, PA is categorised based on its intensity, which is determined by energy expenditure that is expressed in metabolic equivalent unit (METs), with one MET referring to the resting energy expenditure that takes place when sitting quietly (Ainsworth *et al.,* 2000; McArdle, Katch and Katch, 2007; Welk, 2002). The energy cost of one MET, when defined in terms of oxygen uptake, is equal to 3.5 $mL \cdot Kg^{-1} \cdot min^{-1}$ (Pate, O' Neill and Lobelo, 2008).

Different domains of PA include household, occupational, sports or other activities (Caspersen, Powell and Christenson, 1985). While *exercise* is "a subcategory of PA that is planned, structured, and repeatedly carried out to improve or maintain its objectives of physical fitness" (Sodergren *et al.*, 2008), *physical fitness* refers to "a set of qualities that people possess, which may be either health- or skill-related, and enable them to carry out PA" (Caspersen, Powell and Christenson, 1985). PA can be categorised by the intensity of activity performed, one of which is *light PA*, which is defined as a set of activities that involves energy expenditure at the level of 1.6-2.9 METs (Pate, O' Neill and Lobelo, 2008). Examples of light PA include sitting and writing, cooking food, slow walking, and washing dishes (Pate, O' Neill and Lobelo, 2008) . The next category of PA is *moderate intensity activity,* which is defined by the World Health Organisation (WHO) as PA characterised by energy expenditure

ranging from 3.0-5.9 METs (World Health Organisation, 2010). The most strenuous level of PA is *vigorous intensity PA,* which is characterised by energy expenditure equal to or greater than 6.0 METs (World Health Organisation, 2010). Physical inactivity (PI), on the other hand, is defined as the act of "doing no or very little PA at work, at home, for transport or during discretionary time and not reaching PA guidelines deemed necessary to benefit public health" (Barnes *et al.,* 2012; British Heart Foundation National Centre, 2013).

Sedentary behaviour: derived from the Latin word *sedere*, which means 'to sit' (Henson *et al.,* 2016b) (p. 214), can be defined as set of activities that do not cause a substantial increase in energy expenditure beyond resting level, such as lying down, sitting, watching television, sleeping, and computer-based entertainment (Barnes *et al.,* 2012; Pate, O' Neill and Lobelo, 2008). Hendon *et al.* (2016b) provided an operational definition of SB as any sitting behaviour that took place outside of structured exercise. This includes activities with energy expenditure at the level of 1.0-1.5 METs (Barnes *et al.,* 2012). In this thesis, a more recent definition, proposed by Tremblay *et al.* (2017) has been adopted, whereby SB is referred to as "any waking behaviour characterised by an energy expenditure ≤1.5 METs, while in a sitting, reclining or lying posture". Historically, there has been some confusion between SB and PA, with SB referred to as equivalent to a lack of PA (Barnes *et al.,* 2012).

From the understanding of each of the given definitions, PI and SB are two separate constructs. For instance, it is possible for a person not to engage in any MVPA, and yet to have low levels of SB due to demands from an occupation that requires lots of standing and walking, such as a waiter or nurse (Henson *et al.,* 2016b). On the other hand, it is equally possible for individuals to meet or exceed the recommended PA guidelines, yet still spend a large proportion of their day engaged in SB (van der Ploeg and Hillsdon, 2017). This is an

indication that SB and MVPA could be inversely proportional to each other (van der Ploeg and Hillsdon, 2017). For instance, Chu *et al.* (2018), described individuals who meet the current PA recommendations, but who are also extremely sedentary for the rest of the day as "active couch potatoes" (p.1). Saunders *et al.* (2014) have illustrated four different ways by which different categories of SB may co-exist with different volumes of PA (Figure 2). Therefore, although this thesis focuses on SB, PA still plays a central role that needs to be addressed throughout the work.

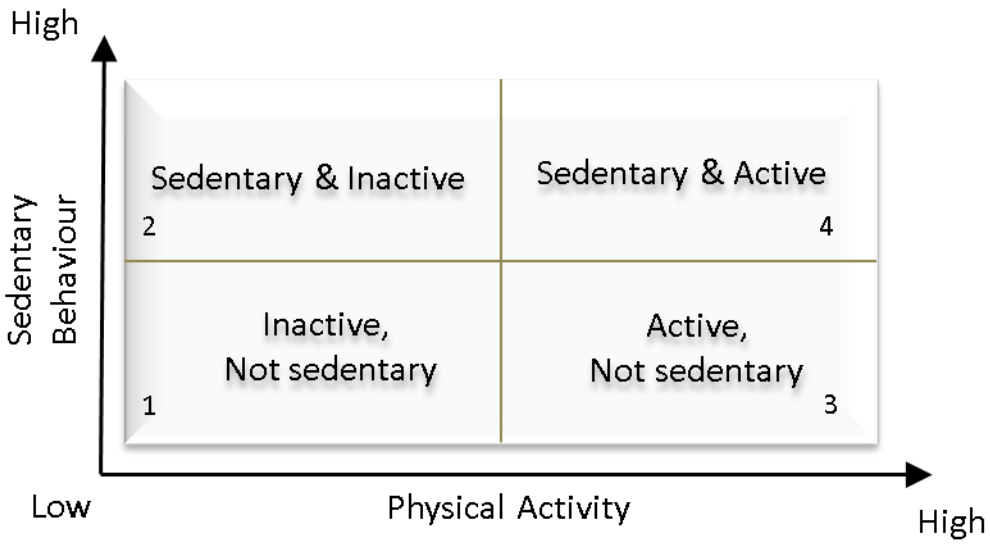

Figure 2: Sedentary behaviour and physical activity as distinct constructs

Individuals are classified into four different groups based on PA and SB: (1) People who spend a small amount of time engaged in SB, but who do not meet the PA guidelines; (2) People who spend a lot of time lying down, in a reclining position or sitting, and also doing no or insufficient PA; (3) People who meet the PA guidelines and have limited SB. Modified from People who spend a small amount of time engaged in SB, but who do not meet the PA guidelines; and (4) People who meet the recommended PA guidelines but also spend a lot of time lying down, in a reclining position or sitting (Saunders, Chaput and Tremblay, 2014).

2.2.1 Physical activity guidelines

In order to be considered as physically inactive, a person needs to have a level of activity that does not meet current recommendations, such as those of the WHO. These guidelines specify that an adult (18-64 y) needs to engage in at least 150 min of moderate-intensity aerobic PA during the week, or not less than 75 min of vigorous-intensity aerobic PA in a week, or a corresponding combination of vigorous and moderate-intensity activity (World Health Organisation, 2010). The WHO is not the only organisation that produces PA guidelines. For instance, the American College of Sports Medicine (ACSM) produces PA guidelines for Americans, with the most recent version being published in 2018. The ACSM recommends that adults need to move more and sit less throughout the day. These guidelines recognise that, it is better to engage in some form of PA than never, and more importantly, that, sitting less coupled with any amount of MVPA confers some health benefits in adults (Piercy *et al.*, 2018). To be specific, adults are advised to engage in between 150 min to 300 min a week of moderate-intensity PA, or between 75 min to 150 min a week of vigorous-intensity aerobic PA (Piercy *et al.*, 2018). However, a combination of both moderate- and vigorous-intensity activity can also be performed to satisfy this recommendation. In addition, adults are recommended to engage in muscle-strengthening activities on two or more days a week (Piercy *et al.*, 2018). The UK guidelines for PA were produced by the Department of Health in 2011, and include recommendations for different age groups, including early years (under 5s), children and young people (5-18y), adults (19-64y) and older adults (over 65s). For adults, these guidelines suggest that similar health benefits can be accomplished by ensuring not less than 150 minutes (2½ hours) of moderate intensity activity in bouts of 10 minutes or more, which can also be achieved by doing 30 minutes of moderate intensity for at least 5 days a

week (UK Department of Health, 2011). An alternative method to achieving the required amount of PA is to engage in 75 minutes of vigorous intensity PA spread across the week ,or by combining both moderate and vigorous intensity PA (UK Department of Health, 2011). In 2019, the UK Chief Medical Officers have published an updated guideline which recommends that in order to maintain good physical and mental health, adults should engage in activities such as heavy gardening, carrying heavy shopping at least twice a week to develop and maintain strength in the major muscle groups. It further states that adults accumulate a minimum of 150 min of moderate intensity activity (such as brisk walking or cycling); or 75 min of vigorous intensity activity (which can be running); or shorter durations of very vigorous intensity activity (for instance, stair climbing or sprinting); or a combination of moderate, vigorous, and very vigorous intensity activity. In addition to this, adults are encouraged to reduce the amount of time spent being sedentary, and when physically possible should break prolonged periods of inactivity with at least light PA (UK Department of Health, 2019). Furthermore, it is recommended that PA can be accumulated in bouts of any duration, which supersedes the previous guidelines that recommended moderate-intensity PA be accumulated in bouts of at least 10 min in duration.

2.2.2 Sedentary behaviour guidelines

The association between SB and cardiometabolic risk factors, irrespective of the participation in PA is clear from a growing body of evidence (Maher *et al.,* 2014). Unlike for PA, the WHO has not produced any guidelines on SB. There have been many calls to incorporate SB reduction recommendations into current health recommendations that promote the health benefits of participation in moderate to vigorous PA (Hamilton *et al.,* 2008; Tremblay *et al.,* 2011a; Tremblay *et al.,* 2011c). For instance, in the United Kingdom, the Department of Health

recommends that all adults should avoid sitting for long periods of time and when possible should break prolonged periods of inactivity with minimum of light PA (UK Department of Health, 2019)**.** Similarly, the Australian guidelines, which were published by the Department of Health for different age groups, recommend that adults keep the amount of time spent in prolonged sitting to minimal levels and break up sitting as often as possible (Australian Government Department of Health and Aging, 2014). This may be confusing and difficult to embrace, as the two guidelines do not specify any time duration. However, the reason behind the unspecified duration for sitting time might be due to variation in the outcomes of different studies and a lack of good quality evidence. For instance, it has been reported that prolonged sitting, which is defined as sitting bouts that last at least 30 minutes (Hadgraft *et al.,* 2016b; Henson *et al.,* 2016a), should not go beyond two hours over an eight-hour workday (Commissaris, Douwes and Looze, 2007). The Canadian Centre for Occupational Health and Safety have recommended taking a five-minute exercise break, such as walking, for every 40-50 min of sitting (Canadian Center for Occupational Health and Safety, 2013). A recent consensus statement by leading researchers has recommended that workers who are in predominantly desk-based occupations should start by accumulating two hours of standing and light activity during working hours each day, until they are able to reach a target of four hours per day (Buckley *et al.,* 2015). The recommendation, which was published by the British Journal of Sports Medicine, is summarised as:

> Office workers should be on their feet for a minimum of two hours daily during working days, and this should be bumped up to four hours a day, breaking up prolonged periods of sitting with the use of height-adjustable workstations, standing based work, and regular walk-abouts (Buckley *et al.,* 2015).

However, there have been questions raised about the credibility of this recommendation, as it was postulated that the intent of this declaration might have been primarily to increase the demand for height-adjustable workstations due to a non-declaration of conflict of interest, despite a co-author having a strong link to the industry (Chau *et al.,* 2018).

2.2.3 Strategies for measuring physical activity and sedentary behaviour

It is important for valid and reliable measures of SB and PA to be developed in order to better understand the associated health consequences of SB. Such measures will also be instrumental in enabling the identification of social, environmental-policy and individual correlates of modifiable behaviour to intervention, and also to monitor and assess sedentariness among different populations (Atkin *et al.,* 2012; Lagerros and Lagiou, 2007; Troiano *et al.,* 2012). Atkin *et al.* (2012) underlined that a measure must possess adequate psychometric properties in order to ensure researchers can be confident about the acceptability, accuracy and consistency of the approach used for their investigations. There are two categories of measurement techniques for SB and PA, which are known as subjective and objective measures (Troiano *et al.,* 2012).

2.2.3.1 Subjective measures of physical activity and sedentary behaviour

SB is usually measured by investigating overall sedentary time in a particular time period, time undertaking specific SBs, such as watching television, or time being sedentary in specific domains, such as transport, leisure and at work (Healy *et al.,* 2011a). Subjective methods, which are also known as self-reported measures, require participants to report the amount of SB over a fixed time period (Chastin, Culhane and Dall, 2014). One advantage of subjective

measures is that they can provide context-specific information about the behaviour as well an individual's perception of the behaviour (Headley *et al.*, 2018). For example, questionnaires on sitting time may ask about the domains in which sitting has occurred such as leisure time, transport and occupational (Marshall *et al.*, 2010). Self-report tools have been favoured for several reasons in a number of studies to assess SB and PA level (Atkin *et al.*, 2012; Bauman *et al.*, 2011; Kurtze *et al.*, 2008; Puig-Ribera *et al.*, 2015). These reasons include the fact that subjective measures are comparatively low-priced, easy to use, can be used to determine the type and context of behaviour taking place in larger observational studies and do not alter the behaviour being investigated (Gupta *et al.,* 2017). In a recent systematic review, PA questionnaires were reported to be the most cost-effective method of assessing PA in large samples (van Nassau *et al.,* 2015). However, a previous study has reported variable reliability in the self-report assessment of SBs, although some of the questionnaires used to measure SB have reported moderate to high reliability (mean ICC: 0.61, 95% CI: 0.55-0.68) (Clark *et al.,* 2009). In addition, SB questionnaires have been shown to have varying validity, with reports of low validity (Pearson's r=0.39, 95%CI 0.22-0.53), moderate validity (ICC 0.54 95% CI 0.36–0.68) and high validity (ICC=0.89 95%CI 0.83–0.92) when compared with accelerometer-based sitting time (Ahammad *et al.,* 2015; Caspersen, Powell and Christenson, 1985; Chau *et al.,* 2011), thereby suggesting potential underreporting and/or over-reporting of SB (Clark *et al.,* 2011).

A commonly-used tool for self-reported PA measurement is the International Physical Activity Questionnaire (IPAQ) (Craig *et al.,* 2003), which has been used across a range of different population groups. The IPAQ has acceptable test-retest reliability (ICC=0.46-0.90) and validity (r= 0.22–0.46) (Ahammad *et al.,* 2015; Caspersen, Powell and Christenson, 1985; Chau *et al.,*

2011) and is widely used to evaluate sitting time in epidemiological research (Celis-Morales *et al.,* 2016; Hallal *et al.,* 2012). Another valid type of questionnaire that has been used to assess both PA and sitting time is the Occupational Sitting and PA Questionnaire (OSPAQ) (Chau *et al.*, 2012a). Previous studies have reported the OSPAQ to be valid and reliable in adult populations (Chau *et al.*, 2012a; Jancey *et al.*, 2014). For instance, an Australian study reported the intra-class correlations (ICCs) for time in minutes spent sitting, standing and walking to be 0.66, 0.83, and 0.77 respectively, indicating moderate to strong test-retest reliability (Jancey *et al.,* 2014). Other questionnaires that have been found to be valid and reliable in assessing SB and PA in adults include the Paffenbarger PA Questionnaire (PPAQ) (Paffenbarger, Wing and Hyde, 1978), the Global PA Questionnaire (GPAQ) (Celis-Morales *et al.,* 2016; Hallal *et al.,* 2012), the SB Questionnaire (SBQ) (Rosenberg *et al.,* 2010), and the Sitting Questionnaire (SIT-Q) (Lynch *et al.,* 2014).

The previous questionnaires are all general with respect to SB, with no discrimination made between domains in which SB might occur. In contrast, the Work Sitting Questionnaire (WSQ) was developed in such a way that it captures behaviour in different domains, thereby making it domain-specific (Chau *et al.,* 2011). The WSQ has been reported to be a reliable (ICC=0.63) and valid (r= 0.45) tool for assessing domain-specific sitting at work (Chau *et al.,* 2011). It has high test-retest reliability (ICC=0.76) and has been validated against Actigraph accelerometers (r= 0.40) as a measure of total sitting time on both working and non-working days (Chau *et al.,* 2011). Although there are cost advantages in using subjective, self-report measures, they rely on individuals' ability to accurately recall past activities and details such as the frequency and duration of activities. Accordingly, such tools have inherent limitations and are prone to both random and systematic errors, which could be due to cultural norms, social desirability,

selective recall bias, while they also have issues in populations with lower cognitive ability selective recall (Adams *et al.,* 2005; Baranowski, 1988; Durante and Ainsworth, 1996; Sallis and Saelens, 2000).

2.2.3.2 Objective measures of physical activity and sedentary behaviour

Energy expenditure as a result of PA can be measured using indirect calorimetry techniques, such as doubly labelled water or metabolic carts (Van Remoortel *et al.,* 2012). The most accurate method is doubly-labelled water (DLW), however this is also the least cost-effective (van Nassau *et al.,* 2015). In addition, the DLW technique is unable to measure the duration, frequency, intensity and context of PA that has taken place (Van Remoortel *et al.,* 2012). The advancement of technology has increased the available options for measuring PA with many new tools developed in recent decades to measure activity and posture including pedometers, inclinometers, accelerometers, and integrated multisensory systems (Van Remoortel *et al.,* 2012). Owing to the interest of this thesis on the development of an intervention to break up and reduce workplace sitting, each of these motion sensor devices will only be discussed in brief, with more emphasis placed on the use of the motion sensor chosen for this thesis.

Pedometers are portable, inexpensive and easy to use motion sensor devices, which have been used in measuring ambulatory activity. Pedometers can be used to identify the number of changes in vertical acceleration, with the number of peaks in vertical acceleration used as an estimate of the number of steps taken (Bassett Jr and Strath, 2002; Montoye *et al.,* 1996).

The original pedometers contained a movement arm that would swing when sufficient acceleration occurred, with this movement calibrated to stepping (Tudor-Locke *et al.,* 2001)

However, standard pedometers are unable to detect physical activities that take place in other planes of movement, such as upper limb or upper trunk movement. Such measurement devices are sometimes referred to as limited when used to measure PA (Bassett *et al.,* 2000; Le Masurier and Tudor-Locke, 2003). Although test-retest reliability is good, it varies with the brand of pedometer used (Bassett Jr and Strath, 2002; Park *et al.,* 2014). Pedometers have been shown to have an inverse relationship between step count and self-reported sitting time (Bassett Jr and Strath, 2002; Tudor-Locke *et al.,* 2002a; Tudor-Locke *et al.,* 2002b). In interventions in which self-monitoring is carried out in conjunction with goal setting, pedometers can provide real-time feedback on step counts to participants, which can increase awareness of the impact of personal behavioural choices (Lubans and Morgan, 2008; Lubans *et al.,* 2009; Lubans, Morgan and Tudor-Locke, 2009; Schofield, Mummery and Schofield, 2005). Thus, it can be argued that pedometers might introduce behavioural bias, and therefore make it difficult to ascertain the exact influence of other accompanying interventions.

Improvements in technology have led to the development of a new range of devices capable of measuring activity by means of an inertial sensor that improves not only the accuracy of step detection, but can also identify steps in different body positions, and estimate walking speeds via step cadence (De Cocker *et al.,* 2012; Giannakidou *et al.,* 2012; Park *et al.,* 2014). Such systems contain accelerometers, which are small devices that are capable of recording changes in acceleration that can be worn on many locations on the body such as the lower back, wrist, hip, upper arm or ankle. Accelerometers work as a cantilever that can be represented by a mass-spring-damper system (Zeng and Zhao, 2011). Such accelerometers can be either capacitive, piezoresistive, or piezoelectric, depending on the mechanism used

to determine the cantilever displacement (Zeng and Zhao, 2011). Motion sensing devices can include a number of different accelerometers to record acceleration in different axes of movement, from uniaxial accelerometers recording in one plane to triaxial accelerometers in three planes of movement (Van Remoortel *et al.,* 2012).

An example of a uniaxial accelerometer is the Actigraph Uniaxial GT1M (Actigraph, Pensacola, FL), which is reported to be one of the most widely used accelerometers in PA research (Kelly *et al.,* 2013). The Actigraph GT1M uses a differential capacitance sensor to record acceleration via a micro-electro-mechanical system (MEMS), which are highly accurate and reliable miniaturised systems for motion sensing (Barbour and Schmidt, 2001). Such systems have an excellent operational bandwidth capable of detecting PA from low frequency (0.1Hz) up to the kHz range (Kelly *et al.,* 2013).

Accelerometers have been shown to have acceptable reliability for research (Welk, Schaben and Morrow, 2004), although reliability does tend to vary between devices (Matthews, 2005; Trost, McIver and Pate, 2005). One major advantage of the latest accelerometers is that their storage capacity enables records of activity to be monitored over days to weeks. The biggest challenge when using accelerometers is the validity of measurement of PA. Most studies have estimated energy expenditure from activity counts in studies in laboratory-based and field-based trials in which indirect calorimetry or doubly-labelled water was used. Equations can then be used to convert activity measurement to energy expenditure. Although, energy expenditure does not directly measure the type of PA, it has been used extensively to reflect PA intensities (Ainsworth *et al.,* 2000). Even though accelerometers can measure activity intensity, they can struggle to differentiate between activities taking place in different postures and do not provide information on the context in which the PA is taking place. In

order to detect such differences in posture, many devices now contain additional sensors, including gyroscopes, inclinometers, and magnetometers, with such Inertial Measurement Units (IMU) now used widely (Ahmad *et al.,* 2013).

In one such study, a portable inclinometer with a data logger (weight 375 g) (Posimeter 100, Biolin AB, Molindal, Sweden) was attached to the thigh in an attempt to distinguish between sitting and standing positions to determine the effect of posture on musculoskeletal pain among call centre workers, (Toomingas *et al.,* 2012). However, it was reported that it was difficult to differentiate between standing and walking, suggesting that some postures documented as "non-seated", could be standing or walking (Toomingas *et al.,* 2012). Other studies have also found that an IMU, such as the ActiGraph GT3X, which contains an accelerometer and an inclinometer, also wrongly classifies some postures (Clemes *et al.,* 2012; McMahon, Brychta and Chen, 2010). One system that has been recognised as a valid measure of posture, movement, and SB in adult populations is the activPAL, which can provide accuracy for posture that is superior in comparison with many self-report measures and accelerometers in terms of measuring the duration of sitting, standing, stepping and postural transitions (Grant *et al.,* 2006; Kozey-Keadle *et al.,* 2012; Oliver *et al.,* 2010; Thorp *et al.,* 2012).

The ease with which electronic devices can be used to objectively measure activity has improved understanding of the health consequences of SB and patterns in which sedentary time is accumulated. However, it has been reported that much of the evidence regarding the association between objectively measured sedentary time and health was obtained from devices that deduce sedentary time from a lack of movement (Carson *et al.,* 2014; Edwardson *et al.,* 2017; Healy *et al.,* 2008b; Henson *et al.,* 2013). Such inferences might result in

inaccuracy by misclassifying low-intensity non-SBs as SB (Edwardson *et al.,* 2017). It is important, therefore, to use a sensor that can directly measure the postural aspect of SB (Edwardson *et al.,* 2017).

The activPAL derives information about body posture (such as sitting, lying and standing), transitions between these postures, as well as stepping and stepping speed, which can be used to determine energy expenditure (Grant *et al.,* 2006; Levine and Miller, 2007; Lyden *et al.,* 2012). The activPAL has been reported to have acceptable agreement with direct observation of sitting or lying time, standing time (Kozey-Keadle *et al.,* 2011), sitting or lying to standing transitions (Lyden *et al.,* 2012), and for identifying sitting reductions (Edwardson *et al.,* 2017). Furthermore, evidence shows that the activPAL is able to accurately differentiate between stepping and standing (Grant *et al.,* 2006) and identify different stepping speeds (cadence) (Ryan *et al.,* 2006). In one study, activPAL was shown to be 32.4% more accurate than ActiGraphs, with an accuracy of 99.1%, for measurement of time spent standing, sitting and slow walking (Kang and Rowe, 2015). In addition to reliability and validity, the activPAL has been reported to be the most accurate monitor to measure sitting time in free-living conditions (Kozey-Keadle *et al.,* 2011; Lyden *et al.,* 2012). Of particular importance in SB research is the ability to detect transitions between sitting and standing, which are needed to evaluate strategies to promote breaks in sitting and curtail sitting. The activPAL has been shown to be capable of detecting such transitions, although there are concerns about its ability to detect stepping at very slow walking speeds such as less than 0.5 m/s (Stansfield, Hajarnis and Sudarshan, 2015). However, as with other objective measures, the activPAL does not provide information on the context in which SB and activity are occurring.

Although posture can be detected accurately, an additional step is required in SB research, which is to isolate periods of participant behaviour of interest, such as waking hours or working hours (Edwardson *et al.,* 2017). Currently, there is no validated or accurate method to segregate these periods of interest (Edwardson *et al.,* 2017). However, the use of self-report diaries or logs has been recommended for participants to note if the monitoring device was put on in the morning and removed in the evening, as well as times of interest such as waking up and going to bed (Edwardson *et al.,* 2017). A major difference between activity logs and activity diaries is that, while an activity log requires participants to complete their daily activities at the end of a day, an activity diary requires the individual to keep record of his or her bouts of activities as they occur in real time (Edwardson *et al.,* 2017; Welk, 2002). Thus, a limitation of self-report diaries is that most of the time such diaries are not fully completed (Edwardson *et al.,* 2017).

The number of days for which activity monitors should be worn to be taken as representative of a person's typical activity varies between studies. For instance, in one study it was recommended that devices be worn mounted on the thigh of participants for at least seven consecutive days (Nooijen *et al.,* 2018). However, other studies suggest that activity monitors must be worn for at least three working days and one weekend day before data from the device can be included in any analysis, although no reason was provided (Gibson *et al.,* 2017; Hagstromer *et al.,* 2010; Trost, McIver and Pate, 2005). In another study, Chau *et al.* (2014a) set a criterion of two workdays of wear for full-time workers, and a minimum of one workday for part-time employees, although once again, no reason was given. Finally, van der Ploeg *et al.* (2010) considered data from an activPAL to be valid if the device was worn for a minimum of 75% of total monitoring time. However, evidence is limited to one study regarding the

number of days required to provide adequate reliability for activPAL outputs (that is, sitting, standing, stepping and transitions) in adults (Reid *et al.,* 2013). This study, which was carried out among a residential adult population, demonstrated that to achieve an intra-class correlation (ICC) of 0.8 for sitting, five days of recording was required, with the number of days required rising to 11 days to achieve an ICC of 0.9. Likewise, five days and 10 days were needed for standing to achieve the same ICCs of 0.8 and 0.9, respectively. When stepping was considered, seven days and 15 days were required to achieve ICCs of 0.8 and 0.9, respectively. There is also mixed evidence regarding minimum number of hours for a day to be considered valid, with some studies reporting waking hours only (Craft *et al.,* 2012), while some reported working hours only (Swartz *et al.,* 2014) or based researcher convenience and availability (Kunkel *et al.,* 2015). However, there has been studies reporting the need to wear the device for 24 hours but remove during water-based activities such as bathing or showering (Aadahl *et al.,* 2014). A continuous wear protocol which allows 24 hours wear time without removing the device is now in place and has gained popularity (Aguilar-Farias *et al.,* 2015; Berendsen *et al.,* 2014). While the disparity in evidence regarding length of days the activPAL should be worn and limited evidence in relation to reliability suggests that additional studies are required for a consensus wear days to be reached, it appears as though researchers are in favour of 24 hours wear time without removing the device (Edwardson *et al.,* 2017).

The long durations over which activity monitors need to be worn requires a system to fix them in place securely, without causing discomfort to participants. If devices are worn continuously, the fixation system needs to also be waterproof to enable participants to shower or bathe. Several different waterproof adhesives are available including medical dressings such as Hypafix, or proprietary fixation systems such as PAL stickies for the activPAL.

While some hypoallergenic waterproof adhesives are designed to last up to five to seven days, participants in some studies have expressed a preference for changing the dressing every two to three days, although this would have additional cost implications from the provision of extra dressings and alcohol wipes for re-attachment, as well as extra time for researchers to replace the devices (Dunstan *et al.,* 2013; Yates *et al.,* 2015). However, Edwardson *et al.* (2017) did suggest that providing verbal, visual, and written instructions to study participants to replace devices correctly could be sufficient.

In summary, both subjective and objective measures of PA and SB possess advantages, although neither method, when used alone, provides a complete picture (Sternfeld and Goldman-Rosas, 2012; Troiano *et al.,* 2012). While subjective SB measures are low-priced, give context, and can be used in large population studies, they are often prone to over or underreporting. On the other hand, objective SB measures, especially using an activPAL, have been reported to be sensitive for detecting changes in SB, valid in measuring SB owing to its capability as a posture-based monitor (Headley *et al.*, 2018), have greater inter-rater reliability and validity. This has thus informed the use of the activPAL in Chapter 8.

2.2.4 Sedentary behaviour and health

Recently, a new paradigm has emerged in the field of PA research (Katzmarzyk, 2010). Several epidemiological studies have revealed that engaging in excessive SB could have a negative impact on a number of health outcomes, irrespective of the amount of time spent in moderate to vigorous PA (Katzmarzyk *et al.,* 2009). Excessive SB primarily takes place in three domains, which are work, leisure and travel (Davis *et al.*, 2011; Owen *et al.*, 2010a; Owen *et al.*, 2011) and SB is on the increase, particularly in developed countries, such as the United Kingdom (Clemes, O'Connell and Edwardson, 2014), Sweden (Hagstromer *et al.,* 2010), United States (Matthews *et al.,* 2008), and Norway (Ekblom-Bak *et al.,* 2015), where the majority of adults reportedly spend approximately two-thirds of their waking day engaged in SB. Research has blamed the increase in SB on factors such as decreases in PA levels, increased pursuits of sedentary leisure at home, and an increase in the number of jobs in which people are seated (Brownson, Boehmer and Luke, 2005). Such SB can be classified as either *discretionary* or *nondiscretionary* (Machado de Rezende *et al.,* 2014). Typical examples of discretionary activities include using a computer, watching television, reading and playing video games, while nondiscretionary behaviours include sitting while at work or school, or traveling in a car or bus (Gabriel, Morrow and Woolsey, 2012).

There have been several attempts at summarising and interpreting the available evidence with regards to SB and associated health outcomes. Some of the reviews in this area have focused on prospective studies (Proper *et al.,* 2011; Thorp *et al.,* 2011), cross-sectional studies (Foster, Gore and West, 2006) or mixed methodologies (van Uffelen *et al.,* 2010; Wilmot *et al.,* 2012). Consistent evidence from prospective studies has revealed a positive association between SB and premature mortality, in particular, cardiovascular disease and all-cause

related mortality, with these associations reported to be independent of body mass index (BMI) and levels of moderate-vigorous PA (Thorp *et al.,* 2011).

The rest of this section of the literature review will focus on the association between SB and cardiometabolic disease risk, which is defined as a condition whereby there is a significant increase in the probability of developing cardiovascular disease (CVD) and T2DM (Mackenzie, Goyder and Eves, 2015). This is in addition to other health outcomes in which research has shown associations with SB, such as all-cause mortality and mental health and wellbeing.

2.2.4.1 Cardiovascular disease (CVD)

Prolonged sitting has been implicated in premature cardiovascular mortality, irrespective of the amount of time spent in leisure PA (Dunstan *et al.,* 2010; Patel *et al.,* 2010). Evidence of the findings from the 2003-2004 and 2005-2006 U.S. NHANES and the 2004-2005 Australian Diabetes, Obesity and Lifestyle (AUSDiab) studies revealed that there is a detrimental association between objectively measured sedentary time and cardiometabolic risk markers (Healy *et al.,* 2008a; Healy *et al.,* 2011b). Similarly, in a prospective study of 7,744 men that investigated the association of time spent watching television and riding in a car, reported that those with a high level of SBs had a significantly higher chance of CVD mortality (Warren *et al.,* 2010). However, CVD mortality was only associated with SB that took place whilst riding in a car for >10 hours per week and >23 hours per week of combined time spent both riding in a car and watching TV (Warren *et al.,* 2010).

Findings from four different meta-analyses have revealed positive and consistent association between sedentary time and CVD. Grontved and Hu (2011) performed a systematic review in which eight studies were retained. They reported that a two-hour increase in time spent

viewing TV on a daily basis played a role in 15% of the increased risk of fatal or non-fatal CVD (95% CI=1.06-1.23), which was the main cause of 38 cases of fatal CVD per 100, 000 individuals per year. Similarly, Wilmot *et al.* (2012) demonstrated that high sedentary time was associated with a 147% increase in the relative risk of cardiovascular events (RR=2.47; 95% CI=1.44-4.24) and a 90% increased risk of cardiovascular mortality (HR=1.90; 95% CI 1.36-2.66). The comparison of participants with lowest amount of sedentary time and those with highest volumes of sedentary time reported in a meta-analysis of 47 studies showed that, independent of PA, those with the highest volumes of sedentary time had a 14 % and 18% increased risk of CVD incidence and mortality, respectively (Biswas *et al.,* 2015). A systematic and dose response meta-analysis by Patterson *et al.* (2018) identified total sitting time of 6-8 hrs /day and television viewing time of 3-4 hrs / day as the threshold for which the risk of CVD increases. The estimated relative risk for each additional hour below the 6 hrs/day threshold for total sitting time was (RR=1.01; 95% CI=0.99 – 1.02), while that for hours above was (RR=1.04; 95% CI=1.03-1.04). For television viewing, the relative risk for each additional hour below the 4 hrs/day threshold was (RR=1.02; 95% CI=0.99 – 1.04), while that above was (RR=1.08; 95% CI=1.05-1.12) (Patterson *et al.,* 2018). In contrast, a cross-sectional study of 3301 adults conducted in the Korean National Health and Nutrition Examination Survey (KNHNES) reported no association of sedentary time on CVD except for high diastolic blood pressure (OR=1.71; 95% CI 1.09-2.68) (Park *et al.,* 2018). Also increasing confidence in the sense that SB has no association with CVD, are findings from a study by Petersen et al., (2014) in which 71363 adults from Danish Health Examination Survey (DANHES) were followed for 5.4 years. There was no clear association between coronary heart disease and SB when hazard ratio associated with total daily sitting of ≥ 10 hrs/day and < 6 hrs/day were compared (HR=1.07; 95% CI 0.91-1.27). However, when sitting < 6 hrs/day and being physically active in

leisure time was compared to sitting > 10 hrs/day and being physically inactive in leisure time, a significant association was reported (HR=1.42; 95% CI 1.11-1.81). A cross-sectional study of 3592 participants enrolled in Jackson Heart Study compared the association of both occupational sitting and television viewing with CVD events (Garcia *et al.*, 2019). It was found, that unlike television viewing, occupational sitting was not associated with risk of CVD events (Garcia *et al.*, 2019). Similarly, a cohort study of 5380 women and 5788 men in employment aged ≥ 40 years from the Health Survey for England (HSE) and the Scottish Health Survey found that a standing or walking occupation had no association with CVD incidence (Stamatakis *et al.*, 2013). While evidence suggests that SB from domains such as leisure time and during travel play a role in CVD risk, further studies are required to elaborate on inconsistencies in findings and explore the interplay of workplace SB and PA on CVD.

2.2.4.2 All-cause mortality

A recent large Australian population study investigated 222,497 participants aged 45 years or older, for two years and reported a dose-response relationship between sitting time and all-cause mortality, independent of PA level (van der Ploeg *et al.,* 2012). They reported a hazard ratio of 1.4 (95% CI 1.25-1.55) for a greater risk of death for those who sat more than 11 hours per day compared to those who sat less than four hours per day. When this was expressed as the risk in moving from one category of SB to the adjacent category with higher SB, such as from 0-4 hours per day to 4-8 hours per day, an 11% increase in mortality was observed (HR 1.11; 95%CI 1.08-1.15).

Similar results were reported in an observational study in the USA in which the relationship between SB and cardiovascular mortality outcomes were reported for 7744 men after 21 years of follow-up (Warren *et al.,* 2010). The authors detected an increased risk of dying from

cardiovascular disease of 82% among those who reported over 10 hours of sitting in automobiles per week in comparison to those with less than four hours per week (Age-adjusted HR 1.82; 95% CI 1.34 – 2.87). In addition, Warren *et al*. (2010) reported that participants who accumulated over 23 hours of SB from time per week spent watching television or sitting in a car were 64% more likely to die from cardiovascular disease than those who reported only 11 hours of television watching per week (Age-adjusted HR 1.64; 95% CI 1.23 – 2.20). Although these studies provide evidence of a link between SB in specific domains and mortality, both studies were based on self-report, and may, therefore, have been under- or over-reported SB levels (Pedersen *et al.*, 2016). However, there is evidence for an association between sitting time and mortality from a prospective study of older adults in which SB has been measured objectively (Ensrud *et al.,* 2014). The 2918 participants in the study, who were all aged over 70 years, were monitored for seven days at baseline using an accelerometer-based activity monitor (SenseWear Pro Armband, BodyMedia Inc., Pittsburgh, PA), and then followed up for an average of 4.5 years. The findings showed that among those who were estimated to sit for at least 15.2 h per day, there was a 56% increase in the risk of all-cause mortality compared to those who sat less than 12.7 h per day (HR= 1.56, 95% CI = 1.15–2.14). Similarly, the results of National Health and Nutrition Examination Survey (NHANES), in which 1906 participants aged 50 years and above were followed from 2003 for approximately 2.8 years, supports this assertion (Koster *et al.,* 2012). Participants were monitored using the uniaxial ActiGraph AM-7164 for seven consecutive days. They found a significant increase in the risk of all-cause mortality related to daily sitting time, with men who sat for a minimum of 9.2h and women who sat for at least 8.7h, four times more likely to die than men who sat for less than 7.6 h and women who sat for less than 7.2 h (HR 4.05; 95% CI 1.55-10.60). When men who sat for at least 10.8h and women who sat for at least 10.1

h were compared to most sedentary participants, they were six times more likely (HR 5.94; 95% CI: 2.49-14.15). In contrast, a longitudinal study of 5132 London-based employees of the British Civil Service found no association between sitting time and all-cause mortality (Pulsford *et al.,* 2015). Sitting is only associated with all-cause mortality where there are high volumes of sitting, however when there is insufficient exposure of the participants to sitting, no association to mortality is found (Pulsford *et al.,* 2015). In the London Whitehall II study, the lack of association between sitting and mortality was said to be possibly caused by a protective effect of the high levels of daily walking reported by the participants. Evidence from numerous prospective cohort studies have shown that daily walking (Hakim *et al.,* 1998; Smith *et al.,* 2007) and habitual active transport (Matthews *et al.,* 2007) have an inverse association with risk for mortality. Although many studies have shown that the relationship between sitting time and adverse health consequences is not moderated by PA, recent research has provided contradictory evidence. A study by Ekelund *et al*. (2016) revealed that moderate intensity PA of 60-75 min may eliminate the increased risk of death associated with high levels of sitting time. However, getting people to achieve this level of activity might be unrealistic.

It can be argued based on the evidence of these subjective and objective studies that sitting time is only associated with all-cause mortality in the absence of high volumes of PA (Ekelund *et al.*, 2019; Ekelund *et al.*, 2016). However, the data did not analyse the associations of occupational sitting with mortality independently. In terms of associations between occupational sitting time and all-cause mortality, the results of the Japan Public Health Centre-based prospective (JPHC) study which recruited 36,516 community-dwelling Japanese workers aged 50-74 years showed that increased occupational sitting time led to an increase

in all-cause mortality in primary industry workers (Kikuchi *et al.*, 2015). Similarly, a cohort study of employed 5380 women and 5788 men aged ≥ 40 years from the Health Survey for England (HSE) and the Scottish Health Survey discussed in section 2.2.5.1 found that a standing or walking occupation was associated with lower risk of all-cause mortality in women compared with sitting occupations, but no associations were seen in men (Stamatakis *et al.*, 2013). In contrast, an inconclusive outcome was observed in the Danish work environment cohort study (DWECS) of 149,773 working population that found no significant association between occupational sitting time and all-cause mortality (van der Ploeg *et al.*, 2015). Therefore, based on studies showing associations between occupational sitting and mortality, it may be important to identify effective interventions for reducing SB.

2.2.4.3 Type 2 Diabetes Mellitus (T2DM)

Although several negative health outcomes have been linked with SB, diabetes has been shown to have the strongest and most persistent association with excessive sedentary time (Wilmot *et al.,* 2012). The relationship that exists between high levels of SB and the propensity to develop T2DM has been reported to be independent of social demographic variables such as age, gender, ethnicity and socioeconomic status. For instance, an independent association was found between high levels of SB and increased risk of developing T2DM in both women (Hu *et al.,* 2003) and men (Hu *et al.,* 2001), and in different ethnic groups (Krishnan, Rosenberg and Palmer, 2009). A number of studies have examined the link between SB in predicting the risk of developing T2DM. These studies have reported that both high levels of SB and low levels of moderate-vigorous PA independently predict an increased chance of developing T2DM (Ford *et al.,* 2010; Foster, Gore and West, 2006; Hu *et al.,* 2001; Hu *et al.,* 2003; Krishnan, Rosenberg and Palmer, 2009). In addition, an increased risk of developing

T2DM has been shown to be related to other SBs, including workplace sitting, sitting when away from home, and sitting while driving (Hu *et al.,* 2003). In contrast, a study using data from the Whitehall II cohort study of 4811 participants has reported that sitting behaviour might not be associated with incident-limited evidence of associating sitting and diabetes over 13 years among civil servants (Stamatakis *et al.,* 2017). This is probably due to the protective effect of the high levels of MVPA, most especially the reported daily walking in the Whitehall cohort. For instance, the reported daily mean walking time of 42.7 ± 22.7 min/day is more than double the national average for the UK (Office for National Statistics, 2006). There has also been evidence from a prospective study that revealed the associations between total sitting time and incident diabetes are only recorded among participants that were the least active and obese (Petersen, Bauman and Tolstrup, 2016). A longitudinal study of 293 Canadian participants from the Quebec Family Study aged 18 to 65 years showed significant negative associations of occupational standing time and diabetes. However, upon adjustment for confounding variables, such as age, sex, smoking habits and daily caloric intake, the association was no longer significant suggesting that increased occupational standing time may not be sufficient by itself in preventing the development of overweight, obesity and T2D in adults (Chaput *et al.*, 2015).

2.2.4.4 Mental health and wellbeing

Apart from chronic illnesses, SB has also been implicated in the occurrence of some mental health issues, including but not limited to depression (Teychenne, Ball and Salmon, 2010), and self-esteem among specific population groups, such as women and adolescents (Nihill, Lubans and Plotnikoff, 2013). Evidence shows the existence of a positive relationship between SB and the aforementioned mental health concerns (Teychenne, Ball and Salmon, 2010;

Tremblay *et al.,* 2011b). The only meta-analysis on SB and the risk of depression was based on 13 cross-sectional and 11 longitudinal studies (Zhai, Zhang and Zhang, 2015). Increased SB was reported to be linked with an increased risk of depression in both cross-sectional studies (RR 1.31; 95% CI 1.16-1.48) and longitudinal studies (RR 1.14; 95%CI 1.06-1.21). Long-term TV viewing (RR 1.13; 95% CI 1.06-1.21) and prolonged computer or internet use (RR 1.22; 95% CI 1.10-1.34) were also reported to increase the risk of depression (Zhai, Zhang and Zhang, 2015). Furthermore, the outcome of a systematic review that examined the relationship between SB and risk of anxiety suggests that a positive association might exist, whereby the risk of anxiety increases with an increase in sedentary time (Teychenne, Costigan and Parker, 2015). However, the study did have some limitations, with most of the studies included being cross-sectional in design, meaning it is difficult to ascertain the causality in the relationships reported. Moreover, the majority of studies selected used self-report or proxy measures of SB, with associated problems of recall bias, meaning that the data used in the study could have been over-reported (Teychenne, Costigan and Parker, 2015). Despite this, other studies have shown that SB could influence anxiety. In one objective study, Gibson et al. (2017) reported that individuals who sat less than eight hours during working days had significantly lower levels of anxiety than those who sat more than eight hours on a working day, which is a large effect ($\eta^2 = 0.18$, confidence interval not reported). In another objective study of 271 adults, the influence of sedentary time was assessed on mood, stress, and sleep across a one-year period. It was found that with reduced total sedentary time and time spent in both short (< 30 min) and long (≥ 30 min) bouts were improved mood, stress and sleep, although only p values were reported so the magnitude of these effects could not be determined (Ellingson *et al.,* 2018). The evidence clearly demonstrated that changes in amount of time being spent in SB over a year was significantly associated with changes in a number of mental wellbeing

(Ellingson *et al.,* 2018). Similarly, an objective study of 430 young adult participants has found SB to be significantly associated with mood over 6 months and one-year duration (DeMello *et al.,* 2018). This study revealed that a 30 min/day difference in SB resulted in a 1.50-unit difference in mood (DeMello *et al.,* 2018). While SB has been implicated in mood swings and depression, its positive effect on depression has also been reported. For instance, in a qualitative study of 18 participants, women stated that they watched television to distract themselves from negative thoughts and other signs of depression (Teychenne, Ball and Salmon, 2011).

This section of the review of literature has shown that both PI and SB are two separate constructs. There is sufficient evidence to suggest grave health consequences of SB, including increased risk of CVD, T2DM, all-cause mortality, anxiety, obesity, and depression. There is also evidence of an indirect economic impact of SB, meaning that it needs to be combatted as a matter of urgency. Although much of the evidence presented regarding association of SB in connection with health is based on television viewing, travel and total daily sitting time, it has been shown that the workplace is the predominant site for the occurrence of the most excessive SB. SB in this setting accounts for about 56% of the overall daily sitting time in comparison with 32% and 11% accounted for by leisure and transport sitting time (Bennie *et al.,* 2015). Accordingly, the workplace could be a key site in which SB could be combatted.

2.3 Section Two: Workplace sedentary behaviour

2.3.1 Sitting in the workplace

Evidence from a WHO (2008) report shows that 60% of the world population is in employment, spending 60% of their waking time at work. It follows, therefore, that workplace interventions could be used to influence the health behaviour of a large percentage of the adult population (WHO, 2008). The workplace has also been identified as one of the main places in which high sitting volumes are accrued, with one study reporting that 82% employees' working time was spent sitting (Hall *et al.,* 2015), and more than 69% of non-working hours were spent in SB (Hall *et al.,* 2015; Parry and Straker, 2013). However, elsewhere, objectively-measured workplace sitting was found to be responsible for approximately 71% of working hours (Clemes, O'Connell and Edwardson, 2014). Recent evidence has revealed that office-based workers engage in sitting for an average of six hours in an eight-hour shift, and that sitting is usually accumulated in prolonged bouts (Bennie *et al.,* 2015; Clemes, O'Connell and Edwardson, 2014; Matthews *et al.,* 2008). Consequently, it has been reported that there is a positive association between office work and sitting time, which has a high contribution to total daily sitting time (Mackenzie, Goyder and Eves, 2015; Parry *et al.,* 2013). The average sitting time across 20 countries on a working day was five hours, with Taiwan, Hong Kong, and Japan sitting up to six hours per day (Bauman *et al.,* 2011). However, in other studies carried out in Australia, the United States (US), and the United Kingdom (UK), from both self-reported and objective measurements of sitting time, between 8-9 nine hours per working day was spent sitting (Bennie *et al.,* 2015; Clemes, O'Connell and Edwardson, 2014; Matthews *et al.,* 2008).

2.3.2 Workplace Sitting and Health

In 1958 Morris and Crawford produced one of the first pieces of evidence in workplace SB when they reported an increased risk of death from coronary thrombosis for drivers of London's double-decker buses compared with bus conductors (Morris and Crawford, 1958). They also reported that clerks were at greater risk of fatal cardiac infarction than were postmen. Based on these similar observations, it was hypothesised that people that are in physically active jobs have a lower incidence of coronary (ischaemic) heart disease. More recently, Hu (2003) reported that individuals' risk of developing obesity and diabetes increases by 5% and 7% respectively, for every two-hour increase in daily sitting at work. Following on from this, Buckley *et al.* (2015) suggested that sedentary living, including time spent sitting at work, as one of the most common causes of morbidity and mortality due to cardiovascular disease, diabetes and some cancers (Buckley *et al.,* 2015). Given that UK office workers spend 65-70% of their working hours sitting, it could be argued that this is a possible cause of increased cardiometabolic diseases such as heart disease and diabetes (Buckley *et al.,* 2015; Wilmot *et al.,* 2012). In contrast, a systematic review of 43 articles of which 21% were cross-sectional, 65% were prospective, and 14% case-control studies, half of the cross-sectional studies showed that workplace sitting was positively associated with BMI, but prospective studies did not confirm any causal relationship (van Uffelen *et al.,* 2010).

Apart from these health consequences and those discussed in section 2.2.5, high occupational sitting time has also been implicated with negative economic consequences, such as higher health-related productivity loss, known as presenteeism, and absenteeism (Brown *et al.*, 2013; Puig-Ribera *et al.*, 2015). According to the Centre for Mental Health (2017), absenteeism among employees was reported as 6.8 days per person in 2015, which

accounted for losses of £10.6 billion, while presenteeism accounted for losses of £21.2 billion. It seems clear, therefore, that occupational sitting time is a problem with health and potentially economic consequences.

2.3.3 The effects of breaking up prolonged sitting time

There is emerging evidence, such as the work of Dunstan *et al.* (2012) that when sitting time is broken up with short bouts of light to moderate-intensity walking, postprandial glucose and insulin levels are reduced. For instance, breaking up prolonged sitting with 2-min bouts of light or moderate walking every 20-min over a five-hour period among overweight and obese adults was found to significantly reduce postprandial glucose and insulin levels by 24% and 23% respectively (Henson *et al.,* 2016a). In support of this finding, Bailey and Locke (2015) reported that 2-min bouts of light intensity walking breaks every 20-min of SB led to a reduction in the concentration of postprandial glucose. A meta-analysis of 13 studies conducted by Chastin *et al.* (2015) revealed that breaks, whether with light or moderate intensity PA, were insufficient to cause any significant effect on lipidemia. The findings also suggested that breaking up prolonged sitting with short periods of standing is beneficial for any cardiometabolic biomarkers (Chastin *et al.*, 2015). Taken together, it is gathered from this review that prolonged sedentary time results in acutely elevated levels of cardiometabolic risk markers. With high levels of prolonged sitting time taking place in the workplace (Clemes, O'Connell and Edwardson, 2014; Hall *et al.,* 2015), especially among desk-based employees, it is paramount for a workplace intervention that targets cardiometabolic risk to be designed. The effects of several workplace interventions on cardiometabolic risk have been reported. For instance, the use of height-adjustable workstations during an eight-week intervention was reported to decrease cardiometabolic outcomes, which included total cholesterol -0.40

mmol/L (95% CI -0.79, -0.003) and diastolic blood pressure -2.5 mmHg (95% CI= -7.2, 2.2) (Graves et al., 2015). Another workplace intervention that has shown an effect on cardiometabolic outcomes is an e-Health intervention (Mainsbridge *et al.*, 2014). In this study, the 13-week prompt-only intervention significantly reduced mean arterial pressure. Similarly, Lin *et al.* (2017) demonstrated that a short-term multi-component intervention significantly decreased waist circumference and diastolic blood pressure. Surprisingly, the intervention did not have any long-term effect on cardiometabolic risk (Lin *et al.,* 2017).

2.3.3.1 Physiological mechanisms underlying the consequences of prolonged sitting

It has been suggested that there is a distinct physiological difference between prolonged sedentary time and inadequate PA (Hamilton, Hamilton and Zderic, 2007). Mounting evidence has shown that the chronic, continuous periods of muscular unloading linked with prolonged sitting time may provoke deleterious biological consequences (Bey and Hamilton, 2003; Hamilton, Hamilton and Zderic, 2004), resulting in vascular and metabolic disorders that involve poor skeletal muscle lipid metabolism such as metabolic syndrome, obesity and T2DM (Bey and Hamilton, 2003). This process can be explained in biochemical and physiological terms. For instance, lipoprotein lipase (LPL) plays a central role in metabolism of lipids (Goldberg and Merkel, 2001). This enzyme, which is the first protein that directly interacts with and regulates lipoproteins, has been researched at the cellular level during PI (Honda *et al.,* 2014). The role of LPL is to aid the uptake of triglycerides between different tissues, as well as the production of high-density lipoprotein (HDL) cholesterol (Bey and Hamilton, 2003). However, evidence has shown that when sitting-induced local contractile stimulation is lost, the activity of skeletal muscle LPL is suppressed, which then leads to a reduction in the uptake

of glucose, which potentially results in postprandial excursions (Bey and Hamilton, 2003; Hamilton, Hamilton and Zderic, 2004), and a decrease in HDL cholesterol levels (Hamilton, Hamilton and Zderic, 2007). Regardless of the mechanism, the activity of LPL appears to be abridged following both acute and chronic SB (Tremblay *et al.,* 2010). A study reported that women who were physically active had significantly lower levels of total cholesterol, LDL-cholesterol (referred to as bad lipids), triglycerides, and higher levels of HDL-cholesterol than sedentary women (Skoumas *et al.,* 2003). Since HDL-cholesterol is a strong, independent inverse predictor of cardiovascular disease (Barter *et al.,* 2007), it would follow that when the levels of HDL increase, there would be a decreased risk of cardiovascular events.

2.3.4 Factors that may influence prolonged workplace sitting time

Past literature has revealed that a wide range of factors contribute to behaviour in the workplace, including cultural context, physical environment and personal factors (Cole, Tully and Cupples, 2015). Before interventions to reduce prolonged and excessive sitting in the workplace can be developed, it is essential to identify factors that can influence the choices made by employees. These factors can either be ones that prevent or encourage breaking up prolonged sitting, known as barriers and facilitators. However, in the past, only a small number of studies have considered the perceptions of office employees prior to the development of behaviour change interventions (De Cocker *et al.*, 2015; Gilson *et al.*, 2011; Hadgraft *et al.*, 2016a). These studies afforded participants the chance to be part of the decision-making processes of behaviour change (McGuckin, Sealey and Barnett, 2017). For the purpose of this thesis, a review of some of factors identified in qualitative and questionnaire-based studies that may influence sitting behaviour was conducted. This was achieved by conducting a thorough literature search using a range of databases (such as

PubMed, Web of Science, CINAHL, Cochrane Library and PsycINFO). The keywords used were barriers, facilitators, enablers, workplace, sitting and sedentary.

The codes that emerged from the findings of the literature search were categorised and illustrated as barriers and facilitators to breaking up sitting in the workplace in Figure 3.

2.3.4.1 Personal Preferences

A recent workplace study, which investigated the perceptions of barriers among young professionals, reported feeling pressure to sit to work due to large commitments even though employers did not confine them to a sitting position (Cole, Tully and Cupples, 2015). A study estimated the percentage of the workforce that smoke to be between 80-90%, and it was reported these employees would go for cigarette breaks rather than any workplace sitting reduction intervention (Renton, Lightfoot and Maar, 2011). A similar study in which both the perceptions of young professional employees and their managers were explored through interviews, blamed participants' perceived sense of autonomy in decision making as a barrier to breaking up sitting time. Most people favoured staying sedentary to be able to focus on work during working hours, with the intention to offset prolonged sitting in the workplace with PA outside of work (Cole, Tully and Cupples, 2015). Low motivation among desk-based workers to break up sitting has also been identified as a reason for prolonged sitting elsewhere (Munir *et al.,* 2018). However, several enabling strategies have been suggested, which include providing access to cordless phones to ease the pressure of having to sit when dealing with high call volumes. Additionally, the introduction of competitions aimed at reducing prolonged siting time in the workplace could be beneficial (McGuckin, Sealey and Barnett, 2017). It is evident, therefore, that despite working in sedentary jobs, employees have the freedom to decide whether to remain sedentary or to choose breaking up prolonged

sitting time. To help employees make the right decision, a workplace intervention targeted at motivating employees, and emphasising the benefits of breaking up prolonged sitting is warranted.



Figure 3: Perceived influences on breaking up workplace sitting

2.3.4.2 Environment

A lack of facilities to break up siting has also been highlighted by a number of studies (Cole, Tully and Cupples, 2015). For instance, the absence of a canteen in the workplace could be a possible hindrance to free movement from employees' desks (Cole, Tully and Cupples, 2015). Consequently, there was a suggestion that workplace environments should be redesigned. However, this requirement was more popular with younger employees, of whom 10% favoured workplace redesign, than with the older employees, of whom only 5% favoured

redesign (Nooijen *et al.,* 2018). If office workers had access to an unrestrictive working environment that permitted a high level of flexibility, employees would be encouraged to engage in more face-to-face communication and personal meetings with their work colleagues rather than depend on email or telephone conversations (Nooijen *et al.,* 2018). Furthermore, access to a height-adjustable workstation has also been identified as a potential solution as it enables users to alternate between sitting and standing without moving away from their desks or leaving their work (Niven and Hu, 2018). In addition, a genuine reason to regularly break up work could be to take a print out from centrally located printers (Cole, Tully and Cupples, 2015). Evidence from these studies suggests that employees might be able to break up their sitting time provided their environment is designed to promote sitting less and standing more. Thus, future interventions should consider modifying the workplace environment to encourage desk-based employees to break up their sitting time.

2.3.4.3 Job requirements

The nature of jobs has been identified as one of the reasons for prolonged sitting time at work. For instance, in one study, participants said their work relied solely on computer use, especially tasks involving the use of spread sheets and online systems, which gives zero tolerance to distraction as it requires full concentration, while some computer programming cannot be carried out off-screen (Hadgraft *et al.,* 2016a). In another study investigating barriers from the point of view of call-centre employers, several barriers were identified including that clients require employees to be on the phones at a particular point in time (Renton, Lightfoot and Maar, 2011). The performance of such employees is often monitored using various key performance indexes, thereby making scheduling flexibility very difficult and limiting participation in such interventions (Renton, Lightfoot and Maar, 2011). Besides

which, a heavy call volume is often received each day, and some of the enquiries need employees to sit down and access information, thereby restricting walking while on a call (Renton, Lightfoot and Maar, 2011).

Tight work schedules and increased workloads have also been identified as one of the reasons for prolonged sitting time with many employees too engrossed in their work to meet deadlines (Hadgraft *et al.,* 2016a). This means that breaking up sitting may not be feasible, as a priority is not given to getting up and moving around (Blackford *et al.,* 2013; Mackenzie, Goyder and Eves, 2015). It is also believed by some employees that getting up and moving around might result in the loss of productive work time (Hadgraft *et al.,* 2016a). In a study by George et al., (2014), problems of time constraints and work commitments were identified. The majority of the participants complained that they barely got five minutes out of their one-hour break, as they often try to catch up with their workload. The effect of this goes beyond participation in the workplace, but also affects them at home, as they become too tired to engage in any form of PA (Blackford *et al.,* 2013). Access to opportunities and/or reminders for breaks in sitting was identified as one of the most favoured facilitators in one qualitative study (Nooijen *et al.,* 2018). This type of strategy might be useful in addressing the problem of forgetfulness, although there is also a tendency for employees to ignore prompts when they are totally engrossed and are in the middle of an important assignment (McGuckin, Sealey and Barnett, 2017). Despite all the evidence blaming prolonged sitting time on employees' commitments to meet deadlines due to heavy workload, there is justifiable evidence to suggest that prompts might be helpful in raising employees' consciousness to how much time they have spent in prolonged sitting. Therefore, it is recommended that

future studies should include this strategy in any workplace intervention to break and reduce siting time, with a special focus on getting employees to comply with the prompts.

2.3.4.4 Workplace culture

Evidence shows that both work colleagues and employers or managers play a crucial role in deciding the behaviour exhibited by individuals working in the office. A study reported the perception of a culture of expectation, in which the people in management roles are of the opinion that employees need to be in a seated position before work can be done (Cole, Tully and Cupples, 2015). In one study, participants expressed feeling weird if they were allowed to engage in any form of PA such as stretching, standing up, moving around or taking other forms of break, other than coffee breaks or lunch breaks authorised by their employers (Hadgraft *et al.,* 2016a). In another study in which employers' opinions were sought regarding barriers to promoting PA and taking regular breaks in sitting among call centre employees, some of the managers expressed concerns about possible feeling of discrimination and harassment if they were to be told to move more (McGuckin, Sealey and Barnett, 2017; Renton, Lightfoot and Maar, 2011). A lack of interest was also mentioned, with many employees attracted to the sedentary nature of the job (Renton, Lightfoot and Maar, 2011). Furthermore, when someone breaks up sitting to engage in PA or to reduce sitting time, work colleagues may feel that such a person is not committed to his/her duties or responsibilities when not at their desk (Mackenzie, Goyder and Eves, 2015; Munir *et al.,* 2018). In addition, other limiting factors including an additional cost for employers in relation to equipment, time lost from breaking up work to exercise and liability insurance were also identified (Hadgraft *et al.,* 2016a). To counteract this barrier, evidence from some studies suggests that breaking up sitting in the workplace should be made acceptable, and entrenched within the

organisation culture, something that could be endorsed through the use of a top-down approach (George *et al.,* 2014; Nooijen *et al.,* 2018). This can be achieved and demonstrated by educating (McGuckin, Sealey and Barnett, 2017) and involving team leaders and managers (De Cocker *et al.*, 2015), which will then ensure that workers do not worry about frequent interruptions to sitting at work.

Although the aforementioned barriers need to be considered, one major barrier that has been identified is the perception of excessive sitting as a habit. According to a qualitative study, the most recurrent barrier to breaking up sitting was employees' perception of sitting as a habit (Nooijen *et al.,* 2018). This suggests that the problem of a sedentary lifestyle in the workplace should be viewed and addressed through the lens of behaviour change strategy. Other frequently occurring barriers found among younger employees compared to older employees were a feeling of discomfort (34% vs. 25%, confidence intervals not reported) and tiredness (30% vs. 16%, confidence intervals not reported) when in a standing position. However, these barriers were found to be more frequent among employees with higher sedentary time (Nooijen *et al.,* 2018).

It is worth noting that most of the evidence available is from qualitative studies with small sample sizes, meaning it is difficult to generalise the applicability of these factors (Cole, Tully and Cupples, 2015). This means that it is yet to be clarified whether any demographic influences on barriers and facilitators to sitting interruption might exist (Cole, Tully and Cupples, 2015). If perceptions of barriers to breaking up sitting time were to vary based on age and gender, it would be logical to expect that sitting time would also differ based on age and gender. This question is specifically addressed in section 2.2.4 of this literature review.

There is growing evidence to suggest that tailored interventions are instrumental in overcoming identified barriers to practice or behavioural change, which might improve care and patient outcomes (Baker *et al.,* 2010; Shaw *et al.,* 2005). Findings from other studies have further elucidated the need for tailored interventions and individualised support to minimise the habit of excessive sitting time effectively (Nooijen *et al.,* 2018). Therefore, it is of importance to develop a variety of behaviour change strategies to investigate and identify preferences for individual (McGuckin, Sealey and Barnett, 2017), organisational, and policy intervention methods that may be used to enhance engagement and participation (Blackford *et al.,* 2013), as a 'one size fits all' strategy to changing behaviour will be very unlikely to succeed (Gilson, Straker and Parry, 2012).

2.3.5 The effect of age, gender and ethnicity on sitting time

The influence of age, gender and ethnicity on workplace PA levels is well-documented (Bhatnagar *et al.*, 2016; Celis-Morales *et al.*, 2012; Wallmann-Sperlich *et al.*, 2014). A NICE (2008) report recommended that research should investigate the effectiveness of workplace PA interventions based on the influence of employees' characteristics such as age, gender and ethnicity. However, research on workplace SB, which can be thought of as an extension of workplace PA interventions, often does not explicitly mention SB. This is despite the consistent adverse health outcomes associated with SB, which has led to a call to incorporate recommendations for sedentary time in PA guidelines (Department of Health, 2011). There has been little research in which sitting time in the workplace has been compared between different age, gender and ethnic groups. Although research evidence suggests that an increase in SB increases the risk of adverse health outcomes, there is still a dearth of evidence regarding the correlates of sedentary time in adult populations (van Uffelen, Heesch and

Brown, 2012). Several strategies have been developed to reduce excessive siting time at work, however, it is of paramount importance for intervention developers to understand factors that may have an influence on the amount of time people spend engaged in prolonged sitting and in PA. Understanding these factors will help in the identification of the specific population groups that interventions need to target (van Uffelen, Heesch and Brown, 2012).

There is a disparity in the outcomes of studies investigating the relationship between sitting time and age (Bauman *et al.*, 2011; Matthews *et al.*, 2008; waters-Sperlich *et al.*, 2014). For instance, some studies have reported that both age and gender did not have any effect on sitting time (Chau *et al.,* 2011; Hadgraft *et al.,* 2016b). However, an Australian study examining the prevalence, correlates and moderating effects of occupational sitting among three different age categories (18-39, 40-64, and 65-80 years) reported that occupational sitting was higher among male and younger employees in comparison with females and employees in the older age categories (De Cocker *et al.,* 2014). It is worth noting that the measures reported in this study were self-reported, which may have underestimated the strength of the associations. Evidence regarding the influence of age has been equivocal, with some studies reporting that younger employees tend to sit more than older employees, while the opposite effect or no effect has been reported in other studies. For instance, a study by Clemes *et al.* (2014), which measured SB and PA objectively in office workers during and outside of working hours, reported that individuals who sat the least were at least ten years younger than those who sat the most. One possible explanation for this difference could be that computer use is more important for young adults than older people who are also close to retirement age (Healy *et al.,* 2011a). On the other hand, Chau *et al.* (2011) and Hadgraft *et al.* (2016b) have reported that age was not a significant correlate of sitting time.

A cross-sectional study by Kazi *et al.* (2014), in which sitting time among UK employees was assessed using self-report questionnaires, found that males had higher work sitting time than females. However, there were some limitations that could have affected the validity and reliability of the findings of the study. For instance, the participants included were self-selected, which could have introduced self-selection bias in the response sample. In addition, the study by Kazi *et al.* (2014) did not separate out desk-based employees from employees in all other types of jobs. The differences could be that male employees were in more sedentary jobs than females; therefore, it would be extremely difficult to ascertain the exact influence of gender on occupational sitting time. A cross-sectional study investigating the use of height-adjustable workstations reported that females were significantly associated with more regular use of height-adjustable workstations (Straker *et al.,* 2013), and hence this could explain why women were reported to sitting less in previous studies (Kazi *et al.*, 2014). Moreover, estimation error could have occurred from self-report of the employees' sitting time (Pedersen *et al.*, 2016). Conversely, two different studies from Ireland and Singapore found female employees to have higher occupational sitting time than male employees (Munir *et al.*, 2015; Uijtdewilligen *et al.*, 2017). With the inconsistencies in evidence from previous research, it is paramount for further studies to be conducted with a focus solely on desk-based employees in order to determine the influence of gender.

Research investigating the influence of ethnicity on sitting time is still developing. For instance, in a cross-sectional study of 9384 participants in which occupational sitting time of Chinese, Malay and Indian participants was compared, Chinese participants were found to have the largest occupational and total sitting time, thereby suggesting that interventions should be targeted at this population (Uijtdewilligen *et al.*, 2017). Two similar cross-sectional

studies conducted among the South-East Asian population also found that Chinese have have higher sitting time than their Malay and Indian counterparts (Win *et al.,* 2015). On the other hand, one other study has attempted to report differences in sitting time based on ethnicity. However, due to low numbers of participants from minority ethnic groups, the association between ethnicity and sitting time could not be established (Hadgraft *et al.,* 2016b).

In summary, while evidence from this review clearly shows that occupational sitting time can be influenced by age and gender, findings based on these two variables are inconsistent, and this could be because studies recruited participants from different job types. Moreover, there is currently a dearth of data regarding the influence of ethnicity; therefore, additional studies that target only desk-based employees and compare different age, gender and ethnic groups are needed. This will be addressed in Chapter five of this PhD thesis.

2.3.6 Strategies to break up sitting time in the workplace

Growing evidence from a number of developed countries has shown that an increased level of sedentary activity is a global phenomenon (Straker and Mathiassen, 2009). The WHO (Quintiliani, Sattelmair and Sorensen, 2008) states that: "Workplaces are important settings for health promotion and disease prevention, and that people should be given the opportunity to make healthy choices in the workplace in order to reduce their exposure to risk". The implementation of strategies to promote PA and reduce SB should, therefore, take place in the workplace (Castillo-Retamal and Hinckson, 2011). Currently, there are no set government guidelines to achieve this in the United Kingdom. In order to achieve the expert consensus recommendation of the daily accumulation of 2-4 hours of standing and light PA at work will warrant the development of strategies that can be used to displace sitting with

standing (Buckley *et al.,* 2015; Mansfield *et al.,* 2018). Some of the interventions that have been proposed include lunchtime PA, prompts to stand or move, the use of active workstations, face-to-face communication, walking meetings and many more. The following two sections of this literature review section will address two key areas, namely prompts and active workstations as there has been lots of evidence regarding their efficiencies in reducing sitting time in the workplace (Alkhajah *et al.,* 2012; Chau *et al.,* 2014a; Donath *et al.,* 2015; Evans *et al.,* 2012; Swartz A.M., 2014).

2.3.6.1 Prompts

To change habits it can be important for individuals to receive prompts to enable them to consciously re-engage in decisions that focus on whether to continue to perform or to break up an existing habit (Aarts and Dijksterhuis, 2000). In the context of SB, a prompt is a strategy put in place to disrupt prolonged minutes of sitting (Swartz, Squires and Strath, 2011). Examples of such interventions include prompts based on steps and standing time (Swartz, Squires and Strath, 2011). A previous study suggested using a 5-min break every hour (Owen, 2012) by prompting employees through the use of a wrist-worn device and a desktop computer application (Swartz, Squires and Strath, 2011). During this prompt, employees were instructed to either take a 5-min walk or stand up (Swartz, Squires and Strath, 2011). It is expected that this type of strategy would have an impact on prolonged sitting time caused by forgetfulness due to tight deadlines or heavy workloads. However, people who are not disciplined might ignore the prompt. Prompts have been used in a number of interventions to reduce sitting time. For instance, in one objective study, point-of-choice (PoC) prompts were used to reduce sitting time at work in combination with education, with the control group receiving an equivalent education session, but no prompts. Although no significant

differences were reported between the intervention and control groups with respect to total sitting time, significant decreases were found in both the number (-0.11 events/hour, confidence intervals not reported) and duration (-12.2%, confidence intervals not reported) of sitting bouts greater than 30 minutes (Evans *et al.,* 2012). However, the study was short-term, lasting only 3-5 days, which means the long-term effect of the intervention is unknown. Secondly, participants in the PoC group were significantly older than those in the control/education group, with mean age of 49 years and 39 years, respectively. Although, the potential effect of age on intervention compliance is not yet known, previous evidence suggests that sedentary time tends to increase in older people (Matthews *et al.,* 2008).

The effect of prompts was also examined in a single-blind randomised controlled trial of 38 people (Donath *et al.,* 2015). In this study, all the participants including those in the control group were allocated a height adjustable desk, however, those in the intervention group were also prompted three times daily for the entire 12-week intervention period with a single message telling participants that "prolonged sitting is harmful", "change your working position", and lift up your desk" appearing each day at 10am, 1pm and 3pm. Although the 9% increase in weekly standing time for the intervention group was not significantly different, a moderate effect size of 0.8 was reported, which suggests the study might have been inadequately powered. In addition, there were issues with the parallel experimental design, which could have permitted cross-talk between employees in the intervention and control groups. Accordingly, future studies should consider a cluster RCT to prevent such contamination (Giraudeau and Ravaud, 2009; Torgerson, 2001). This has thus informed the design of the cluster randomized trial in chapter 8. In addition, the accuracy of the result may have been affected due to the choice of device used for the objective measure. The

ActiGraph, which was used in the study, was reported as 32.4% less accurate than the activPAL, which has shown 99.1% accuracy for assessing standing, sitting and slow walking (Kang and Rowe, 2015).

A similar effect of the single-blinded RCT was reported in a 13-week Tasmanian study that examined the effectiveness of a workplace health and wellbeing intervention (WHWI) for 34 desk-based Police Officers, who were randomised into intervention and control groups (Pedersen, Cooley and Mainsbridge, 2014). The intervention group received computer prompts every 45 min to stand up and have a short burst of PA. The intervention resulted in a significant pre-post increase in the energy expenditure of 188 calories when compared to the control group (Cohen's d 0.74; not reported in the paper but calculated from the first table in the article). Although the primary aim of the study was to increase energy expenditure, this was only made possible by breaking up periods of prolonged sitting, which in turn may have caused a decrease in the overall sitting time at work but this was not evaluated. In contrast, a trial by Cooley *et al.* (2013) appraised software that could shut down employees' computers every 45 min to ensure that breaks were taken from computer work to allow for participation in light PA. Despite interviews suggesting that the strategy produced some benefits, such as improved awareness of unhealthy sitting behaviour, some of the participants raised concerns over forced interruptions to the flow of their work. Therefore, it can be argued that the intervention, in spite of its potential efficacy, may lack acceptability among desk-based employees. If this was the case, the intervention may not be implementable in real life settings (Gardner *et al.,* 2017). However, this study does reinforce the need for a tailored intervention to promote acceptability (Nooijen *et al.,* 2018).

2.3.6.2 Active workstations

A number of studies seeking to increase PA and reduce sitting time in the workplace have employed ergonomic adaptations, including the use of adjustable desks (Healy *et al.,* 2013; Neuhaus *et al.,* 2014b), cycling workstations (Elmer and Martin, 2014), treadmill workstations (Thompson *et al.,* 2008) and portable pedal machines (Carr *et al.,* 2013; Carr, Walaska and Marcus, 2012). Growing evidence from recent studies has shown that breaking up prolonged sitting with frequent short bouts of slow walking, or alternating between sitting and standing at work using height-adjustable workstations, can increase energy expenditure and reduce risk factors for cardiometabolic disease (Bailey and Locke, 2015; Thorp *et al.,* 2014). For instance, an Australian RCT pilot study objectively measured sitting and revealed that height-adjustable workstations decreased time spent sitting per working day by 73 min (95% CI = 39, 106) and increased time spent standing at work per day by 65 min (95% CI= 47, 83) (Chau *et al.,* 2014a). In another Australian pilot study in which "stationary sitting desks" were replaced with "height-adjustable workstations" to enable office workers to alternate between sitting and standing, similar results were found (Alkhajah *et al.,* 2012). Sitting time significantly decreased in both the workplace by 143 min (95% CI= 102, 184 min), and during all waking time by 97 min (95% CI= 50, 144 min) when compared to the control group, within one week of the intervention stopping. These effects remained almost unchanged three months post-intervention with workplace and waking sitting time decreased by 137 min (95% CI= 95, 179) per day and 78 min (95% CI= 30, 125 min) per day, respectively. However, this study was limited, as it was not randomised, which suggests that the participants might not be representative of the entire workplaces and workers (Alkhajah *et al.,* 2012). In addition, the intervention participants were public health officers, and this means they might have had

prior knowledge of the health consequences of prolonged sitting, which could have influenced their behaviour during the intervention. Arguably, the actual effect of height-adjustable workstations could have been determined if participants were recruited from different worksites rather than the public health team (Alkhajah *et al.,* 2012). In contrary to these findings, a recent Cochrane review reported there to be only very-low to low-quality evidence that demonstrates the potential of height-adjustable workstations to reduce sitting in the workplace, with no evidence of any long-term effects (Shrestha *et al.,* 2016). In addition, it is yet to be ascertained whether the use of height-adjustable workstations will be universally acceptable, despite evidence regarding minimal disruption to workflow (Chau *et al.*, 2014a; De Cocker *et al.*, 2015; Mackenzie, Goyder and Eves, 2015; Waters *et al.*, 2016). This is partly due to the cost concerns of height-adjustable workstations raised by some managers, which at the moment costs ≥£279 (US $375) per single unit (Gardner *et al.,* 2017) and US $400 for a double-monitor unit (Healy *et al.,* 2013).

The acceptability of height-adjustable workstations was evaluated in an RCT cross-over pilot trial entitled "Stand@Work" in which the perceptions and experiences of desk-based employees on the use of height-adjustable workstations were assessed using focus group interviews after a 4-week intervention (Chau *et al.,* 2014b). Participants expressed feeling self-consciousness and that they were intruding on their fellow colleagues in the open-plan office. In addition, participants experienced a lack of privacy to carry out confidential assignments, make telephone calls, as well as wrist discomfort when moving the mouse and sore eyes due to their close proximity to the monitor when standing (Chau *et al.,* 2014b; Mackenzie, Goyder and Eves, 2015). Therefore, while height-adjustable workstations appear to be beneficial in reducing sitting time, open-plan workspaces might not be ideal for such

interventions. In contrast, a study using interviews (Grunseit *et al.,* 2013) among employees following the use of height-adjustable workstations reported high levels of usability and acceptability.

Similarly, a group of experts working on a 1-year prospective trial using treadmill desks reported a significant decrease in total daily sedentary time of office workers at the end of six months of 9%, from 1,020 ± 75 min per day to 929 ± 84 min per day (Cohen's d = 1.20, calculated from data reported) (Koepp *et al.,* 2013). However, by the end of the 12-month intervention, the effect had reduced to only 978 ± 95 min (Cohen's d = 0.55, calculated from data reported) spent sitting per total day. However, details of sedentary time at work in the study were not reported. Although treadmill desks were reported to be effective in reducing sitting time among desk-based employees, the results could have been influenced by the time-series design in which there was no control group, with pre- and post-intervention data collected from the same participants. Finally, a systematic review by MacEwan *et al*. (2015) found that standing and/or treadmill desks were useful for breaking up sitting and have potential for improving some selected cardiometabolic health markers, although effect sizes were not reported. In contrast, a study by Gilson *et al.* (2012) in an open plan office, in which office employees were encouraged to use "hot desks" in a two-week intervention, did not find any significant change in sitting time of the employees (Cohen's d = 0.05; calculated from data in Figure 1 of the study).

Nevertheless, mounting evidence has indicated that there would be better impacts on workplace sitting if height-adjustable workstations are employed alongside a wider approach that focuses on several levels of influence on behaviour (Chu *et al.*, 2016; Owen *et al.*, 2011). For instance, a multicomponent intervention was assessed in an RCT, with the intervention

consisting of a portable pedal machine, access to a motivational website for breaking-up sitting tips, and a pedometer to enable participants to self-monitor their behaviour (Carr *et al.,* 2013). The authors reported a significant reduction in workplace sedentary time of 58 min per day (95% Cl= 1.0, 118.4) at the end of the 3-month intervention. However, this study was limited due to concerns over the generalisability of findings, as only a small sample size of 40 middle-aged women employees from a single institution were included. Similarly, a decrease in sitting time at work was observed in a 4-week non-randomised multicomponent intervention trial conducted by a group of Australian experts (Healy *et al.,* 2013). The components of the interventions included provision of height-adjustable workstations as well as both organisational and individual strategies. The organisational strategy comprised a 45-min researcher-led meeting with unit representatives from the management and intervention group to highlight the importance of organisational support for the successful adoption of the intervention, while individual strategies ensured that verbal instruction on the use of the desks provided was given, followed by 30-min face-to-face coaching sessions and a weekly follow-up telephone call in the remaining three weeks to give feedback to participants on their sitting behaviour. The intervention resulted in an average decrease in sitting time of 122 min (95% CI= 89, 161) and an average decrease in prolonged bouts greater than 30 min during the 8-hour working day of 65 min (95% CI= 40, 105) (Healy *et al.,* 2013). However, it is not clear if the observed change in employees' sitting behaviour would remain the same if the intervention were longer-term. In addition, selection bias could have been introduced by the non-randomisation of the participants.

There have been few studies that have been purposely targeted both reducing occupational sitting and increasing walking in the workplace. Evidence from two such studies based on the

'sit less, move more' web-based program referred to as *Walk@Work*, makes use of incidental, and sustained walking strategies (Gilson *et al.,* 2013; Gilson *et al.,* 2009). These studies reported no significant difference in sitting time (Cohen's d = 0.14, calculated from article) (Gilson *et al.,* 2009), but there was a significant increase in walking time of almost 1,500 steps per day (Cohen's d = 0.73, calculated from article) (Gilson *et al.,* 2013; Gilson *et al.,* 2009). However, there was evidence of intra- and inter-individual variability in sitting and changes in walking across the programme. This is an indication that combination strategies might be effective in some, but not all employees.

Elsewhere, a Danish study investigated the adherence and effectiveness of a multi-component intervention for reducing sitting time in the workplace using a cluster-RCT design (Danquah *et al.,* 2017). They reported a reduction in daily sitting time of 71 min (95% CI = 57, 85) and of 48 min (95% CI= 34, 62) after both month and three months, respectively, compared to the control group. The intervention provided social support (appointment of ambassadors and managers as role models to ensure commitment), environmental modification (installation of high meeting tables, and provision of walking meeting routes), a lecture (provision of a leaflet and delivery of a 15-min lecture to increase knowledge on SB), workshops, emails and text messages. One of the strengths of this objective study is that a relatively large population size of 317 workers from 19 different locations was included. However, the study did not include follow-up measures, and used the ActiGraph rather than the activPAL, which might have decreased its accuracy for measuring sitting time (Kang and Rowe, 2015).

It appears that active workstations and computer prompts, when used individually, in combination, or when used jointly with other components such as education and social

support, might be effective in the reduction of sitting time and time spent engaged in prolonged sitting bouts whether in the short-term or in the medium-term. However, the efficacy of multi-component interventions is variable across the limited number of studies available. Furthermore, many employers might be reticent to implement some of these strategies if they feel that employees may be distracted, which may lead to a reduction in their productivity (Pereira *et al.,* 2015). There is a dearth of evidence in this area, perhaps due to the focus of most studies of active workstations on the effect on health, rather than on productivity (Conn *et al.,* 2009). The evidence regarding activity-permissive workstations for decreasing occupational sedentary time was evaluated in a systematic review (Neuhaus *et al.,* 2014a). This review reported that activity-permissive workstations might be effective in reducing sedentary time at work by 77 min (95% CI= 35, 120) without any harmful effect on the performance of office workers. Similarly, a qualitative study that explored the experience of using a height-adjustable workstation from an employer's point of view reported that such environmental modification does not cause any interruption to work, as tasks can still be carried out in the same location (Chau *et al.,* 2014b), which suggests that productivity time might not be lost. A recent multicomponent SMArT study of 146 participants that reduced siting time at three months by 50.6 min (95% CI= 78.7, 22.5) and six months by 64.4 min (95% CI= 97.3, 31.5) has shown a sustainable long-term effect on job performance after 12 months duration (Edwardson *et al.*, 2018b). However, the evidence base in this area is still in its infancy, meaning that further studies, such as a systematic review, should be carried out to investigate if the effect of workstations on productivity is positive or negative, and future interventions should determine whether the productivity of employees is modified.

2.3.6.3 Other strategies

There are many other strategies that could be used to decrease workplace sitting such as lunchtime walking (Thogersen-Ntoumani *et al.,* 2015), walking meetings (Danquah *et al.,* 2017), standing meetings (De Cocker *et al.*, 2015; Gilson *et al.*, 2011) or lunchtime yoga programmes (Cheema *et al.,* 2011). According to Thogersen-Ntoumani *et al.* (2010), lunchtime walking interventions are beneficial for employees who are unable to embark on active commuting, for instance, workers with logistic reasons or childcare commitments. In a different study, lunchtime walks were also found to improve enthusiasm, relaxation and nervousness at work (Thogersen-Ntoumani *et al.,* 2015). One advantage of such interventions is that they are cost-efficient and could be sustainable in the long-term (Brown *et al.,* 2012). Other strategies to break up sitting time include having standing or walking meetings, privileging face-to-face communication over emails and phone calls, and strategically placing facilities such as bins, printers, and water dispensers in centralised locations within the workplace (Hadgraft *et al.,* 2016a). Findings from interview studies suggest that desk-based employees would find standing meetings to be an acceptable strategy for reducing sitting (De Cocker *et al.*, 2015; Gilson *et al.*, 2011), however, only limited evidence regarding lived experiences of standing in normally-seated meetings exits. To date, research into standing meetings has solely focused on responses to the subject matter and frequency of meeting (Stray, Sjoberg and Dyba, 2016), rather than the experience of standing in meetings (Mansfield *et al.,* 2018). One factor that could determine whether standing in meetings would be acceptable is that experience when doing so would correspond to expectations (Grunseit *et al.,* 2013; Rothman, 2000). This, however, suggests that there is a likelihood for employees to discontinue standing during seated meetings, especially if people encounter intolerable or

hostile experiences (Rothman, 2000). However, a Cochrane systematic review of 34 studies reported that no studies were found to have investigated the effects of either standing and walking meeting on sitting time (Shrestha *et al.,* 2018). Smith *et al.* (2016) elucidated that if a printer is positioned too far away from an employee's desk, there is a tendency for such individual to compensate for the distance by accumulating print documents, and also collecting printing once or twice a day, which would increase step counts but lead to only a few breaks in sitting time. However, positioning the printer too close to the employee's desk may cause the employee to print more regularly and, therefore, increase the number of breaks in their sitting time, without increasing their number of steps. Thus, intervention developers need to identify an optimal distance to enable desk-based employees to accrue a high number of steps and breaks from sitting.

Based on this review, it appears to be paramount for public health intervention strategies that focus on decreasing and breaking up occupational sedentary time to be developed and tested. Although a few interventions have been reported to be effective in reducing SB in the workplace, studies reveal inconsistent findings. Thus, it remains unclear which types of interventions and modes of delivery should be recommended (Shrestha *et al.,* 2016). However, one important aspect of intervention development is acceptability testing, which checks if the strategies used in the delivery of intervention targeted at a particular population will be received by the same set of people (Craig *et al.,* 2008). Evidence from this review shows that interventions need to target different areas that predict behaviour, and this is why multicomponent interventions have been reported to be more effective in breaking up and reducing sitting time (Shrestha *et al.,* 2016).

2.3.7 Measuring productivity and performance

In order to determine whether there is any effect of an intervention to reduce occupational sitting or break up sitting time on productivity and performance, it is essential to be able to accurately measure productivity and performance. These two terminologies have been used interchangeably; however, performance refers to a generic terminology that can be applied to all concepts that determine the level of success of a particular company (Tangen, 2005). Performance has also been described as the expertise with which individuals carry out the core substantive or technical tasks crucial to the requirements of their job (Koopmans *et al.,* 2016). Performance in this context refers to the efficiency of employees in tasks central to their office work including, but not limited to, data entry, reading and browsing. Productivity, on the other hand, is defined as the rate of making something, which is often judged in terms of the resources needed to do so, either people or materials (Oxford, 2009). This definition could be used for either a company or organisation, as well as for an individual worker, in which case productivity would be the output of the worker for a given period of time. In this thesis, worker productivity is defined as evaluations of work output, together with cognitive function that could be required to perform office-related tasks (Miyagi *et al.,* 2009). Evidence from several studies investigating the impact of active workstations on productivity has used cognitive performance as a proxy measure of productivity (Chau *et al.*, 2016; Donath *et al.*, 2015; Koepp *et al.*, 2013). In this context, cognitive performance refers to employees' performance in cognitive tasks, such as maths, attention, processing speed and memory, and this is considered an important measure of work productivity (Alderman, Olson and Mattina, 2014; Bantoft *et al.*, 2016; Chau *et al.*, 2016; Donath *et al.*, 2015; Elmer and Martin, 2014; Koepp *et al.*, 2013; Koren, Pisot and Simunic, 2016; Larson *et al.*, 2015a; Larson *et al.*, 2015b;

Matthews *et al.*, 2008; Ohlinger *et al.*, 2011; Sliter and Yuan, 2015; Torbeyns *et al.*, 2016). There are several ways in which productivity has been evaluated in research. One method is to use subjective appraisals of productivity, by either the employee or their line manager. Such assessments often take the form of questionnaires, such as the Endicott Work Productivity Scale (EWPS) (Endicott and Nee, 1997), the Health and Labour Questionnaire (HLQ) (Rajaratnam *et al.,* 2014), the Work Limitations Questionnaire (WLQ) (Arumugam and MacDermid, 2013; Takegami *et al.,* 2014), and the Work Productivity and Activity Impairment Questionnaire (WPAI) (Varela *et al.,* 2016). However, as with all questionnaires, problems related to recall bias have been reported. Another possibility that avoids this problem would be to use ecological momentary assessment (EMA), which has been used in a variety of different contexts (Runyan *et al.,* 2013). The EMA technique involves participants being prompted at random times throughout the day to respond about their current behaviour and symptoms, which has the advantage of sampling as close as possible to the event (Moskowitz and Young, 2006). This technique is being increasingly common due to the availability of electronic devices such as smartphones, which can be used to deliver prompts at random time points throughout a working day and thus could be adapted to an office environment.

There are also objective performance metrics related to productivity. These tend to be role-dependent and can also be related to health. Commonly-used metrics include absenteeism and presenteeism. It is straightforward to measure absenteeism in most workplaces, with either the number of days absence collated by the human resources department or self-reported absenteeism typically used (Isah *et al.,* 2008; van den Heuvel *et al.,* 2005). With respect to presenteeism, which can sometimes be referred to as working while sick, three questionnaires (Work Limitation Questionnaire, the Work Ability Index, and Health and Work

Questionnaire) were identified as most suitable for research use when considering the effect of PA (Brown *et al.,* 2014).

This review has shown that excessive SB occurs in the workplace through prolonged sitting. It has identified that there are different factors that might be barriers and facilitators to reducing and breaking up prolonged sitting in the workplace. However, these barriers may differ from person to person, which could have caused the problems of adherence that have been noted. Furthermore, there are some concerns about the effect of SB interventions such as active workstations on employees' productivity. Therefore, a behavioural diagnosis should be carried out to address these problems. This thesis will develop an intervention that takes the needs of office workers into consideration to as increase adherence to the intervention. Since the problem of excessive sitting was recognised as behavioural, different behaviour change strategies will be reviewed in the next section to successfully identify the most suitable theory to adopt.

2.4 Section Three: Developing Complex Interventions

2.4.1 The Medical Research Council guidance on complex interventions design

There is mounting evidence that theoretical, evidence-based frameworks should inform interventions targeted at changing behaviour in order to gain insights into the mechanisms through which implementation might likely succeed. The Medical Research Council guidelines recommend that interventions should start with a "theory" phase and then progress to a "modelling" phase, before a final series of experimental phases, which, in order, are exploratory trial, definitive RCT, and long-term implementation (Craig *et al.,* 2008; Medical Research Council, 2000; Michie *et al.,* 2008). These processes have now been condensed into four stages: "Development", "Feasibility / Piloting", "Evaluation" and "Implementation", as illustrated in Figure 4 (Craig *et al.,* 2019). Within the development phase there are three stages. Firstly, there is a requirement to identify the evidence base, closely followed by the identification of the theoretical frameworks through which the intervention will be developed and modelled. The final stage in this initial phase, which is known as modelling, involves hypothesising and testing what is being targeted, such as determinants of behaviour, and how this can be done, such as behaviour change techniques (Campbell *et al.,* 2007). However, these phases do not inevitably take place in a sequential order, and rather than being seen as a fixed "to do list", they should be seen as a framework to help researchers define where they are in the research procedure, as some preliminary evidence might already exist (Medical Research Council, 2000). This current thesis focuses primarily on the first two phases of development, both theory and modelling, and feasibility/piloting testing. Accordingly, the

next section of the literature review for this thesis focuses on relevant theories, ending with the identification of the most suitable theory in which this thesis can be rooted.

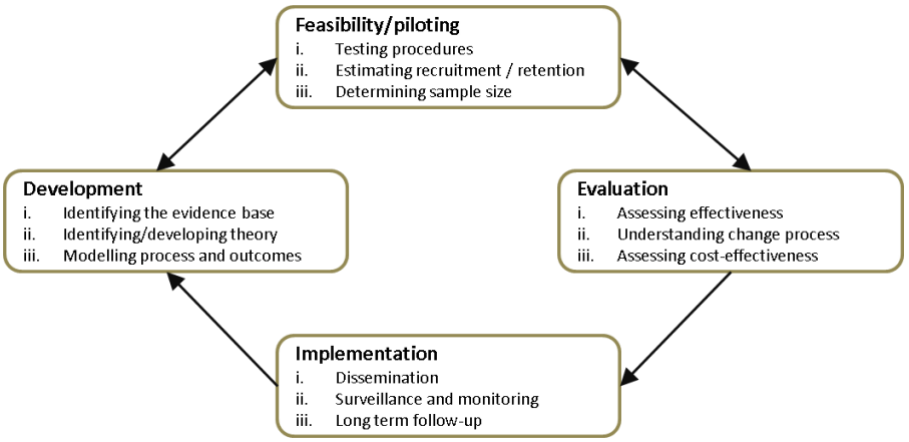

Figure 4: The MRC framework for developing and evaluating complex interventions

Adapted from The Medical Research Council (2006).

2.4.2 Theoretical foundations for behaviour change

While changing behaviour can be challenging, interventions are more effective if they are informed by theory. There are a wide range of theoretical models of behaviour that could be employed in this endeavour, including, but not limited to, the Social Ecological Model (SEM) (Bronfenbrenner, 1979), and models of health-related behaviour including Social Cognitive Theory (SCT) (Bandura, 1986), Transtheoretical model (Prochaska and Diclemente, 1983), and the Theory of Planned Behaviour (TPB) (Ajzen, 1991).

2.4.2.1 The Social Ecological Model

The Social Ecological model (SEM) provides a framework that can be used to comprehend and conceptualise a wide range of factors that can predict behaviour (Sallis *et al.,* 2006). Contrary to the assumptions that behaviour is determined by a narrow set of psychological variables

(Sallis *et al.,* 2006), SEM posits that it is probable for the determinants of behaviour to be context precise, numerous, interrelating, and operate from multiple domains, such as the environment and social context (Sallis, Owen and Fisher, 2008). Determinants of behaviour change can be on four levels, which are intrapersonal, interpersonal, policy and environmental. These determinants have direct or indirect influences on behaviour through the provision of signals that predict the ease with which a specific behaviour will occur (Sallis *et al.,* 2006).

Sallis *et al.* (2006) elucidated that to achieve an optimal change in behaviour, there has to be positive social norms and social supports for behaviour change, as well as the support of both policy and environmental factors for healthy choices, coupled with motivated individuals that have been educated about the importance of making healthy choices. The SEM has been used successfully in a number of interventions that have targeted PA (Cochrane and Davey, 2008; Essiet *et al.,* 2017; Sallis *et al.,* 2006) and SB (Dunstan *et al.*, 2013; Neuhaus *et al.*, 2014c), however its use in interventions targeting SB in the workplace is still at the infancy stage (Healy *et al.,* 2013; Mullane *et al.,* 2017). Most intervention studies targeting SB in the workplace have investigated the influence of environmental strategies, such as the introduction of height-adjustable or treadmill desks, on work tasks (Alkhajah *et al.,* 2012; Beers *et al.,* 2008; Gilson *et al.,* 2012; McAlpine *et al.,* 2007; Pronk *et al.,* 2012; Thompson and Levine, 2011). However, there is emerging evidence that both intrapersonal differences and interpersonal factors could also be responsible for differences in the success of interventions targeted at SB (Gilson *et al.,* 2012; Straker *et al.,* 2013). Adopting such an approach might be difficult in practice, as the determinants behind the factors are complex and diverse in nature (Biddle and Fuchs, 2009). Mullane *et al.* (2017) reported a connection between work-specific

individual, cultural, physical and organisational factors and workplace SB. In their study, face-to-face interaction was found to be negatively correlated with pronged sitting, while employees who have private offices were found with higher sitting, lower standing and higher prolonged sitting times than those in open plan offices (Mullane *et al.,* 2017), which underlines the need for workplace interventions to reduce SB to consider both job types and sectors. It should be noted that despite the comprehensiveness of the SEM framework, it is somewhat vague and fails to explicitly identify constructs for possible inclusion in interventions. Given that the list of probable constructs is quite long and needs to be identified based on theoretical relevance, the adoption of health behaviour models is warranted to foster a better understanding of workplace SB (Biddle and Fuchs, 2009; Owen *et al.,* 2011).

2.4.2.2 Models of health-related behaviour

A wide range of health behaviour theories have been employed to understand numerous health-related behaviours, such as condom use (Gomes and Nunes, 2018; Reid and Aiken, 2011), PA behaviours (Howlett *et al.*, 2017) and healthy eating, all using the TPB (Fila and Smith, 2006). Each of these theories is discussed below:

2.4.2.2.1 Social Cognitive Theory

Social cognitive theory (SCT; Bandura, 1986) is a modified and improved version of social learning theory (Bandura, 1986). It is formed from three different types of expectancy namely situation-outcome, action-outcome, and perceived self-efficacy (Bandura, 1986). Situation-outcome expectancies have to do with beliefs about what the outcome would be if there was no personal action. On the other hand, action-outcome expectancies are based on the belief

that outcomes only occur due to the effect of personal actions, while perceived self-efficacy refers to the confidence level and beliefs that people have about their ability to perform a behaviour or action needed for a particular outcome (Bandura, 1997; Bandura, 2004). According to Williams *et al.* (2005), SCT posits that individuals will take actions that are deemed to result in positive outcomes, but will evade behaviours perceived to lead to negative outcomes. In contrast, Schwarzer (1992b) puts forward that while situation-outcome expectancies signify the belief that things happen without being prompted by personal action, both action-outcome and self-efficacy expectancies enable the possibility to change and to be able to manage any sort of health threats by taking action. Taking this into consideration, a clear causal ordering is believed to exist among the three types of expectancy. This is based on the assumption that situation-outcome expectancies influence behaviour based on the impact they have on action-outcome expectancies, which are believed to be progenitors of self-efficacy. Through interaction with other components of SCT, self-efficacy expectancies are projected to have both direct and indirect influences on behaviour (Lee *et al.,* 2018). Indeed, self-efficacy can be considered to be the most important prerequisite for changing behaviour using SCT (Plotnikoff, Gebel and Lubans, 2014). It has been suggested that people who have a high level of self-efficacy pursue more challenging and ambitious goals (Luszcznska and Schwarzer, 2005) and often see themselves succeeding (Chater and Cook, 2014).

Therefore, SCT postulates that the tendency that an individual has to embrace a health-enhancing behaviour or eschew a health-impairing behaviour is contingent on: the expectancy that the individual is at risk, the expectancy that behaviour change would minimise risk, and lastly, the expectancy that the individual has the capability to adopt or

refrain from the behaviour (Chater and Cook, 2014). For instance, two Australian studies revealed that the probability of having negative perceptions of the amount of PA facilities within a 2km radius around the home was higher among adults with low self-efficacy for PA than those with high self-efficacy (Ball *et al.,* 2008; Gebel, Bauman and Owen, 2009). Research investigating the relationships between social-cognitive factors and SB is limited. However, evidence from cross-sectional studies indicates that some social-cognitive constructs may be correlates of occupational sitting time. For instance, a cluster RCT that investigated the mediating role of social-cognitive constructs during an intervention to reduce workplace sitting time, reported that social-cognitive factors could only explain part of the variation in occupational sitting reduction (Hadgraft *et al.,* 2017). Therefore, it would be more beneficial to understand the significance of other levels, such as environmental and interpersonal, which can influence instigating and sustaining change in workplace SB (Hadgraft *et al.,* 2017).

2.4.2.2.2 Theory of Planned Behaviour

The Theory of Planned Behaviour (TPB: Ajzen,1985) is an extension of the Theory of Reasoned Action, which seeks to understand and predict behaviours (Fishbein and Ajzen, 1975). Compared with the HBM, the TPB has amassed significantly more evidence from systematic reviews and meta-analyses regarding the predictive abilities of its components (Coulson *et al.,* 2016). The TPB is based on the principle that attitudes, subjective norms (SN) and perceived behavioural control (PBC), have a direct influence on the intention of an individual to execute behaviour, and that PBC has a direct relationship with behaviour (Ajzen, 1991).

The TPB has been applied to a number of health behaviours including smoking behaviour (Karimy *et al.,* 2015), PA behaviour (Shafieinia *et al.,* 2016), and SB behaviour (Prapavessis, Gaston and DeJesus, 2015). In the context of SB, the TPB proposes that the main determinant of actual sedentary time is a person's intention to engage in sedentarism (Prapavessis, Gaston and DeJesus, 2015). Rhodes and Dean (2009) reported that intentions to carry out four different SBs including television viewing, using a computer, listening to music or reading, and socialising, were typical for all of these behaviours, and that these behaviours are influenced through intention. Similarly, in a systematic review of 16 studies, differences were identified in the predictive utility of TPB, with intention being the most predictive construct for all behaviours, suggesting that the TPB model is population and behaviour-specific (Akbar, Anderson and Gallegos, 2015). For instance, a higher level of perceived behavioural control over sitting has been reported to have a link with decreased occupational sitting time (De Cocker *et al.,* 2014; Prapavessis, Gaston and DeJesus, 2015) and increased levels of standing at work (Meyer, Wu and Walsh, 2016).

On the other hand, there are limitations to the use of the TPB, with most studies using a cross-sectional design when exploring correlations and prospective connections between the components of TPB and behaviour (Noar and Zimmerman, 2005). However, in the case of actual experimental application of TPB, a systematic review of 24 studies concluded that there was insufficient evidence to comment on the usefulness of the theory (Hardeman *et al.,* 2002). Since then, several other experimental studies have reported that variations in attitudes, PBC, and SN, as used in the TPB, have not eventually led to behaviour change (Chatzisarantis and Hagger, 2005; Sniehotta, 2009). This is because people might not follow through with their intention to change and maintain their behaviour, thereby suggesting that

intention is not a good predictor of health behaviour change, otherwise known as 'intention-behaviour gap' (Faries, 2016; Sniehotta, Presseau and Araujo-Soares, 2014). Sheeran *et al.* (2013) criticised the theory for placing too much emphasis on rational reasoning, whilst unconscious influences on behaviour were excluded.

It is, therefore, suggested that whilst cognitions itemised by the TPB remain relevant in helping to understand, predict, and change health-related behaviour, emphasis should be placed on an alternative broader theoretical approach to health behaviour and behaviour change, rather than more correlational studies of the TPB (Sniehotta, Presseau and Araujo-Soares, 2014).

2.4.2.2.3 Transtheoretical model

Initiatives seeking to promote workplace PA programmes often suffer from poor adherence due to interventions not being tailored to meet the individual needs of employees (Wong, Koh and Lee, 1998). In contrast, health interventions that offer tailored information have been shown to be more effective when individuals who are habitually sedentary or motivated to change are being targeted (Ogilvie *et al.,* 2007). The TTM is a model of intentional change that takes the ability of individuals to make decisions into consideration. The TTM was developed from a systematic amalgamation of various theories of psychotherapy, in addition to an analysis of notable theories of behaviour change (Prochaska and Diclemente, 1983). This model integrates four interrelated constructs that are deemed crucial for behaviour change, including stages of change, decisional balance, self-efficacy and the processes of change (Callaghan, Khalil and Morres, 2010).. The TTM is based on the principle that five discreet

stages are involved for individuals to change their behaviour (Sutton, 2005). These stages are pre-contemplation, contemplation, preparation, action, maintenance, and relapse.

The model considers the concept of behaviour change to be dynamic (Marshall and Biddle, 2001), meaning that navigation can occur through the different stages in a cyclical, rather than a sequential, pattern, as people make various efforts to change behaviour prior to reaching their goals (Marcus *et al.,* 1996). Self-efficacy reveals that the confidence level of people with respect to their capability to survive high-risk situations, without relapse, is situation-specific (Huang *et al.,* 2016). Based on the assumptions of the TTM, self-efficacy consistently rises from pre-contemplation to maintenance stages upon weighing the pros and cons (Levy and Cardinal, 2006; Spencer *et al.,* 2006), suggesting that efforts should be targeted at decision-making capability as well as psychological factors that predict a person's behaviour change, rather than the behaviour itself (Daniels *et al.,* 2014). A recent study reported that the stage distributions for evading SBs varied in males and females, highlighting the need for interventions to reduce SB to be tailored to individuals within each stage (Han, Gabriel and Kohl, 2017). However, the application of this model has received so much criticism that it may not be applicable to PA interventions due to its complexity, the dearth of validated staging algorithms and the probability that the actual determining factors changing activity are excluded in the TTM (Adams and White, 2005). Adams and White (2005) elucidated that interventions targeted at promoting PA should have long lasting effects in order to have public health impacts, however, staged-targeted interventions are mostly short-term, and circumscribed to educational strategies. This suggests that TTM may not be applicable to interventions targeting SB, which is often depicted as an integral part of PA programmes. Finally, the TTM has been described as not suitable for behaviour change, despite evidence

to suggest its ability to induce stage progression, since simply moving between stages might not result in behaviour change, or indeed lead to any increase in motivation or intentions (Adams and White, 2005). It has therefore been suggested that the model is retired (West, 2005).

2.4.2.2.4 Behaviour Change Wheel: A new approach to changing behaviour

One common problem associated in all the previously reviewed theories is that the primary purpose of many of these theories adopted in designing behaviour change interventions is only to help understand or predict behaviours (Kok *et al.,* 2004), but not to understand and facilitate behaviour change (Brug, Oenema and Ferreira, 2005). This indicates that some theories have a high tendency to overlook important constructs, such as skills, action planning, environment and habit (Fishbein *et al.,* 2000; Schwarzer, 1992a).

A systematic review of 19 frameworks with theoretical constructs of behaviour change was conducted by Michie, van Stralen and West (2011). Three criteria were used to evaluate these frameworks, namely comprehensiveness, coherence and a clear link to an overarching model of behaviour. Despite the importance of these determinants in understanding behaviour and developing interventions, it was noted that a number of research studies developing interventions to change behaviour failed to specify their adopted theoretical model, as well as failing to state and monitor the constructs that could serve as mediators of behaviour within a theoretical model (Michie, van Stralen and West, 2011). There has been a limited empirical literature that describes how such interventions can be designed using psychological theory (Michie *et al.*, 2014). One reason for the poor use of theory could be due

to the difficulty in differentiating a wide range of available theories and their constructs due to confusion from overlap (Michie *et al.*, 2014). In addition, there is no single theory that can be used to describe all of the differences in actual or predicted behaviour across different conditions and contexts (Michie, van Stralen and West, 2011). Consequently, Michie, van Stralen and West (2011) developed a comprehensive and pragmatic framework, which is now being used to develop interventions, and this is termed the Behaviour Change Wheel (BCW). The BCW follows a three-stage process (see section 6.3; Figure 8) to the development of intervention, beginning with understanding the behaviour, followed by identifying intervention options, and finally identifying components and implementation options (Michie, Atkins and West, 2014). The first stage, which analyses behaviour, seeks to understand the behaviour of interest in as much detail as possible, while the second stage screens the intervention functions and policy categories to identify what would be most effective to cause a change in the target behaviour. The final stage identifies the intervention content, including the Behaviour Change Techniques (BCTs), that would best suit the intervention functions and modes of delivery of the intervention (Michie, Atkins and West, 2014).

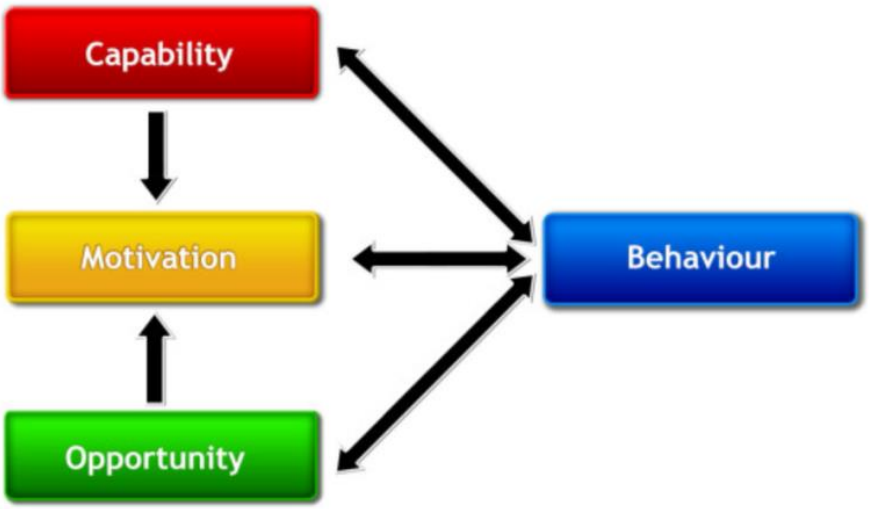

Figure 5: The COM-B system: A framework for understanding behaviour

Reproduced from (Michie, van Stralen and West, 2011).

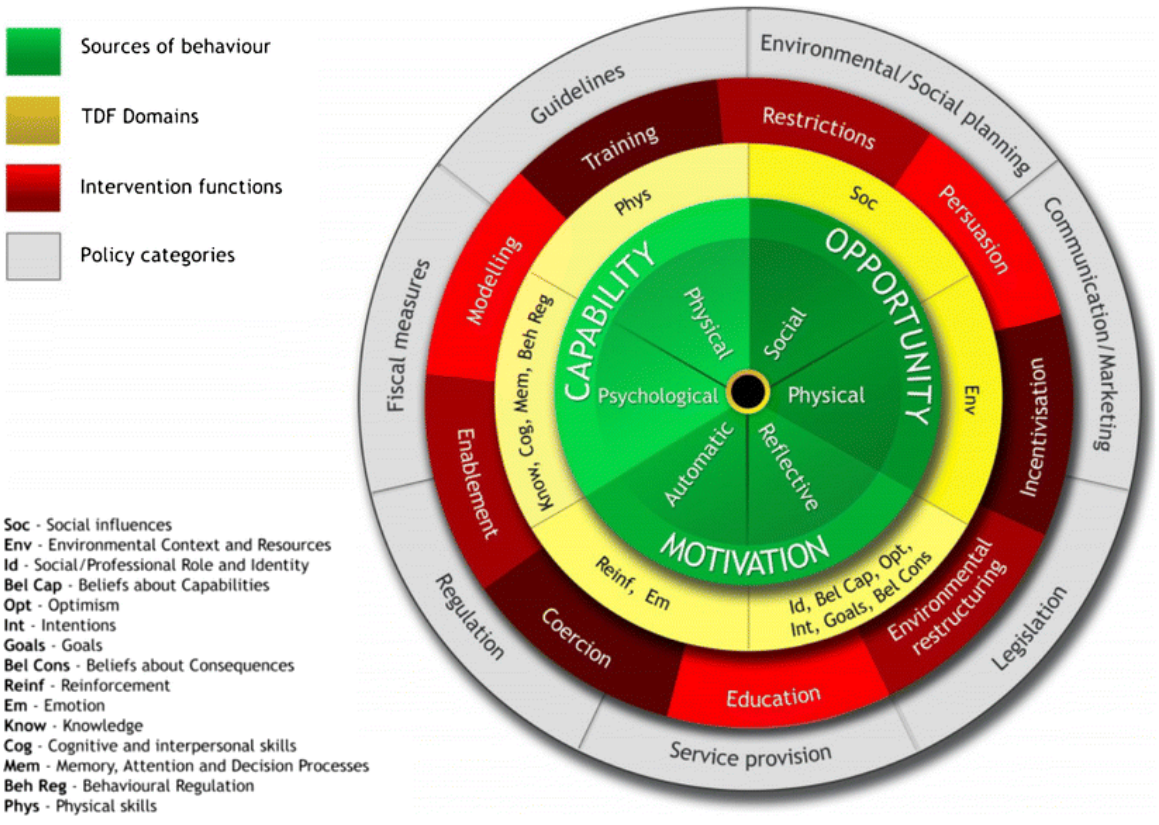

Figure 6: The Behaviour Change Wheel

Reproduced with permission from (Michie, Atkins and West, 2014).

Michie, van Stralen and West (2011) are of the opinion that people need Capability (C), Opportunity (O), and Motivation (M) to perform a Behaviour (B), with this concept leading to the development of the COM-B model to guide the understanding of behaviour in context, as well as to develop behavioural targets when designing an intervention. The COM-B model, which is presented in Figure 5, is the at the core of the BCW (Michie, Atkins and West, 2014; Michie, van Stralen and West, 2011), which is presented in Figure 6. The BCW was designed to help intervention developers' transition from a behavioural analysis of the problem to the design of an evidence-based intervention. This framework was first published to be three-layered; however, it has now been modified to a four-layered wheel due to the addition of the TDF layer. The innermost layer is the COM-B model, with each of the three components subdivided into two separate categories, which are physical and psychological Capability, physical and social Opportunity, and reflective and automatic Motivation.

Capability refers to individual's physical and psychological ability to enact the target behaviour, which usually involves having the required cognitive processing ability, such as attention, memory, knowledge, and skills. Motivation on the other hand refers to the belief systems that strengthen and guide behaviour such as beliefs about capability, intention, and outcome expectancies. It further encompasses habitual processes, and emotional responses. Opportunity points to other factors beyond the individual, both social and physical, which can influence the enablement of the behaviour (Michie, van Stralen and West, 2011). Each of the three components can be further subdivided to capture important distinctions. For instance, (1) 'psychological capability' has to do with the capacity to engage in essential thought processes, while (2) 'physical capability' is concerned with skills to execute the behaviour. In terms of opportunity, (3) 'physical opportunity' is what is afforded by the environment to

enable the behaviour, while (4) 'social opportunity' centres around cultural and social influences. With respect to motivation, (5) 'reflective motivation' involves thinking with the head, which includes evaluations and intentions while (6) 'automatic motivation' involves emotions and habits (Michie, van Stralen and West, 2011). This system does not place priority on any of the individual components, however, it provides a way of identifying to what extent changing one or more components could lead to the desired change in behaviour (Michie, van Stralen and West, 2011).

The second layer of the BCW is the Theoretical Domain Framework (TDF), which functions to unpack the COM-B further to allow a deeper exploration of Capability, Opportunity and Motivation. Cane *et al.* (2012) mapped these domains onto the COM-B, thus allowing intervention developers to come up with an approach that will help to identify key determinants for a particular behaviour, as well as recommend a set of behaviour change techniques that may be useful in addressing them (Cane *et al.*, 2015; Michie, Atkins and West, 2014). The TDF includes constructs drawn from 33 psychological theories, to increase the understanding of behaviour to ensure the processes for change are targeted affectively (Cane, O'Connor and Michie, 2012; Michie *et al.*, 2005). The TDF has 14 key determinants of behaviour change, which are: 'knowledge', 'skills', 'social/professional role and identity' 'beliefs about capabilities', 'optimism', 'beliefs about consequences' 'reinforcement', 'memory, attention and decision processes', 'intentions', 'goals', 'environmental context and resources'**, '**social influence', emotion, 'behavioural regulation' (Cane, O'Connor and Michie, 2012). However, the domain of behavioural regulation has been under-theorised and has not been used to its full capacity (Michie, van Stralen and West, 2011). TDF has been used to identify factors that predict adherence to guidelines and for structuring both interview

questions (Murphy *et al.*, 2014; Patey *et al.*, 2012) and how data analyses are performed (Islam *et al.*, 2012; McSherry *et al.*, 2012). Once detail from the BCW and TDF have been obtained, optimal behaviour change techniques (BCTs) can be identified (Michie *et al.*, 2013). Several scholars have underlined the significance of barriers to change in the context of PA (Bailey, Coller and Porter, 2018; Hoare *et al.,* 2017), with these identified barriers representing common ideas from the previously-mentioned behaviour and behaviour change theories and frameworks. However, inventing an implementation strategy for all guidelines or recommendations may not be achievable and effective, as studies using a one-size-fits-all approach to implementation have not been successful (Lawton *et al.,* 2016). On the other hand, theoretical frameworks provide a common language that can be used to categorise both the targeted problems and interventions in generalisable terms, which will then guide how implementation of strategies can be adapted (Lawton *et al.,* 2016).

A number of theories applied to implementation are targeted at just one role of individual cognitions, social context, and characteristics. The TDF is different as it integrates all the different levels of influence, even though it still focuses on the opinions of people whose behaviour needs to change, as the chief target of the intervention. This does not void its potential to target features of both physical and social environments that may be identified as key determinants of behaviour (Lawton *et al.,* 2016). More succinctly, this pragmatic framework identifies key determinants and constructs, and serves as a guide in explaining current behaviours, which can then be evaluated. The framework can then signal opportunities and methods for an intervention, rather than explaining a set of behaviours theoretically by trying to identify causal processes that can be linked to theoretical constructs (Michie *et al.,* 2008). It should be noted that the TDF component of the BCW, when used

alone, was criticised for two reasons in a study of the experiences of TDF users across diverse clinical environments (Phillips *et al.,* 2015). Firstly, the TDF was found to be time-consuming, especially during interviewing and transcribing phases, and when analysing data. Secondly, variation in the way in which the TDF has been used by researchers was also identified, which could make it difficult to understand and adopt (Phillips *et al.,* 2015).

The third layer of the BCW gives direction, which can then help in the identification of intervention functions from the choice available of Persuasion, Education Training, Modelling, Restriction, Environmental restructuring, Enablement, Training, and Incentivisation (Michie, van Stralen and West, 2011). These functions serve as the means through which an intervention can change behaviour (Michie, van Stralen and West, 2011). The outermost layer of the BCW helps to identify seven types of policy, namely communication/marketing, regulation guidelines, legislation, fiscal, service provision, and environmental/social planning. Policy types and intervention functions then need to be chosen using set criteria (Michie, Atkins and West, 2014). The preferred criteria are known as APEASE, which stands for Affordability, Practicability, Effectiveness and cost-effectiveness, Acceptability, Side effects/safety and Equity (Michie, Atkins and West, 2014; Westland *et al.*, 2017). This concept is important, as individuals, organisations and/or the population at large may be unwilling to embrace interventions that are difficult to implement, too expensive and not cost-effective.

The final step in the design of an intervention is to look beyond the BCW and identify the ideal BCTs from the list of 93 that is proposed (Michie *et al.*, 2013). However, since there could be

other BCTs not yet been identified, the BCT taxonomy needs to be continually updated to allow for easy coding (Michie *et al.,* 2015).

2.4.2.2.5 Justification for choosing the Behaviour Change Wheel

The BCW provides a wide range of benefits for developing a workplace intervention to break up and reduce occupational sitting in office workers. This model is a hybrid of 19 existing models of behaviour change and integrates numerous behavioural determinants that may have an influence on workplace SB, such as unconscious biases and motivation, beliefs and perceptions, and the environment (Michie, Atkins and West, 2014). Moreover, whilst developing the BCW, several multiple level factors, including individual, interpersonal and systems, were taken into consideration (Michie, Atkins and West, 2014). As revealed in the earlier section of this literature review, multi-level factors can dictate the kind of behaviour exhibited by office workers in relation to workplace SB. Thus, it becomes a necessity to address these factors when developing interventions to change behaviour. Furthermore, in contrast to other health behaviour models, the BCW goes beyond merely explaining and predicting workplace SB, but rather offers a systematic method to develop workplace sedentary interventions beginning with an exhaustive analysis of the behaviour (Michie, Atkins and West, 2014). In addition, there is emerging evidence of the BCW being successfully used to change workplace SB (Brierley *et al.*, 2019; Munir *et al.*, 2018) with a long-term viable effect on job performance (Edwardson *et al.*, 2018b). The BCW delivers a rigorous examination of determinants of behaviour at the individual level, as well as behaviour change techniques. However, despite the inclusion of context and system-level BCTs, the BCW does not provide explicit information on organisational-level factors.

CHAPTER 3 METHODOLOGICAL APPROACH AND DESIGN

3.1 Chapter overview

The previous chapter reviewed the literature that informed the rationale for this thesis. Workplace SB, in particular, excessive and uninterrupted sitting is prevalent among office workers and those in desk-based employment (Buckley *et al.,* 2015; Hall *et al.,* 2015; Wilmot *et al.,* 2012). There are many health problems associated with this behaviour, which in turn can lead to economic consequences (Brown *et al.,* 2013; Buckley *et al.,* 2015; Puig-Ribera *et al.,* 2015; Wilmot *et al.,* 2012). Therefore, it is important that interventions are developed to curtail SB in the workplace and its associated consequences. This current chapter details the research approach and design that were used to develop a tailored intervention to decrease SB in the workplace. This chapter also provides details of the philosophical stance taken by the researcher.

3.2 Philosophical Framework and Research Approach

This research study adopts a mixed-methods approach coupled with a randomised control trial (RCT) as a pilot study. Several studies have identified RCT as the gold standard for research, including assessing the effectiveness of workplace interventions (Bhatnagar, Shaw and Foster, 2015; McEachan *et al.,* 2011; Power *et al.,* 2014; Victora, Habicht and Bryce, 2004). The use of RCT minimises selection bias and enables a comparison to be made between the intervention and control groups (Kendall, 2003; Kunz, Vist and Oxman, 2007). However, most studies fail to consider heterogeneity and individual preferences when designing

interventions (Conn *et al.,* 2009), which could be a hindrance to compliance and acceptability (Kunz, Vist and Oxman, 2007; Ye *et al.,* 2014).

The mixed-methods aspect of the research design makes use of a qualitative phase that enables the researcher to understand the actual needs or preferences of the stakeholders (that is, the target audience), through a small representative sample, which could be used to develop a template for an intervention phase. This is consistent with the Medical Research Council guideline for developing complex interventions (Craig *et al.,* 2008; Medical Research Council, 2000; Medical Research Council, 2006).

The research approach for this thesis is found under the pragmatic paradigm and makes use of pluralistic approaches to derive knowledge about the problem, in order to procure a solution (Creswell, 2014; Creswell, 2011). However, there are other philosophical paradigms through which the world can be viewed, which include post-positivist, constructivist and transformative (Creswell, 2014; Creswell, 2011). The post-positivist assumptions are ones that represent the conventional form of research, and often support quantitative research more than qualitative studies. Post-positivism is a way of thinking that challenges the notion of the absolute truth of knowledge and, therefore, sees the need to test a theory empirically (Creswell, 2014; Creswell, 2011). This form of assumption is also referred to as reductionist, as it reduces ideas into a small, discrete set to that is then tested (Creswell, 2014; Creswell, 2011). The constructivist worldview, on the other hand, is regarded as an approach for qualitative research. Social constructivists often make sense from multiple and varied subjective interpretations of other individuals' viewpoints about many things, which are also shaped by the experience and background of the researcher (Onishi, 2013). In the case of a

transformative worldview, emphasis is placed on the need for research to delve into politics to initiate political change, which will confront social oppression at different levels (Mertens, 2010). This worldview centres on the needs of different categories of people or individuals that may have been marginalised (Onishi, 2013).

However, one advantage of pragmatism over all other worldviews is that it provides researchers the freedom of choosing the methods and procedures of research that best suit the purpose of their research study (Onishi, 2013). This is an indication that pragmatists do not commit to a specific philosophy and reality (Creswell, 2011), as this approach relies on a version of abductive reasoning, which switches between induction and deduction (Morgan, 2007). Moreover, it allows for the inductive results obtained from a qualitative approach to act as contributions to the deductive goals of a quantitative approach, and vice versa (Creswell, 2014; Kunz, Vist and Oxman, 2007; Mertens, 2010; Morgan, 2007; Ye *et al.,* 2014). In addition, pragmatism has a high level of belief in the outside world that is both dependent and independent of the mind, and thus opens the door to multiple methods, as well as different worldviews, and assumptions (Onishi, 2013). Other studies in the field of workplace PA and SB interventions have also held the philosophical view of pragmatism, and have followed mixed-methods, as seen in (Edmunds, Stephenson and Clow, 2013; Frantz and Ngambare, 2013; Poobalan *et al.,* 2012; Thogersen-Ntoumani and Fox, 2005; Waters, 2016).

3.3 Research Design

Research designs, often referred to as strategies of inquiry (Denzin and Lincoln, 2011), can be defined as types of inquiry that fall within qualitative, quantitative, and mixed methods approaches, which provide precise direction for procedures (Creswell, 2014). A mixed

methods research (MMR) design is chosen for this study, as it will provide a better understanding of the research problems of this study (Bowling, 2014). This approach has been reported to be more comprehensive than solving a problem from only one point of view, as the two methods that form mixed methods compensate for the weakness of one another. One of the advantages of this design is that numerous themes are generated, allowing each data set to form a part of the research story. On the other hand, its major challenges lie in high time consumption, as the researchers often need to contact participants again for data collection. Moreover, specialist training is often required in both qualitative and quantitative methods. However, in this present PhD thesis, the researcher has experience of data collection and interview skills from previous work as a research assistant, as well as lecturing research methods to undergraduate and postgraduate students. This combination of experiences ensures the researcher can use both methods, without requiring additional training. The aim of the quantitative part of the MMR design is to study a large sample that can be analysed statistically, which could provide a good understanding of the best predictors of an outcome, as well as to test a theory deductively to generalize and replicate findings. The qualitative part of the MMR design, on the other hand, looks at the subject of the research inductively. There are different types of MMR, examples of which include: convergent, exploratory, explanatory, and multiphase (Creswell and Clark, 2011).

Convergent parallel mixed methods is a type of design in which researchers collect both quantitative and qualitative data about the same time, and such data are then merged to generate a comprehensive analysis of the research problem (Creswell and Clark, 2011). An **explanatory sequential mixed method** is a form of design that gives precedence to quantitative studies, which are then sequentially followed by qualitative research for an

explanation of the quantitative findings (Creswell and Clark, 2011). An **exploratory sequential mixed method**, on the other hand, follows the reverse sequence of the explanatory sequential design. In this design, a qualitative study first explores the views and perceptions of participants, which is then followed by an experimental or quantitative phase for testing based upon the qualitative analysis (Creswell and Clark, 2011). However, this thesis adopts the **multi-phase mixed method design.** This research method, which is commonly used in evaluation and programme interventions, enables each separate study to sequentially address a particular set of research questions that evolve from each of the objectives of the overall aim (Creswell and Clark, 2011). This present thesis comprised three different phases: the first phase is a systematic review, which investigated the effect of active workstations on work productivity and performance. The second phase is a mixed-methods explanatory sequential design. This phase started out with a quantitative assessment of the level of PA and sitting time of desk-based employees within two different organisations (a local authority and university in the East of England). The population that sat the most were selected for the qualitative component of the study and were subsequently interviewed to identify the perceived barriers and facilitators to breaking up sitting time, which then led to the identification and development of the workplace intervention, which was tested in an experimental pilot study (quantitative) that included some elements of feasibility. Details of the methods used for each of the studies are presented in each individual study chapter.

CHAPTER 4 THE IMPACT OF ACTIVE WORKSTATIONS ON WORKPLACE PRODUCTIVITY AND PERFORMANCE: A SYSTEMATIC REVIEW

This chapter was conducted in keeping with the MRC framework, which recommends that all complex interventions must start with a systematic review. This review was important as there is currently insufficient evidence regarding the effect of workplace SB interventions on productivity. This chapter has been published in an academic journal listed on page vi.

4.1 Introduction

SB can be defined as "any waking behaviour characterized by an energy expenditure ≤1.5 metabolic equivalents (METs), while in a sitting, reclining or lying posture" (Chaput *et al.*, 2015). Epidemiological studies have revealed that excessive time spent sitting can increase the likelihood of many health outcomes, as highlighted in section 2.2.5, (Dunstan *et al.*, 2010; Dunstan *et al.*, 2012; Dunstan *et al.*, 2013). This is regardless of the amount of time spent in MVPA (Dunstan *et al.*, 2010; Katzmarzyk *et al.*, 2009). Office workers are at increased risk as they spend more than half of their workday sitting (Juneau and Potvin, 2010; Pronk *et al.*, 2012). In one study, office-based employees spent 82% of working hours and 69% of non-work hours engaged in SB (Pronk *et al.*, 2012).

Increasing evidence has shown that SB in the workplace can be curtailed by making changes to the work environment, such as the introduction of active workstations (Manini *et al.*, 2015). For instance, a pilot study replaced "stationary sitting desks" with "height-adjustable

workstations" to allow office workers the option to alternate between sitting and standing (Alkhajah *et al.*, 2012). After one week, the intervention group significantly decreased their sitting time by 143 minutes per day compared with the control group (Alkhajah *et al.*, 2012). A similar study using treadmill desks reported a significant 9% reduction in sedentary time by over 90 minutes at the end of a six month intervention, but this effect declined to 43 minutes at 12 months post-intervention (Koepp *et al.*, 2013). In contrast, during a two-week intervention, the adoption of standing 'hot' desks in an open plan office in which office workers were encouraged to stand as often as possible whilst working did not change employees' sitting time (Gilson *et al.*, 2012). Portable pedal machines have also been used to increase activity while sitting, which is termed "active sitting" and one study reported a 60 minute per day reduction in sedentary time at the end of a three-month intervention (Carr *et al.*, 2013). These studies suggest that sitting time can be reduced in the workplace using active workstations.

While the initiatives outlined above appear to be effective in reducing sitting time, there has been limited research regarding the effect of active workstations on performance and productivity variables (Rhodes, Mark and Temmel, 2012). There is a need, therefore, to investigate the effect of active workstations on productivity and performance to identify their suitability for use in the workplace. The term performance, which is often used interchangeably with productivity, is sometimes described as an umbrella terminology for every concept that determines how successful companies are (Tangen, 2005). Performance can also be defined as "the proficiency with which individuals perform the core substantive or technical tasks central to their job" (Koopmans *et al.*, 2016). In the present study, performance refers to the efficiency of employees in tasks central to their office work

including, but not limited to, data entry, reading and browsing. The term productivity is defined in this review as the quality or state of yielding large result or yielding abundantly, which is often determined by the ratio of output to input (Tangen, 2005). It is inherently complex to determine the productivity of office workers as their activities vary widely, including both repetitive tasks and creativity, depending on the job requirements. For the purposes of this review, as defined in Chapter 2 (section 2.3.7) of this thesis, worker productivity will include evaluations of work output, as well as evaluations of cognitive function that could be required to carry out office-related tasks (Miyagi *et al.*, 2009).

The evidence regarding the effect of active workstations on productivity and performance is equivocal (Hadgraft *et al.*, 2016a). For instance, in one study in which height-adjustable workstations were used, office workers were reported to feel more productive, energized, and focused (Pronk *et al.*, 2012). In contrast, small non-significant reductions in data entry efficiency and accuracy for a data entry task were found among male university students while standing, when compared to sitting (Husemann *et al.*, 2009). However, in such studies using simulated workspaces, it is debatable whether the results are applicable to a real office environment.

Elsewhere, the “Opt to Stand” pilot study which examined the efficacy of height-adjustable workstations in a two-week intervention found no changes in the productivity outcomes; however there was documentation of the long-term effect of the intervention (Chau *et al.*, 2016). Similarly, a systematic review of 12 studies involving the use of cycling, treadmill and standing workstations reported short-term productivity benefits (Dupont *et al.*, 2019). Furthermore, other studies involving the use of treadmill desk, identified walking as a

hindrance to mouse-related tasks such as typing, possibly due to such tasks require a steady posture and the use of hands for precise execution (John *et al.*, 2009; Straker and Mathiassen, 2009). Given the inconsistency in the current research findings, most managers might be reluctant to implement active workstations in the workplace. It has been suggested in one study that it would be very unlikely for organizational management to institute the use of treadmill desks if productivity is harmed (Ben-Ner *et al.*, 2014). This uncertainty reinforces the need for further investigation of the effects of active workstations on productivity and performance of workers. The aim of this systematic review was to examine literature investigating the effect of using active workstations on productivity and workplace performance.

4.2 Materials and Methods

4.2.1 Data sources and study selection

Ethical approval for the systematic review protocol was obtained from the Institute for Health Research Ethics Committee at the University of Bedfordshire on the 28th April 2016 (IHREC611) (See Appendix 2). A systematic literature search was carried out to identify relevant studies. The searched databases were PsycInfo, SPORT Discus, Web of Science, and PubMed for studies published between January 2005 and December 2016. The 2005 cut-off was chosen as very little literature on active workstations exists before this date. The search terms included "active workstation," "height-adjustable workstation" "treadmill workstation," "treadmill desk," "workplace," "work setting," "productivity" and "performance." Duplicates were removed before two reviewers (SO and DH) independently screened titles and abstracts of all identified articles. Only studies that were published in peer-

reviewed journals were included. Additional relevant studies were sourced manually from the reference lists of the retrieved articles. Studies were eligible for inclusion if they met the criteria stated in Table 1, using the PICO (T) framework (Eakin *et al.*, 2010). The PRISMA four-phased flow diagram was used in summarizing the study selection processes (Liberati *et al.*, 2009).

Table 1: Inclusion and exclusion criteria

Term	**Inclusion Description**	**Exclusion Description**
Population	Healthy, working age, adult employees (≥18 years old) from developed countries	Studies where recruited participants have specific comorbidities or diseases (such as diabetes, arthritis, cancer, stroke), special populations (pregnant, physical disability, or cognitive disability), or targeted pain management or musculoskeletal issues. Non-employees (students) in an office-simulated environment
Intervention	Use of workstations such as height-adjustable workstation, treadmill desk; cycling desk	Not office based, not workstations
Comparison	Any comparative study with either baseline measures or non-intervention group as control for comparison.	No comparison measures
Outcomes	Productivity or work performance	No measure of productivity or work performance
Trial design	Randomized controlled trials or quasi-experimental trials	Observational studies

4.2.2 *Quality appraisal*

The methodological quality of the selected articles was independently assessed by two reviewers (SO and DB). Disagreements were resolved with scores from a third reviewer (DH). Eligible studies were assessed with a modified version of the Downs and Black checklist (1998) for reporting, internal validity-confounding, internal validity-bias and external validity (See Appendix 3). The original checklist contains 27 questions, but four questions were considered inapplicable, three of which related to blinding and concealment, which are not relevant in active workstation interventions. A question related to determining power was also omitted. Downs and Black assign two points compliance criteria, giving a maximal score of 24, with the cut-off for inclusion set to 12 (See Appendix 4).

4.2.3 *Extraction and management of data*

Authors of included studies with missing or incomplete data were contacted by email to retrieve further information. In studies where effect sizes were not provided, Cohen's d, otherwise known as the Standardized Mean Difference (SMD), was calculated to determine the effect of the intervention on performance and productivity. The SMD is calculated by dividing the mean difference by the pooled standard deviation (Cohen, 1988). The scale proposed by Hopkins and colleagues was used to describe the magnitude of the SMD observed (Hopkins *et al.*, 2009). This scale describes effects as "trivial" (<0.2), "small" (0.2-<0.6), "moderate" (0.6-<1.2), "large" (1.2-<2.0) or "very large" (≥2.0). A copy of the scale can be seen in Appendix 7. Effect sizes were expressed as negative to indicate decreased performance, irrespective of the direction of the effect. For instance, an increased error rate for a task corresponded to a negative effect size, whereas an increased word count when

typing would have given a positive effect size. All reported effect sizes are in comparison with the control or baseline condition. In addition, studies were categorised into acute, sub-chronic and chronic, based on the duration of the intervention and when the productivity or performance measures were taken. Studies whose interventions lasted ≤ 24 hours (Sardeli, Gaspari and Chacon-Mikahil, 2018) and in which outcome measures were taken during the intervention were classified as 'acute'. In essence, such studies sought to determine whether the use of an active workstation on a single occasion had an adverse effect on productivity or performance. Those interventions that took measurements while using the active workstation, but after allowing at least one day to become accustomed to their use were classified as 'sub-chronic'. Finally, studies in which productivity and performance were evaluated post-intervention after a period of long-term use were termed as 'chronic'.

4.3 Results

4.3.1 Article selection

A flow chart of the selection process is shown in Figure 7. The initial search identified a total of 3303 articles, which was reduced to 1826 after duplicates were removed. The titles and abstracts of the remaining articles were screened against the inclusion criteria, with 1796 articles excluded for reasons including relevance, the population studied, and being an exercise or PA intervention rather than an intervention targeting SB. Twenty articles were identified as potentially relevant and assessed for eligibility. Thirteen articles were rejected after full-text screening as some of these studies did not report effect sizes or data to calculate effect size, and six studies used students working in simulated office environments. The resulting sample consisted of seven articles, with no additional studies identified following a

search through the references of the included articles (Alderman, Olson and Mattina, 2014; Bantoft *et al.*, 2016; Chau *et al.*, 2016; Donath *et al.*, 2015; Elmer and Martin, 2014; Koepp *et al.*, 2013; Koren, Pisot and Simunic, 2016; Larson *et al.*, 2015a; Larson *et al.*, 2015b; Matthews *et al.*, 2008; Ohlinger *et al.*, 2011; Sliter and Yuan, 2015; Torbeyns *et al.*, 2016).

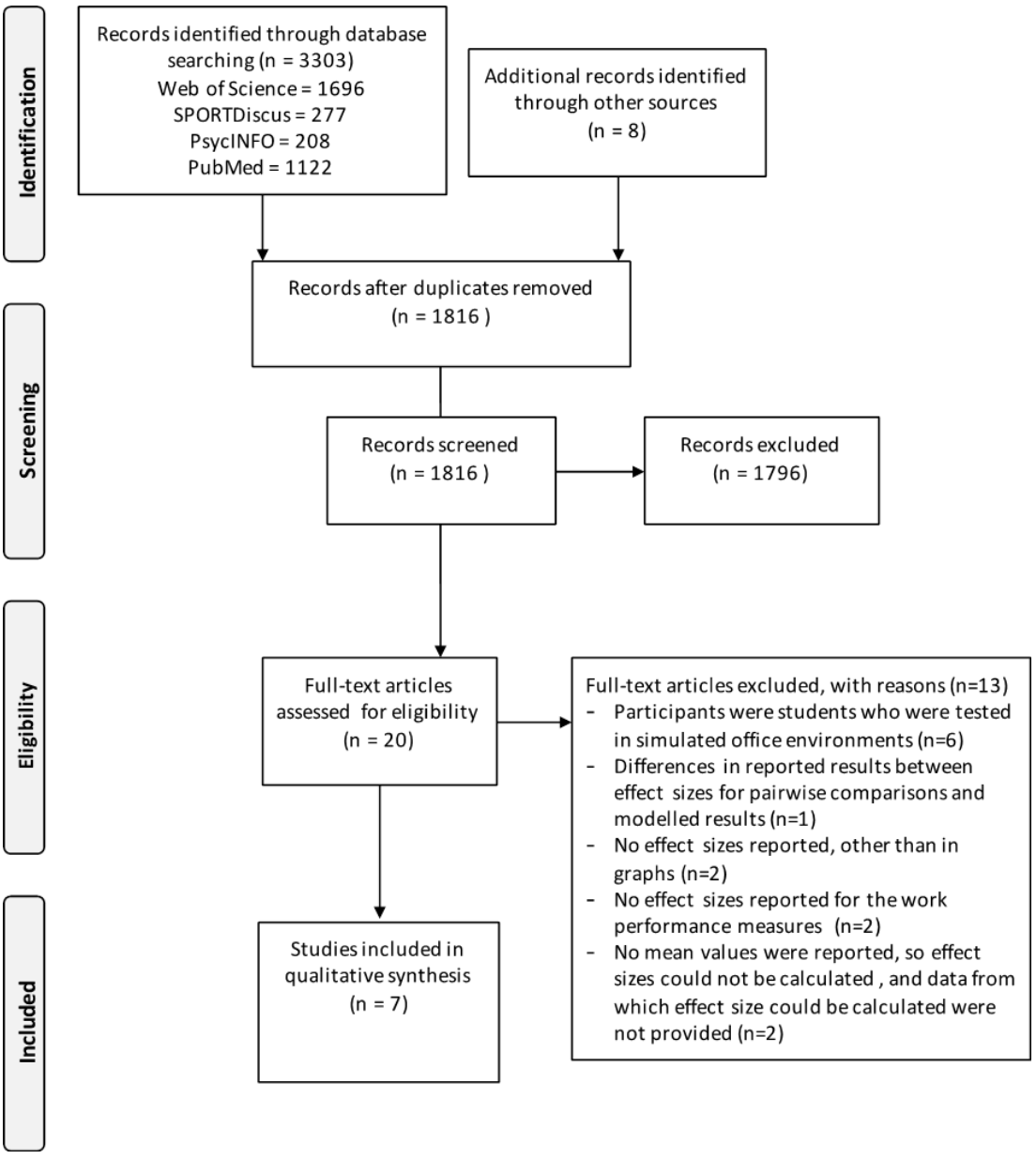

Figure 7: Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) flow chart of study selection

Reproduced from (Liberati et al., 2009)

4.3.2 Study Characteristics

All included studies used office workers as participants (Chau *et al.*, 2016; Donath *et al.*, 2015; Koepp *et al.*, 2013; Koren, Pisot and Simunic, 2016; Matthews *et al.*, 2008; Ohlinger *et al.*, 2011; Torbeyns *et al.*, 2016). The articles contained three different intervention types including treadmill desks (Koepp *et al.*, 2013; Ohlinger *et al.*, 2011), cycling workstations (Koren, Pisot and Simunic, 2016; Torbeyns *et al.*, 2016), and height-adjustable workstations (Chau *et al.*, 2016; Donath *et al.*, 2015; Ohlinger *et al.*, 2011; Russell *et al.*, 2015). Three of the studies (Koren, Pisot and Simunic, 2016; Ohlinger *et al.*, 2011; Torbeyns *et al.*, 2016) were categorised as assessing the acute effects of the intervention , two (Donath *et al.*, 2015; Russell *et al.*, 2015) assessed the sub-chronic effect, while the remaining two studies (Chau *et al.*, 2016; Koepp *et al.*, 2013) examined the chronic effect of active workstations. A total of 16 different productivity and work performance outcomes were identified. To this end, it was deemed that a meta-analysis would not be appropriate given the diversity of the outcome measures and study designs. Detailed characteristics of the selected studies including quality appraisal scores are shown in Table 2. Six of the studies reported details of ethical approval. The authors of the remaining study were contacted by email and confirmed details of their ethical approval.

Table 2: Characteristics of the selected articles

Authors	Participants	Study design and intervention	Study type	Performance measures	Quality (Max 24)
Chau *et al.* (2016) Australia Call center staff	14 females, 17 males 33.0 ± 10.8 years, unspecified health status BMI 26.8 ± 5.5 kg/m^2	Quasi-experimental trial 19-week intervention Height-adjustable workstation	Chronic	Work performance - Call handling time - Time on call - Hold time on call - Wrap up time on call - Customer rating	13
Donath *et al.* ((2015) Switzerland	23 females, 8 males 42.4 ± 11.0 years, Healthy office workers BMI 24.2 ± 4.4 kg/m^2	Single-blinded RCT 12-week intervention Height-adjustable workstation	Sub-chronic	Cognition performance: - Attention (Brickenkamp d2)	19
Koepp *et al.* ((2013) USA	25 females, 11 males 42 ± 10 years, Office workers able to walk at 3mph for 30 min, not pregnant BMI 29 ± 7 kg/m^2	Prospective trial 1-year intervention Treadmill desk	Chronic	Work performance - Employee-rated performance - Supervisor -rated performance	15
Koren *et al.* (2016) Slovenia	13 participants but no. of females and males not specified 30.6 ± 3.8 years, healthy office workers BMI 21.2 ± 12.0 kg/m^2	Crossover design 30-min intervention with two exercise intensities Cycling workstation	Acute	Cognitive performance - Reasoning (Wonderlic test) Work performance - Typing speed and error rate	17
Ohlinger *et al.* (2011) USA	Unreported no of females and males 43.2 ± 9.3 years, university ≤ 150kg, walk unaided BMI 28.5 ± 5.9 kg/m^2	Quasi-experimental trial 75-min intervention Treadmill desk Height-adjustable workstation	Acute	Cognitive performance - Attention (Stroop) - Memory (Auditory Consonant Trigram)	14
Russell et al. (2015) Australia	26 females, 10 males 40.1 ± 11.9 years, university employees unreported health status Unreported BMI	RCT Five-day intervention Height-adjustable workstation	Sub-chronic	Cognitive performance - Attention (Stroop) - Memory (Digit Span) - Reaction Time (Digit Symbol Coding) Work performance - Proof reading (speed and error rate)	17

Torbeyns *et al.* (2016) Belgium	16 females, 7 males 35.7 ± 10.3 years, Healthy office workers BMI 23.2 ± 3.0 kg/m^2	Quasi-experimental trial 30-min intervention Cycling workstation	Acute	Cognitive performance - Attention (Stroop, Rosvold) - Memory (Rey Auditory Verbal Learning) Work performance - Typing speed and error rate	17

*Quality measured using modified Downs and Black checklist; Data reported to 1 significant figure where authors included sufficient precision. BMI: Body Mass Index.

4.3.3 Cognitive performance: a measure of productivity

Cognitive performance was presented as an outcome measure for productivity in five of seven studies all of which were classified as either acute or sub-chronic (Donath *et al.*, 2015; Koren, Pisot and Simunic, 2016; Ohlinger *et al.*, 2011; Russell *et al.*, 2015; Torbeyns *et al.*, 2016). A variety of tests were used to assess cognitive performance, with these tests classified into the following categories depending on the element of cognitive function being assessed: attention and concentration, memory, and reasoning. All cognitive function changes were made in comparison to a control condition of sitting.

4.3.3.1 Attention and concentration

Three studies assessed attention responses when using active workstations (either treadmill, cycling or height-adjustable workstations) (Ohlinger *et al.*, 2011; Russell *et al.*, 2015; Torbeyns *et al.*, 2016) while only one study assessed concentration when using height-adjustable desks (Donath *et al.*, 2015), with the results shown in Table 3. With respect to standing workstations, almost all differences observed from both acute and sub-chronic effects of the interventions were trivial except for one test of concentration that showed a moderate but non-significant increase. When participants used a cycling workstation, there were 12 different attention tests used, with most of these showing no difference in attention, or a small improvement (Torbeyns *et al.*, 2016). Only one test of attention was reported while walking using a treadmill desk with a trivial increase in attention reported when compared with sitting (Ohlinger *et al.*, 2011).

4.3.3.2 Memory

Two studies examined memory performance in response to acute use of an active workstation, with results shown in Table 4 (Ohlinger *et al.*, 2011; Russell *et al.*, 2015; Torbeyns *et al.*, 2016). In one study, a trivial increase in memory performance was observed using both height-adjustable workstation and treadmill desk (Ohlinger *et al.*, 2011; Russell *et al.*, 2015). However, in the other study, memory performance was decreased when using a cycling workstation (Torbeyns *et al.*, 2016). The decreases observed in this study were trivial, regardless of the component of the auditory verbal learning test used, but none of these differences were statistically significant. Only one study assessed memory performance during sub-chronic use of a height-adjustable workstation, with a trivial increase observed (Russell *et al.*, 2015).

4.3.3.3 Reasoning and reaction time

One study investigated acute reasoning responses (Koren, Pisot and Simunic, 2016) and another sub-chronic reaction times (Russell *et al.*, 2015), with the results of both studies shown in Table 5. None of the differences in reasoning responses between a cycling workstation and sitting were significant. No significant differences in reaction times were found when using a height-adjustable workstation, compared to sitting.

Table 3: Effect of active workstation use on attention

Condition	Duration	Author	Performance test	n	SMD	Effect size magnitude
Standing	Acute	Ohlinger *et al.* (2011)	Stroop colour word test (T-score - number of correct items)	50	0.02	Trivial decrease
	Sub-chronic	Russell *et al.* (2015)	Choice Reaction Time (ms)	36	0.06	Trivial increase
			Choice Reaction Time accuracy (%)	36	0.02	Trivial increase
			Stroop incongruent (sec)	36	0.06	Trivial decrease
		Donath *et al.* (2015)	Brickencamp d2 test (% correct, 3 prompts/day)	15	0.37	Small increase
			Brickencamp d2 test (net performance, 3 prompts/day)	15	0.46	Small increase
			Brickencamp d2 test (% correct, no prompt)	16	0.45	Small increase
			Brickencamp d2 test (net performance, no prompt))	16	0.69	Moderate increase
Cycling	Acute	Torbeyns *et al.* (2016)	Rosvold continuous performance test reaction time (ms)	23	0.73	Moderate increase*
			Rosvold continuous performance test accuracy (%)	23	1.00	Moderate decrease
			Stroop accuracy color congruent stimuli (%)	23	0.00	Trivial - no change
			Stroop accuracy color incongruent stimuli (%)	23	0.06	Trivial decrease
			Stroop accuracy neutral stimuli (%)	23	0.03	Trivial decrease
			Stroop accuracy word congruent stimuli (%)	23	0.06	Trivial increase
			Stroop accuracy word incongruent stimuli (%)	23	0.02	Trivial increase
			Stroop reaction time color congruent stimuli (ms)	23	0.20	Small increase
			Stroop reaction time color incongruent stimuli (ms)	23	0.09	Trivial increase
			Stroop reaction time neutral stimuli (ms)	23	0.18	Trivial increase
			Stroop reaction time word congruent stimuli (ms)	23	0.21	Small increase
			Stroop reaction time word incongruent stimuli (ms)	23	0.34	Small increase
Walking	Acute	Ohlinger *et al.* (2011)	Stroop color word test (T-score - number of correct items)	50	0.03	Trivial increase

*Significantly different from sitting condition; Brickencamp d2 test evaluates concentration.

Table 4: Effect of active workstation use on memory

Condition	Duration	Author	Performance test	n	SMD	Effect size magnitude
Standing	Acute	Ohlinger *et al.,* (2011)	Auditory consonant trigram test (number of correct consonants)	50	0.11	Trivial increase
	Sub-chronic	Russell *et al.* (2015)	Digit Span subtest - number correct backwards	36	0.11	Trivial increase
			Digit Span subtest - number correct forwards	36	0.13	Trivial increase
			Letter number sequencing test	36	0.19	Trivial increase
Cycling		Torbeyns *et al.* (2016)	Rey Auditory Verbal Learning Test (Correctly recognized words)	23	0.15	Trivial decrease
			Rey Auditory Verbal Learning Test (Incorrectly recognized words)	23	0.00	Trivial - no change
			Rey Auditory Verbal Learning Test (Recalled words)	23	0.13	Trivial decrease
			Rey Auditory Verbal Learning Test (Repeated words)	23	0.12	Trivial increase
Walking		Ohlinger *et al.* (2011)	Auditory consonant trigram test (number of correct consonants)	50	0.06	Trivial increase

*Significantly different from sitting condition

Table 5: Effect of active workstation use on reasoning and reaction time

Condition	Duration	Author	Performance test	n	SMD	Effect size magnitude
Cycling	Acute	Koren *et al.* (2016)	Reasoning: Wonderlic test score (40W workload)	13	0.13	Trivial increase
			Reasoning: Wonderlic test score (80W workload)	13	0.25	Small decrease
			Reasoning: Wonderlic test time (sec) (40W workload)	13	0.05	Trivial decrease
			Reasoning: Wonderlic test time (sec) (80W workload)	13	0.52	Small increase
Standing	Sub-chronic	Russell *et al.* (2015)	Reaction time: Digit Symbol Coding subtest (total)	36	0.02	Trivial decrease
			Reaction time: Trail making test (sec)	36	0.09	Trivial decrease

*Significantly different from sitting condition.

4.3.4 Work-related performance

Two different types of work-related performance (typing and proofreading task) were assessed in three different studies. The results of using active workstations on work-related performance tests are shown in Table 6. Two studies examined the acute effect of interrupted sitting using a cycling workstation on typing performance (Koren, Pisot and Simunic, 2016; Torbeyns *et al.*, 2016), while and one study evaluated sub-chronic proofreading performance when using a height-adjustable workstation (Russell *et al.*, 2015). With respect to typing, the only significant changes reported were in the study by Koren *et al.* (2016), in which a small decrease in acute performance was observed. However, only a trivial decrease in performance was reported by Torbeyns *et al.* (2016). Trivial increases were recorded for the proofreading performance, although no significant difference was observed (Russell *et al.*, 2015).

Table 6: Effect of active workstation use on work-related performance tasks

Condition	Duration	Author	Performance test	n	SMD	Effect size magnitude
Standing	Sub-chronic	Russell *et al.* (2015)	Proof reading task (errors identified)	36	0.03	Trivial increase
			Proof reading task (time)	36	0.11	Trivial increase
Cycling	Acute	Torbeyns *et al.* (2016)	Typing test (net words per min)	2	0.05	Trivial decrease
		Koren *et al.* (2016)	Typing time (sec) (40W workload)	13	0.51	Small decrease*
			Typing time (sec) (80W workload)	13	0.58	Small decrease*
			Typing errors (number) (40W workload)	13	1.66	Large decrease
			Typing errors (number) (80W workload)	13	1.81	Large decrease

*Significantly different from sitting condition; § statistical significance not provided

4.3.5 Effects of active workstations on productivity

Two studies assessed workplace productivity after prolonged use of height-adjustable workstations (Chau *et al.*, 2016; Donath *et al.*, 2015; Koepp *et al.*, 2013), both of which were classified as chronic. The methods used to assess productivity were through monitoring average call handling time, hold time on a call, talk time and wrap up time on a call (Chau *et al.*, 2016), and through employee- and supervisor-rated performance (Koepp *et al.*, 2013). In the study by Chau *et al.* (2016), participants used the workstation for 19 weeks while Koepp *et al.* (2013) assessed chronic productivity after one year of use. The results obtained from both studies are shown in Table 7. No significant differences were observed in response to either of the interventions, although some of the outcomes measured did have moderate changes in productivity.

Table 7: Effect of active workstation use on work-related productivity tasks

Condition	Duration	Author	Performance test	n	SMD	Effect size magnitude
Standing	Chronic, 19 weeks	Chau *et al.* (2016)	Average call handling time (min)	16	0.33	Small decrease
			Customer rating	16	0.16	Trivial increase
			Hold time on call (min)	16	0.60	Moderate decrease
			Talk time on call (min)	16	0.05	Trivial increase
			Wrap up time on call (min)	16	0.20	Small increase
Walking	Chronic, 1 year	Koepp *et al.* (2013)	Employee-rated performance (weekly survey) - overall	23	0.04	Trivial decrease
			Employee-rated performance (weekly survey) - overall	13	0.22	Trivial decrease
			Employee-rated performance (weekly survey) - quality	13	0.05	Trivial increase
			Employee-rated performance (weekly survey) - quality	23	0.37	Small decrease
			Employee-rated performance (weekly survey) - quantity	23	0.13	Trivial decrease
			Employee-rated performance (weekly survey) - quantity	13	0.24	Small increase
			Employee-rated performance (weekly survey) - interaction	13	0.04	Trivial decrease
			Employee-rated performance (weekly survey) - interaction	23	0.33	Small decrease
			Supervisor-rated performance (weekly survey) - overall	23	0.35	Small decrease
			Supervisor-rated performance (weekly survey) - overall	13	0.60	Moderate decrease
			Supervisor-rated performance (weekly survey) - quality	13	0.15	Trivial decrease
			Supervisor-rated performance (weekly survey) - quality	23	0.31	Small decrease
			Supervisor-rated performance (weekly survey) - quantity	13	0.18	Trivial decrease
			Supervisor-rated performance (weekly survey) - quantity	23	0.26	Small decrease
			Supervisor-rated performance (weekly survey) - interaction	23	0.05	Trivial decrease
			Supervisor-rated performance (weekly survey) - interaction	13	0.15	Trivial decrease

*Significantly different from sitting condition.

4.4 Discussion

The aim of this review was to determine whether using an active workstation had any effect on productivity or workplace performance. The seven studies reviewed were grouped into three categories with respect to whether productivity assessment was acute, sub-chronic, or chronic. In addition, two types of methods were used to assess both productivity and performance. Most of the studies estimated productivity based on cognitive performance tests using laboratory-based and/or simulated-office tasks as outcome measures, while work performance was estimated by typing, and proofreading. Five studies evaluated acute or sub-chronic effect of interrupted sitting using active workstations on productivity and work-related performance, whereas the other two studies assessed chronic effect of prolonged use of active workstations on productivity. The studies examining cognitive performance as a measure of productivity used a range of tests to assess different elements of cognition, including attention, concentration, memory, reasoning, and reaction time. With respect to attention, both of the studies reported only trivial effects when using a height-adjustable workstation (Ohlinger *et al.*, 2011; Russell *et al.*, 2015). Similar results were reported in the studies in which attention was measured while using a cycling or walking workstation, with most tests producing trivial differences (Ohlinger *et al.*, 2011; Torbeyns *et al.*, 2016). In contrast, moderate sub-chronic effects of the intervention were reported when using a height-adjustable workstation, however, this effect was not significant (Donath *et al.*, 2015).

The results of the studies in which acute effect of the intervention on memory was assessed while using an active workstation followed the same pattern with use of three types of

workstations leading to trivial increases in memory that were non-significant (Ohlinger *et al.*, 2011; Russell *et al.*, 2015; Torbeyns *et al.*, 2016). The same findings were observed when memory was assessed based on sub-chronic effect of height-adjustable workstation (Russell *et al.*, 2015).

It appears that using a height-adjustable workstation has no effect on productivity when the person is standing, indicating that alternating between standing and sitting may not have any detrimental effect on the amount and quality of work being produced. A lack of significantly different results were observed for both cycling and walking workstations, which could be an indication that these two workstations may not pose any threat to the quality of work produced, although it is worth noting that several effects that could be considered moderate using the Hopkins' scale were not detected as statistically significant, perhaps owing to low power in the studies (Hopkins *et al.*, 2009). It should also be noted that participants lacked familiarity with the active workstations used in most of the studies, so work productivity and performance could be expected to improve with habitual use. It is also possible that any potentially beneficial chronic effects of active workstations would not have been observed given the short time in which participants used the workstations. It has been suggested that using an active workstation could influence long-term performance and workplace productivity. Only two studies assessed workplace productivity after prolonged use of active workstations, with the duration of studies ranging from 19-52 weeks (Chau *et al.*, 2016; Donath *et al.*, 2015; Koepp *et al.*, 2013). None of these studies reported any change in productivity after long-term use of an active workstation. However, as with the acute studies

assessing productivity responses, two studies (Koren, Pisot and Simunic, 2016; Torbeyns *et al.*, 2016) had relatively low power but with effect sizes as large as 1.8. This indicates a large effect that was not found to be statistically significant (Hopkins *et al.*, 2009). Future research in this area needs to be carried out with sufficient power to investigate the exact impact of acute use of active workstations on productivity.

Based on the findings of this review, it appears that there is insufficient evidence regarding the chronic effect of active workstations on productivity and workplace performance. The studies reviewed fell into three categories, one of which focused on cognitive performance while using an active workstation that participants were not familiar with, while cognitive performance was also examined after using an active workstation for some time. Finally, two long-duration studies in which productivity was measured using simple tools such as self-rated questionnaires and call handling time. Future research should investigate the effect of active workstations on productivity, making sure to use non-subjective measures of productivity. The potential of active workstations to reduce the amount of SB in the workplace was the focus of another recent systematic review. In this review, Chu *et al.* (2016) reported that height-adjustable workstations were effective in reducing sitting time, although not as effective as multi-component interventions. However, this review did not examine whether the use of active workstations had any effect on productivity or workplace performance. In another systematic review, MacEwen *et al.* (2015) looked at the effect of height-adjustable and treadmill desks on both physiological and psychological outcomes. The psychological outcomes included both typing and mouse clicking performance. They reported no change in

work performance when using a standing workstation, but a decrease in performance when using a treadmill desk that was proportional to the speed at which the participants were walking. The results of this present review is consistent with the review of MacEwen *et al.* (2015), in which typing task performance had a large decrease when cycling (Koren, Pisot and Simunic, 2016). The magnitude of the decrease in performance could be attributed to the intensity of the activity (Cao *et al.*, 2016). A similar systematic review by Cao *et al.* (2016) examined the effect of active workstations on both energy expenditure and work performance. They evaluated performance when using a treadmill desk, with decreased performance in typing tasks, mouse clicking, and transcribing speed. However, none of the articles included were longitudinal studies in which changes in performance were evaluated over time. Likewise, Commissaris *et al.* (2016) evaluated the effect of workplace interventions to reduce SB on PA levels and productive work. They reported conflicting evidence for the effects of active workstations on work performance, however, most studies were of short duration, with performance assessed using self-reported performance measures.

The key finding of the present study was that height-adjustable workstations do not appear to significantly decrease performance, regardless of the length of time the workstation was for used for, which contradicts a potential concern of employers (De Cocker *et al.*, 2015b). In fact, in some cases active workstations might enhance employee performance and productivity. However, although the acute use of treadmill and cycling workstations might decrease both productivity and performance, inappropriate study design, including small sample size and lack of familiarity with the workstations, meant that a true reflection of sub-

chronic and chronic effect of such interventions could not be determined. The articles included in this systematic review were limited to those from peer-reviewed journals, thus excluding other studies such as unpublished papers, dissertations and thesis. Although this might have introduced selection bias, it also ensured that the sources selected were of sufficient quality. In addition, further research is needed to identify the most appropriate tools to quantify work productivity and workplace performance. It has been suggested that the Work Limitations Questionnaire (WLQ) (Lerner *et al.*, 2001) is the most suitable for research use when considering the effect of PA (Brown *et al.*, 2014). The WLQ provides subjective measures of both productivity and presenteeism (Brown *et al.*, 2013). An alternative measure of productivity could be ecological momentary assessment (EMA), which has been used in a variety of different contexts (Runyan *et al.*, 2013). The EMA technique involves participants being prompted in their normal working environment at random times throughout the day to respond about their current behaviour and symptoms, which has the advantage of sampling as close as possible to the event, thus limiting recall bias (Moskowitz and Young, 2006). This technique is being increasingly used due to the availability of electronic devices such as smartphones, which can be used to deliver the prompts at random time points throughout a working day, so can easily be adapted to an office environment.

4.5 Conclusion

This systematic review was undertaken to identify whether active workstations had any acute or chronic effects on productivity or workplace performance. Most studies evaluated acute effect of active workstations on productivity and work performance during single-session trials with the evidence suggesting that height-adjustable workstations have no detrimental effect on these outcomes. Limited evidence was found to suggest that acute use of treadmill and cycling workstations might decrease work-related performance, such as typing, but this could be due to a lack of familiarity with the workstations. In the remaining studies in which the chronic use of active workstations was examined, the tools used to assess productivity and work performance were inadequate. Future studies should investigate the impact of active workstations on employees' productivity and work performance in the workplace.

CHAPTER 5 THE EFFECT OF AGE, GENDER, AND ETHNICITY ON SELF-REPORTED SITTING TIME AND PHYSICAL ACTIVITY IN DESK-BASED WORKERS

This chapter presents the findings of an evaluation of workplace sitting time and PA of desk-based office workers to identify a specific population with high levels of sitting that would be selected for interviews to gain an insight into factors influencing workplace sitting time. It also addresses magnitudes of differences in SB between ages, gender and ethnic groups to inform future powered study.

5.1 Introduction

As stated previously in Chapter 2, sedentary lifestyles and physical inactivity (PI) have become widespread, leading to major global public health concerns (Ekelund *et al.*, 2016). SB, including prolonged sitting has been documented to have both medium- and long-term detrimental effects on health (Magnon, Vallet and Auxiette, 2018). Specific health consequences associated with SB have been highlighted in section 2.2.5 (Dunstan *et al.*, 2010; Healy *et al.*, 2011b; Teychenne, Costigan and Parker, 2015; Thorp *et al.*, 2012; Warburton, Nicol and Bredin, 2006; Wilmot *et al.*, 2012).

The workplace remains a setting of particular concern, with workplace sitting time accounting for 56% of total daily sitting time compared with 32% and 11% for leisure and transport sitting time, respectively (Bennie *et al.,* 2015). Combining sitting reduction strategies with efforts to increase PA have been identified as important and complementary public health priorities (Puig-Ribera *et al.*, 2015). However, access to such strategies, such as height-adjustable workstations, neither guarantees its use nor automatically makes individuals replace sitting with standing (Nooijen *et al.*, 2018). Research has shown that non-participation in workplace interventions to decrease sitting and increase PA is often due to higher perceived barriers, and lower perceived benefits (Chinn *et al.*, 2006; Edmunds, Hurst and Harvey, 2013; Lakerveld *et al.*, 2008). According to Nooijen *et al.* (2018), office workers have numerous perceived facilitators and barriers, which can restrict their level of sitting in the workplace, and these differ based on age and gender. However, there is no evidence in relation to barriers and facilitators or workplace sitting time across different ethnic groups. Based on this evidence, it would be expected that differences in barriers and facilitators to workplace SB could lead to variations in responses to interventions between different office worker groups.

A recent systematic review reported that age, gender, and ethnicity were related with occupational PA (Smith *et al.,* 2016). However, the reported effects of these variables on occupational PA are equivocal (Smith *et al.,* 2016). With respect to occupational sitting time, some studies have reported no effect of age or gender (Chau *et al.*, 2011; Hadgraft *et al.*, 2016c). However, in a study by De Cocker *et al.* (2014) in which employees' were categorised into three age groups (18-39, 40-64, and 65-80 years), it was reported that males and younger

employees engaged in significantly greater amounts of occupational sitting time compared with female employees and those in older age categories. In contrast, a recent Singaporean study reported that females had greater occupational and total sitting time than males (Uijtdewilligen *et al.*, 2017).

Some studies have also reported increased occupational sitting time among younger employees compared with their older counterparts, highlighting the potential importance of targeting younger employees in sedentary jobs (Bennie *et al.*, 2015; Clemes, O'Connell and Edwardson, 2014; Wallmann-Sperlich *et al.*, 2014). These inconsistent findings in relation to the effects of age and gender on occupational sitting time could be due to studies using participants from a variety of job types, such as both blue- and white-collar jobs, rather than any underlying differences caused by age or gender. However, there is currently limited evidence regarding desk-based occupational sitting time, as only three of the aforementioned studies were in desk-based employees only (Bennie *et al.*, 2015; Clemes, O'Connell and Edwardson, 2014; Hadgraft *et al.*, 2016c), highlighting the need for more research in this area. Furthermore, to the authors' knowledge, no previous studies have examined the effects of ethnicity on occupational sitting.

Evidence suggests that understanding factors that influence the amount of time people spend sitting and engaging in PA could help identify specific population groups that sitting time interventions should be targeted towards (van Uffelen, Heesch and Brown, 2012). Therefore, the primary aim of this current study was to identify a specific population with high levels of sitting that would be selected for questioning to gain an insight into factors influencing their

sitting time in the workplace. This study also sought to identify magnitudes of differences in sitting time between ages, gender and ethnic groups for a future study that would be powered to detect changes.

5.2 Methods

5.2.1 Participants

Participants were recruited from a university and local council offices in the East of England region, United Kingdom. Desk-based staff members who met the inclusion criteria (i.e. no physical limitations such as musculoskeletal impairments, hip/knee replacement, and not pregnant) who were aged 18 years and above were eligible to participate in the study. Participants were recruited via display of posters and emails sent to all employees that included a link to complete the questionnaires described below via an online survey. Volunteers were entered into a prize draw for three persons to win a £15 shopping gift voucher as an incentive to take part (See Appendix 6). Ethical approval was obtained from the University of Bedfordshire Institute for Health Research Ethics Committee (approval number IHREC610) as shown in Appendix 5.

5.2.2 Study design and procedures

All data was collected via online survey developed using Qualtrics survey software (Qualtrics, Provo, Utah, USA). The first page of the survey was a participant information sheet and consent form, including inclusion criteria, which participants needed to complete before

being directed to the questionnaire (See Appendix 8). Participants completed an initial section on socio-demographic information, including ethnicity (classified using the Office for National Statistics categories (Office for National Statistics, 2012)), gender, age, height, and weight, followed by two questionnaires on PA and sitting time. Both sitting time and PA levels were assessed using questionnaires (Wanner *et al.*, 2016). The two questionnaires used in this study were the International Physical Activity Questionnaire (IPAQ) (Craig *et al.,* 2003) and the Workforce Sitting Questionnaire (WSQ) (Chau *et al.,* 2011).

As stated in section 2.2.3.1 of this thesis, the long version of the IPAQ used for self-reported PA measurement has acceptable test-retest reliability (ICC=0.46-0.90) and validity (r=0.22–0.46) (Ahammad *et al.,* 2015; Caspersen, Powell and Christenson, 1985; Chau *et al.,* 2011) . The main outcome measures of the IPAQ are total MET minutes of PA per week and PA level classification. A MET is the rate of energy expenditure compared to rest, with MET-minutes calculated as the product of the MET for an activity and number of minutes in which a person performed it. The IPAQ definitions were used to classify participants as inactive if they reported <600 MET-minutes/week, moderately active if they reported at least 600 MET-minutes/week, and engaging in Health-Enhancing Physical Activity (HEPA) if a minimum of 3000 MET-minutes/week was reported (www.ipaq.ki.se). Participants who met current UK and international guidelines of at least 150 minutes per week of MVPA were also identified, with the prevalence reported for each group.

Domain-specific estimates of sitting time were made using the Workforce Sitting Questionnaire (WSQ), which provides reliable and valid estimates of sitting time comparable

to accelerometry. Chau *et al.* (2011) reported a fair to excellent test-retest reliability (ICC=0.46–0.90) for total sitting time based on a workday and non-workday, while domain-specific sitting time at work was also reliable (ICC=0.63) and valid (r=0.45) using the WSQ. The only domain-specific outcome measure used in the present study was total daily sitting time at a desk during work (Chau *et al.,* 2011; van Nassau *et al.,* 2015). Two composite outcome measures were also used, which were total sitting time on a workday (sum of sitting time in all domains on a workday) and total sitting time on a non-workday (sum of sitting time in all domains on a non-workday).

5.2.3 Statistical Analysis

The power of the present study to detect worthwhile effects was calculated using magnitude-based inferences (Hopkins *et al.,* 2009). The smallest worthwhile effect was considered to be equivalent to a difference in the means of 0.2 (Cohen, 1988; Hopkins *et al.*, 2009). The resulting sample size required for the chosen effect size was 268 subjects for a cross-sectional study. All statistical analyses were performed using SPSS (Version 23, IBM, Chicago, IL, USA). Data were tested for normality using the Kolmogorov-Smirnov test. All data were non-normally distributed, therefore the bias-corrected and accelerated (BCa) bootstrap method was used to produce unbiased estimates of the confidence limits (Kelley, 2005). PA levels are reported as median minutes and MET minutes per week. Bootstrapped analysis of variance was used with the dependent variables of sitting time and MET minutes while the independent variables were age, gender, and ethnicity. Three age groups were used for all statistical analysis (< 40 years, 40 – 60 years, and > 60 years).

5.3 Results

5.3.1 Participant Characteristics

Two hundred and fifty participants from the university (n=164 / 65.6%) and the council (n=86 / 34.4%) completed the online questionnaire with 73 participants removed from the study due to incomplete data (23% of total responses) and having a disability (6%). The remaining 177 participants comprised of 113 participants (63.8%) from the university and 64 participants (36.2%) from the council, with the distribution by organisation similar to that before participants were excluded. The smallest effect size that can be detected with 177 participants is 0.25, which is marginally above the threshold for a trivial but worthwhile effect of 0.2 (Hopkins *et al.,* 2009).

Most participants were white (n=147 / 83.1%), with 17 Asian participants (9.6%), 11 Black participants (6.2%), and the remaining two participants from other ethnic backgrounds (i.e. Greek Cypriot and Middle-East White). Owing to the small number of non-white participants, all Black, Asian, and Minority Ethnic (BAME) participants were grouped together for subsequent analysis of ethnic differences with respect to sitting time and PA. 121 of the participants were female (68.4%) and 56 were male (31.6%), which was representative of the workforces from which the participants were recruited (34% male for the local council and 32% male for the university). The median age of the participants was 40 years (29–54). Participants' median weight was 69.9 kg (57.2-87.0), with a median height of 1.68 m (1.60-

1.78). Participants' median BMI was 24.7 kg/m^2 (20.8 - 29.7). Fourteen percent of participants were classified as obese, with 30% overweight, 64% normal weight, and 2% underweight.

5.3.2 Sitting time

Overall median sitting time on a workday using the WSQ was 11 h 30 (8 h 35-15 h 05), while weekend day sitting reported with the WSQ was 8 h 30 (5 h 10-12 h 00). Total time spent sitting at a desk on a workday was 6 h 30 (5 h 00-7h30). There was no difference in workday sitting time ($F=1.07$, $p=0.347$), overall weekend day sitting time ($F=1.50$, $p=0.226$), and time spent sitting at a desk on a workday ($F=1.79$, $p=0.170$) between different age groups. Bootstrapped mean differences between genders and ethnic groups for workday sitting time, total weekend day sitting time, and time spent sitting at a desk on a workday are shown in Table 8. The only significant difference was for weekend day total sitting, with BAME participants sitting significantly more than white participants.

Standardised mean differences for the effect of age, gender, and ethnicity on workday sitting were estimated in order to identify the sample size required for a fully powered study for each effect. The SMD for ethnicity was 0.123, which would require 351 participants per ethnic group (BAME and White). The SMD for gender was 0.145, which would require 253 participants for each gender. Finally, the SMD for the age-group analysis was 0.223, which would require 108 participants for each age group (< 40 years, 40 – 60 years, and > 60 years).

5.3.3 Physical activity

PA levels for each activity type are shown in Table 9, with IPAQ PA level classifications shown in Table 10. Fifteen percent of the sample did not meet the PA guidelines of at least 150 minutes per week of MVPA. No differences in PA levels were observed between gender (F=0.31, p=0.578), age (F=0.45, p=0.640), or ethnic groups (F=0.31, p=0.579). Correlations between sitting time and PA levels are shown in Table 11. None of the relationships were significant, with no correlations greater than 0.15.

Table 8: The effect of gender and ethnicity on sitting time

Effect	Dependant variable	Mean diff. (min)	95% CI (min)	Test statistic
Gender‡	Workday sitting at a desk	12.8	-25.4 - 47.6	F=0.81, p=0.371
	Workday total sitting	32.5	-27.7 - 96.2	F=1.15, p=0.292
	Weekend day total sitting	52.5	-21.5 - 122.3	F=2.06, p=0.153
Ethnicity§	Workday sitting at a desk	-13.0	-56.0 - 30.0	F=0.36, p=0.552
	Workday total sitting	-59.9	-137.0 - 17.2	F=2.35, p=0.127
	Weekend day total sitting	-154.8	-244.7 - -64.8	F=11.53, p=0.001

‡Mean differences are women-men; §Mean differences are White-BAME.

Table 9: Physical activity levels for the total sample

Type of activity	Weekly minutes (95% CI)	MET-Minutes per week (95% CI)
Walking	125 (75 -220)	413 (264 -627)
Moderate activity	252 (180 -355)	1010 (716 -1406)
Vigorous activity	60 (55 -60)	480 (420 -480)
Total activity	633 (540 – 775)	5067 (4204-6064)

Values are medians and bootstrapped 95% confidence limits.
MET = Metabolic Equivalent

Table 10: Physical activity level classification for the study sample

Physical activity level	n	% of sample
Inactive	27	15.3
Moderately active	90	50.8
HEPA Category	60	33.9

HEPA = Health-Enhancing Physical Activity

Table 11: Correlation matrix of sitting time and physical activity levels

Activity level	Workday sitting at a desk	Workday total sitting	Weekend day total sitting
Walking MET-minutes per week	r=-0.12, p=0.112	r=0.06, p=0.447	r=0.02, p=0.769
Moderate MET-minutes per week	r=-0.13, p=0.092	r=-0.03, p=0.700	r=0.02, p=0.802
Vigorous MET-minutes per week	r=-0.15, p=0.051	r=-0.08, p=0.268	r=-0.04, p=0.616
Total MET-minutes per week	r=-0.15, p=0.053	r=-0.02, p=0.802	r=0.02, p=0.769

5.4 Discussion

The primary aim of this present study was to identify a population with high levels of sitting for the subsequent studies in this thesis. Participants in the study had a high sitting time, with a median of 11.5 hours per working day. This amount of sitting time exceeds the threshold of eight hours that is associated with a high risk of mortality (Chau *et al.*, 2013; Patterson *et al.*, 2018), meaning that over half the workers surveyed were at high risk (van der Ploeg *et al.,* 2012). Previous studies involving desk-based workers have shown similar amounts of sitting time, with Bennie *et al.* (2015) reporting a median of nine hours per day. Similar volumes of sitting to the present study were reported in another study of UK employees recruited across

various job domains, with 11.3 hours of sitting per workday, of which 6.5 hours occurred at work (Kazi *et al.*, 2014). When weekday sitting time is compared to the recommended guidelines for excess SB, which may be defined as at least 540 minutes per day (Scholes *et al.,* 2016), over 82% of the participants in this study could be classified as excessively sedentary. Similarly, Chau *et al.* (2011) reported a total workday sitting time of 11 hours and occupational sitting time of 6.5 hours among Australian desk-based employees. Occupational sitting time accounted for over 70% of daily sitting time, which is similar to the 60% and 75% reported in two previous studies (Bennie *et al.,* 2015; Toomingas and Gavhed, 2008). However, some studies have also reported much lower levels of occupational sitting of around four hours per day (De Cocker *et al.,* 2014). A possible reason for this difference is that the present study and other investigations (Bennie *et al.,* 2015; Toomingas and Gavhed, 2008) assessed employees who were desk-based, whereas in the study by De Cocker *et al.* (2014), participants were Australian adults who were employed in any type of paid work. The evidence from the present study in addition to previous work suggests that those in desk-based jobs accrue high amounts of sitting both at work and outside of work.

An expert statement on reducing SB in office workers recommends at least two hours of light activity (standing or light walking) per day initially, increasing to four hours per day (Buckley *et al.,* 2015). Although the amount of light activity per day at work was not specifically measured in the present study, it can be estimated based on the workday sitting time reported. The median sitting time of 6 h 30 would suggest that most participants do not meet the two-hour minimum, if an eight-hour working day is assumed. Other studies such as that

of Ryan *et al.* (2011) have compared sitting time with previous sitting recommendations. In this study (Ryan *et al.,* 2011), only 8% of workers met a previous recommendation to interrupt sitting every 55 minutes, while no participants interrupted sitting every 20 or 30 minutes on every working day. Based on the results of both the present study and previous work (Bennie *et al.*, 2015; Chau *et al.*, 2011; Kazi *et al.*, 2014), the majority of desk-based employees do not meet recommendations for at least two hours of light activity per working day (Buckley *et al.,* 2015). Feasible and effective interventions to reduce sedentary time in the workplace thus need to be developed.

The secondary aim was to identify magnitudes of differences in sitting time between ages, gender and ethnic groups for a future study that would be powered to detect changes. No differences were observed with respect to sitting time between age groups in the present study. This was possibly due to the lack of power in the present study, with 108 participants required per age group. With respect to the lack of difference observed, other studies have reported similar results, which demonstrated that sitting time did not differ between age groups (Chau *et al.*, 2011; Hadgraft *et al.*, 2016c). However, in some previous studies older people have been reported to sit less than younger people. For instance, one study reported that individuals who sat the least at work were ten years older than those who sat the most (Clemes, O'Connell and Edwardson, 2014). Another study also observed an inverse relationship between age and sitting time at work, although the correlation was trivial (Bennie *et al.,* 2015). The inconsistent findings could be due to the present study using different age classifications to previous research (Bennie *et al.,* 2015). However, other studies with age

classifications different from the present study also observed no difference in sitting time between age groups (Chau *et al.*, 2011; Hadgraft *et al.*, 2016c). Another possible explanation could be the subjective nature of self-report measurements used in the present study and the previous studies (Bennie *et al.,* 2015; Chau *et al.,* 2011). However, discrepancies were also found between two studies that utilised objective measures of sitting time (Clemes, O'Connell and Edwardson, 2014; Hadgraft *et al.*, 2016c). Therefore, further research is required using objective measures and consistent age classifications to determine the effects of age on occupational sitting time in fully powered studies.

The present study found no effect of gender on employee sitting time, which is in agreement with previous research (Chau *et al.*, 2011; Hadgraft *et al.*, 2016c). The present study identified a required sample size of 253 per gender for a fully powered study, which could thus explain why no significant difference was observed. Other studies have reported higher occupational sitting time for men compared with women for people in full-time paid work (Mummery *et al.,* 2005). However, the study by Mummery *et al.* (2005) included both blue-collar and white-collar workers, meaning that gender differences could have been due to the nature of the jobs performed. A UK-based study also reported that males spent more time sitting while at work than females (Kazi *et al.*, 2014). Possible explanations for the differences between the study by Kazi e*t al.* (2014) and this present study could be due to the greater number of female participants in the present study (64% vs 48%) or differences in job types within the samples of each study. The present study recruited only desk-based participants, while Kazi *et al.* (2014) recruited workers from multiple domains including retail and telecoms, in which more

standing is required. However, another study reported higher occupational sitting time among women than men (Munir *et al.,* 2015), with this difference attributed to women in the Irish public sector reporting higher dedication, absorption, and work performance than men. Given the differences in findings reported between studies, further objective research in this area is needed to help determine gender differences in occupational sitting and the potential factors that influence any such differences.

The present study found no differences in total workday sitting time or time spent sitting at a desk on a workday between ethnic groups. The required sample size for a fully powered study was 351 per ethnic group based on the findings of this study. It should be noted that this power calculation was obtained when all BAME participants were grouped into a single category. Low numbers of participants from minority ethnic groups has been cited as a possible cause for not establishing any link between ethnicity and sitting time in previous research (Hadgraft *et al.*, 2016c). In a study in which equal numbers of African American, White, and Hispanic participants were assessed, African Americans spent more time sitting at the weekend than the other two ethnic groups (Taylor *et al.,* 2016). A Singaporean study attributed differences in sitting time between ethnic groups to lifestyle factors and other socio-demographics (Uijtdewilligen *et al.*, 2017). For instance, separated or widowed participants of Malay and Indian ethnic origin and those who smoked were reported to have lower occupational sitting time (Uijtdewilligen *et al.*, 2017). In a study in which daily objective sedentary time was compared between adults living in Amsterdam of Dutch, African, Turkish, Moroccan, and South-Asian Surinamese ethnic backgrounds, no differences in sedentary time

were found between the ethnic groups (Loyen *et al.,* 2017). Based on the limited findings to date, it is difficult to conclude on the effects of ethnicity on occupational sitting. Further powered studies using objective measures to compare sitting time between ethnicities are warranted, particularly those carried out in the workplace to confirm the findings of the present study.

Although both questionnaires used in this study have been validated against accelerometers, self-reported data are prone to under-reporting or over-reporting due to recall bias (Pedersen *et al.*, 2016). For instance, Chastin *et al.* (2014) reported that sitting time was underestimated by nearly two hours using the IPAQ compared with concurrently measured objective sitting time from an accelerometer. Self-reported data thus may not provide valid estimates of employees' sitting time, although it does capture important domain and behaviour-specific sedentary time (Healy *et al.*, 2011b). Therefore, additional studies using questionnaires in conjunction with data obtained via objective methods are needed to provide a valid estimate of total, domain, and behaviour-specific sitting time (Pedersen *et al.*, 2016).

Participants in the present study were more active than office workers in previous studies (Biernat, Tomaszewski and Milde, 2010; Kazi *et al.*, 2014). Only 16% of workers were classified as inactive in the present study based on guidelines of at least 150 minutes per week of MVPA. This is far lower than the 40% of participants with insufficient MVPA in the Health Survey for England (Scholes *et al.,* 2016). In studies in which the majority of participants were bank officials or civil administrators, reported levels of inactivity (i.e., no activity at all or insufficient activity to meet moderately active and HEPA active categories) was 35-80%, depending on

the category of worker (Biernat, Tomaszewski and Milde, 2010; Kazi *et al.*, 2014), which is higher than the present study. One reason for the excessive inactivity observed by Kazi *et al.* (2014) and Biernat *et al.* (2010) was lack of time that could be devoted to leisure time physical activities. Although high levels of occupational sitting time were recorded for office workers in the present study, the majority of participants were either moderately or HEPA active. A logical explanation could be that the majority of participants compensated for long periods of sitting by increasing their levels of PA outside of work, despite evidence showing that this may not prevent the harmful effects of excess daily sitting time (Katzmarzyk *et al.,* 2009).

The present study did not find any relationship between PA level and sitting time, which differs from previous investigations (Bennie *et al.*, 2015; Puig-Ribera *et al.*, 2015). Bennie *et al.* (2015) identified a negative relationship between daily sitting time and PA minutes per week. In another study, people who spent the most time sitting at work also spent the least amount of time engaging in PA (Puig-Ribera *et al.*, 2015). One reason for these differences might be that the participants in the present study who were predominantly sedentary when at work, compensated by increasing their activity levels outside of work. Indeed, this was reported in an Australian study, which found that employees with sedentary jobs were more likely to be more active during leisure-time than those in blue-collar jobs (Chau *et al.*, 2012b). Another potential explanation for the differences in the relationship between sitting time and PA could be different lifestyles between Australian and British populations, as was suggested in a previous study (Clemes, O'Connell and Edwardson, 2014). However, the high level of activity found in the present study and the Australian study (Chau *et al.*, 2012b) could

be attributable to an awareness of the benefit of PA in the two population samples (Abula *et al.,* 2018).

The present study has some potential limitations that should be considered in future investigations. Firstly, the proportion of BAME participants was only 16%, meaning that South Asian and Black participants were grouped together. It would be better to examine each ethnic group separately to detect whether sitting time differs between ethnicities, for which a greater number of ethnic minority group participants would be required for sufficient statistical power (351 participants per ethnic group). In any questionnaire-based study, self-reporting of PA and sitting time may be less reliable than accelerometer-based assessment, although validity may be strong (Pedersen *et al.*, 2016). The questionnaires used in the present study have been previously validated against accelerometers and have been reported as reliable (Chau *et al.,* 2011; van Nassau *et al.,* 2015).

Moreover, the power calculations for sitting time at work were based on subjective measures, therefore, a study using objective measures is needed to confirm the required sample sizes. Furthermore, the participants who took part in the study might not be a representative sample. The present study was limited to two workforces, both of which are in the public sector and in the same region, so the generalisability of results to other work environments needs to be addressed. In addition, the sample contained less obese and overweight individuals than the English national average (Baker, 2017). This could mean the results of the present study might not be representative of the general population.

5.5 Conclusion

A high level of occupational sitting time was observed in this sample of office workers, irrespective of age, gender, or ethnicity. However, BAME participants sat for an additional 2 h 30 on non-working days when compared with one other ethnic group. In contrast, most participants met recommended guidelines for PA, with no differences observed between different age, gender and ethnic groups. Therefore, interventions to reduce workplace sitting could be targeted at all desk-based employees irrespective of age, gender, or ethnicity, although this should be confirmed in a fully powered study.

CHAPTER 6 IDENTIFYING INTERVENTIONS TO REDUCE AND BREAK UP WORKPLACE SITTING TIME USING THE BEHAVIOUR CHANGE WHEEL

This chapter presents findings of a qualitative study that sought to identify active ingredients that can be used as content during workplace SB intervention development. This study has been published as two standalone articles in different academic journals listed on page vi.

6.1 Introduction

Due to modernisation of society and technological advancements, there is now heavy reliance on computers in the workplace resulting in occupations being less physically demanding and more sedentary (Church *et al.*, 2011; Katzmarzyk, 2010). The definition of SB has been given in section 2.5.1 as any waking activity, such as sitting, reclining or lying which expends less than 1.5 metabolic equivalents (Tremblay *et al.*, 2017). From an operational standpoint, prolonged sitting at a desk is the type of SB typically observed in the office workplace. Evidence from review of literature shows that seventy-three percent of the UK population aged 16-64 are currently in employment (Alesi *et al.*, 2014; Hall *et al.*, 2015) with a large number of these workers in office-related jobs (Thorp *et al.*, 2012). Studies have identified that the workplace contributes to the majority of excessive daily sitting time in office-based employees (Bennie *et al.*, 2015; Clemes *et al.*, 2016). Self-reported occupational sitting time has been estimated at 6 h 30 min (IQR= 6 hrs 20 – 6 h 45 min) on a workday (Chau *et al.*,

2011), which is in accordance with objective measurements of workplace sitting suggesting 71% (Clemes, O'Connell and Edwardson, 2014) to 82% of the workday is spent seated (Parry and Straker, 2013). Due to a growing epidemiological evidence linking excessive sitting time to adverse cardiometabolic outcomes (see section 2.2.5), the workplace has become an important public health concern.

Evidence from observational studies and meta-analyses presented in 2.2.5 has shown that daily participation in MVPA for 60-75 min a day may eliminate the increased risk of premature mortality associated with high amounts of sitting (Chastin *et al.*, 2019; Ekelund *et al.*, 2019; Ekelund *et al.*, 2016; Pulsford *et al.*, 2017). However, the majority of the population do not engage in such high levels of MVPA (Colley *et al.*, 2011; Troiano and Berrigan, 2008). For those who are unable to achieve these high levels of MVPA, and in order to mitigate the remaining cardiometabolic health risks, the workplace could be a potential intervention environment to break up and reduce excessive sitting (Mache *et al.*, 2015; Quintiliani, Sattelmair and Sorensen, 2008; Strickland *et al.*, 2015). To develop effective breaking up and sitting reduction interventions, it is pertinent to understand what works and why (Gardner *et al.*, 2016).

6.2 Theoretical framework underpinning the intervention design

As stated in section 2.4.1, interventions targeted at changing behaviour need to be informed by theoretical, evidence-based frameworks. The Medical Research Council (Medical Research

Council, 2000) has outlined recommendations that should be used when developing and evaluating complex interventions. These guidelines state that interventions should start with a theory phase before progressing to modelling and then an experimental phase (Craig *et al.*, 2008; Medical Research Council, 2000; Michie *et al.*, 2008). Whilst this current work focuses on modelling, the theory phase involves the collection of evidence and analyses via theoretical frameworks through which an intervention can be developed and modelled. The modelling stage involves hypothesising what should be targeted (determinants of behaviour) and how this can be achieved (via behaviour change techniques) (Campbell *et al.*, 2007). A wide range of theoretical models of behaviour (see section 2.4.2) have been developed , however, one common limitation is that they only help to understand or predict behaviour (Kok *et al.*, 2004) and do not help to understand behaviour change (Brug, Oenema and Ferreira, 2005) or develop interventions. In order to help researchers transition from the behavioural diagnosis of a problem to the design of an intervention, the Behaviour Change Wheel (BCW) was developed (Michie, Atkins and West, 2014; Michie, van Stralen and West, 2011) from 19 behaviour change frameworks. The COM-B model (Figure 1) is at the hub of the BCW and is used to determine what needs to change. COM-B has been found to be an effective model in explaining PA behaviours (Howlett *et al.*, 2017), however, less is known of its ability to predict SB. The BCW recognises that behaviour change occurs as a result of an interacting system with intervention functions and policy categories as the second and outer layer of the wheel (Michie, van Stralen and West, 2011). The Theoretical Domains Framework (TDF) (Cane, O'Connor and Michie, 2012) has since been added to the BCW (Alexander, Brijnath and Mazza, 2014; Michie *et al.*, 2014) in order to help unpack COM-B further and allow deeper exploration

of the barriers to and facilitators of change. The TDF has 14 domains [‘Knowledge’, ‘Skills’, ‘Social/Professional Role and Identity’, ‘Beliefs about Capabilities’, ‘Optimism’, ‘Beliefs about Consequences’, ‘Reinforcement’, ‘Intentions’, ‘Goals’, ‘Memory, Attention and Decision Processes’, ‘Environmental Context and Resources’, ‘Social Influences’, ‘Emotions’ and ‘Behavioural Regulation’ (Cane, O'Connor and Michie, 2012)].

While it is important to identify how a behaviour maps to COM-B, the intervention functions (that form the third layer of the BCW) selected as a result must also make practical considerations. One method that has been developed to assist researchers narrow down feasible intervention functions is to consider Affordability, Practicability, Effectiveness and Cost-effectiveness, Acceptability, Side effects/safety and Equity through the APEASE criteria (Michie, Atkins and West, 2014). Use of these criteria allow researchers to look beyond the BCW and explore feasibility issues before trialling an intervention. Using the BCW to design interventions is becoming more common, and it has been successfully used to understand behaviour change in different contexts, such as sexual counselling (Mc Sharry, Murphy and Byrne, 2016), medication management (Jackson *et al.*, 2014; Sinnott *et al.*, 2015), auditory rehabilitation (Barker, de Lusignan and Cooke, 2018), and PA (Webb, Foster and Poulter, 2016). Development of interventions using the full BCW to reduce workplace sitting however is limited, as stated in the Chapter One of this thesis, with only the Stand More AT Work (SMArT) study found to target hospital office workers (Munir *et al.*, 2018). Ten behaviour change techniques that could be used to target individual, environmental and organisation level barriers to reducing sitting were identified in the SMArT study (Munir *et al.*, 2018). This

intervention decreased workplace sitting time by 50.6 min at three months and by 64.4 min at six months and with evidence of sustainable long-term positive effects on job performance (Edwardson *et al.*, 2018b). Therefore, further studies using this BCW framework are required. The aim of this work is to develop through qualitative interview a tailored intervention package using the BCW that could be used in future breaking up and reducing workplace sitting interventions with desk-based employees.

6.3 Method

Ethical approval was obtained from the University of Bedfordshire Institute for Health Research Ethics Committee (approval number IHREC610). The processes of intervention development have been broadly categorised into three stages over eight steps as recommended for the BCW (Michie, Atkins and West, 2014) and illustrated in Figure 8. This study briefly describes steps one through three for contextual purposes but focuses on steps four through eight for intervention development.

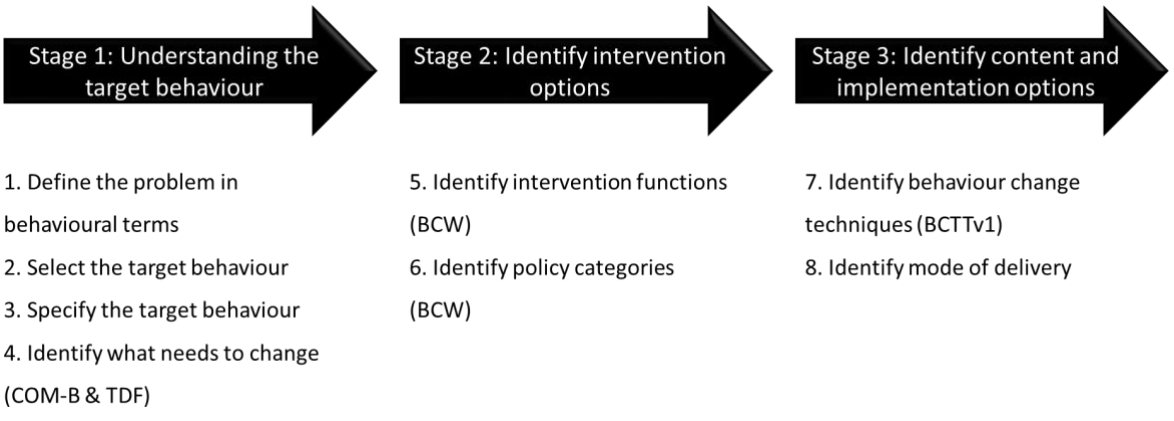

Figure 8: Stages involved in the development of an intervention using the BCW

Reproduced from (Michie, Atkins and West, 2014)

Step 1: Define the problem in behavioural terms

The first step involves defining the problem of interest that requires intervention in behavioural terms. This means identifying the problem, and specifying the behaviour and target population (Michie, Atkins and West, 2014). Previous evidence (Clemes, O'Connell and Edwardson, 2014; Dunstan *et al.*, 2013; Graves *et al.*, 2015; Healy *et al.*, 2013; McCrady and Levine, 2009; Parry and Straker, 2013) suggests that increased sedentary time is a behavioural problem significantly associated with cardiometabolic risk and poor mental wellbeing (Dunstan *et al.*, 2010; Katzmarzyk *et al.*, 2009; Wilmot *et al.*, 2012). With office workers engaging in sitting for approximately two-thirds of their total working time and their sitting bouts often lasting at least 30 minutes (Evans *et al.*, 2012; Parry and Straker, 2013; Ryan *et al.*, 2011; Thorp *et al.*, 2012), there are possibilities that workplace may be a major contributor to increased cardiometabolic disease risk.

Step 2: Select the target behaviour

This step explains that long lists of all other behaviours that may influence the target behavioural problem need to be generated. This can then be systematically reduced by considering the possible impact of each of these behaviours. For this research, behaviours such as PA, SB and sitting time were considered.

Step 3: Specify the target behaviour

Step three specifies the target behaviour by outlining the new behaviour in greater detail. Specifications should include: who needs to perform the behaviour, what do the persons need to do differently, when, where, how, and with whom will they do it (Michie, Atkins and West, 2014). In this research, the target behaviour is to break up and reduce sitting time at work which may follow guidelines in a recent expert statement (Buckley *et al.*, 2015), which states that office workers should initially reduce daily occupational sitting time by engaging in two hours of standing or walking during working hours and gradually increasing this to four hours per working day.

Step 4: Identify what needs to change

The recommended method to understand what needs to change is interviews or focus group discussions (O'Connell *et al.*, 2015), as this would ensure future interventions are participant-centred and co-created (Parry *et al.*, 2013). This research aims to inform Step 4 by using semi-structured interviews to explore sitting behaviour in office workers drawing from both the COM-B and TDF.

Step 5 and 6: Identify intervention functions and policy categories

This study also aimed to identify relevant intervention functions and policy categories to be used following the COM-B and TDF analyses and how each of the intervention functions could be supported at an organisational level (Michie, Atkins and West, 2014). The BCW guide recommends that intervention functions and policy categories should be assessed through

the use of the APEASE criteria (Michie, Atkins and West, 2014). However, as this screening process is largely contingent on resource availability, which might be different for intervention developers, the onus to use APEASE criteria would lie on individual intervention developers. In this present qualitative study, relevance of APEASE criteria is highlighted but not applied.

Step 7 and 8: Identify behaviour change techniques and mode of delivery

The research finally aimed to identify the most appropriate BCTs that could result in the desired breaking up and reduction in workplace sitting. BCTs mentioned within the qualitative interviews were individually identified and selected for the development of a future intervention by two members of the team (SO and MB). These were then discussed with the rest of research team led by AC for consensus. Then, the most appropriate mode of delivery of each technique was deliberated upon and selected by the authors. Examples of modes of delivery include face-to-face or distance delivery at the individual or group level via phone (voice or text), print or digital media, broadcast media, outdoor media, or individually accessed computer programmes (Michie, Atkins and West, 2014).

The overall aim of this chapter to develop through qualitative interview a tailored intervention package using the BCW, which could be used in future breaking up and reducing workplace sitting interventions with desk-based office employees.

6.3.1 Design

This study consisted of qualitative semi-structured interviews with desk-based employees between April and July 2017. The interview approach was chosen rather than focus group

discussion to ensure participants could express themselves freely without any undue influence from others (Leung and Savithiri, 2009). This qualitative report informs the development of a behaviour change intervention being developed and evaluated with the aim of breaking up and reducing workplace sitting time.

6.3.1.1 Participant recruitment

A purposive sampling technique was used to identify desk-based employees working for a local authority and university located in the East of England. Participants were identified based on a prior quantitative study that assessed the levels of sitting time of desk-based employees in these two organisations. Participants aged 18 - 65 years with no mental or musculoskeletal impairment that may inhibit compliance with a future intervention and who reported a minimum of 5 ½ hours of sitting per workday which equates to a threshold of 75% of a working day were eligible to participate. The study was advertised to staff using an email invite sent out to those who met the inclusion criteria. Thirty-two interviews were initially scheduled to take place at the two worksites, however, saturation was reached after 25 interviews, with no new information or themes observed in the data (Guest, Bunce and Johnson, 2006). No incentive was offered for participation.

6.3.1.2 Materials

The interview schedule presented in Table 12 was developed by SO and AC, informed by the Theoretical Domains Framework (TDF) (Cane, O'Connor and Michie, 2012), and then mapped onto each of the components of the COM-B model, as illustrated in Table 12. The COM-B

model is based on the notion that behaviour will only occur if an individual is both physically and psychologically Capable, they possess both social and physical Opportunity to carry out the behaviour and are Motivated to perform the behaviour more than any contending behaviour at that time (Michie, van Stralen and West, 2011)

Table 12: Capability, Opportunity, and Motivation to Behaviour system (COM-B)/Theoretical Domains Framework (TDF)-informed interview schedule

COM-B Component	COM-B micro-component	TDF Domain	Eliciting Questions
CAPABILITY	Psychological	Knowledge	*Can you start by telling me your understanding of current advice by experts about how much sitting time is okay?*
			Prompt—At what point do you think sitting becomes too much?
			Prompt—What do you think are the consequences of sitting for long periods?
			How do you think your sitting time compares with this advice?
		Memory, Attention and Decision Processes	*What do you think could help you overcome barriers that might prevent you from breaking up and reducing your sitting at work?*
		Behavioural Regulation	*What would need to change to help you break up long periods of sitting at work?*
	Physical	Skills	*What things might prevent you from breaking up and reducing your sitting time at work?*
OPPORTUNITY	Social	Social influences	*How do the people you work with influence your sitting time?*
			How could your work colleagues and employer help you to break up and reduce your sitting time?
	Physical	Environmental context and Resources	*How does your environment at work influence your sitting behaviour?*
			How would your environment need to change to make breaking up and reducing sitting easier for you?
MOTIVATION	Reflective	Beliefs about Capabilities Social/Professional Role & Identity	*How confident are you that you could break up your sitting time?*
		Beliefs about Consequences Optimism	*How much benefit do you feel breaking up your sitting time would give you?*
		Intentions Goals	*What would need to change to help you break up long periods of sitting at work?*

Automatic	Emotion	*How do you think your mood during the day would influence your sitting patterns?*
		What about your habits?
	Reinforcement	*How could you overcome these to break up and reduce your sitting time at work?*

6.3.1.3 Procedure

The semi-structured face-face interviews began with a general introduction and explanation of what the interview entailed. Prior to questioning, participants were given a participant information sheet and a consent form to sign, and were asked if they were happy for the interview to be audio-recorded (See Appendix 9). The duration of each interview was between 30 to 60 minutes, which is in line with that deemed to be appropriate for this type of research (Jamshed, 2014). No further amendments were deemed necessary following pilot interviews with three of the participants.

6.3.1.4 Ethical considerations

Decisions regarding moral and ethical in issues in this study were informed by the four principles of Beauchamp and Childress for data sharing, which were respect for autonomy; non-maleficence; beneficence and justice (Beauchamp and Childress, 2001). Participating office workers were verbally informed and provided with an information sheet about the study. All of their questions were sufficiently addressed to their satisfaction prior the commencement of interviews. Participants were told that they were not under any obligation to answer all the questions and that they could withdraw at any time during the interview. Anonymity was maintained throughout, with pseudonyms assigned for data collection and analysis to prevent a breach of confidentiality. The interview data was held on a password-protected computer that could only be accessed by the researcher.

6.3.1.5 Data analysis

Demographic data collected during the interviews were summarised through the use of descriptive statistics and analysed using SPSS (Version 23, IBM, Chicago, IL, USA). The recorded semi-structured interviews were anonymously transcribed verbatim (Kaiser, 2009) then analysed using NVivo qualitative data analysis software (Version 10, QSR International, Melbourne, Australia). All transcription was performed by SO. Using a combination of Thematic Analysis (Braun and Clarke, 2006) and the Framework method of analysis (Ritchie and Spencer, 1994), and following an iterative process, SO reviewed the transcripts through the stages of familiarization, developing a thematic framework, indexing, charting, mapping and interpretation. Inter-rater reliability of the final thematic analysis was assessed using 10% of the transcripts, which were coded by AC. Phrases and sentences that were salient and referred to barriers and facilitators to breaking up sitting time in the workplace were inductively identified and assigned codes by the researchers. Comparisons of codes were made, and discrepancies resolved by discussion to produce an analysis of what needs to change to ensure the creation of collective behavioural plan for breaking up and minimising prolonged sitting in the workplace (Campbell *et al.,* 2013). Recurrent major themes were presented and then each of the themes was then deductively linked with the TDF domains and COM-B (Barker, Atkins and de Lusignan, 2016; Gale *et al.*, 2013). Using the Framework method allowed naturally occurring themes and codes to be determined and allocated to pre-selected theoretically-driven domains to assist in answering the research question (Gale *et al.,* 2013).

6.4 Results

Steps 1-3 have been described in the methods above. This research has generated new qualitative data from Steps 4-8 as described below.

6.4.1 Demographics of interview participants

Twenty-five desk-based employees aged 26-59 years (40.9 ± 10.8 years) were interviewed (17 females, 8 males). Eight of the 25 participants were from the council offices, while the remaining 17 were university employees. All participants are presented using pseudonyms (Kaiser, 2009) and their characteristics are shown in Table 13. The mean body mass index (BMI) of participants was 25.7 ± 3.5 kg/m2. Four participants were classified as obese (BMI ≥ 30), with 10 participants overweight (BMI ≥25 to 30), and 11 participants normal weight (BMI ≥18.5 to < 25). Ethnicity was mixed with White British/Other as dominant (*n* = 15), Black Caribbean/African/British (*n* = 3), Pakistani (*n* = 3), Asian (*n* =1), Greek (*n* = 1), Cypriot (*n* = 1) and Russian (*n* = 1).

Table 13: Participant demographics

Participant	Age	Gender	Ethnicity	BMI (Kg/m^2)
1. Julie	37	F	White British	26.7
2. Jackie	47	F	White British	32.6
3. Salma	27	F	Pakistani	24.8
4. Lilian	55	F	Black Caribbean	30.3
5. Farouq	30	M	Asian	30.1
6. John	27	M	White British	21.7
7. Jake	37	M	White British	29.6
8. Terry	37	M	White British	27.6
9. Jocasta	34	F	Greek	23.5
10. Abi	40	F	White British	29.4
11. Louisa	41	F	White British	25.6
12. Cheryl	31	F	White British	24.8
13. Sophia	26	F	Cypriot	25.4
14. Marcos	31	M	White Other	22.4
15. Amira	29	F	Pakistani	19.9
16. Jude	57	M	Black British	28.6
17. Precious	50	F	White British	20.8
18. Vickie	59	F	White British	27.3
19. David	32	M	Black African	23.8
20. Taher	44	M	Pakistani	22.6
21. Tina	58	F	White British	25.7
22. Tiana	47	F	White British	30.1
23. Becky	58	F	White British	20.4
24. Eunice	47	F	White British	25.0
25. Nikita	41	F	Russian	23.5

6.4.2 Core Themes—Determinants of Breaking Up and Reducing Sitting Time in the Workplace (COM-B Behavioural Diagnosis)

Inductive thematic analysis led to the identification of seven core themes, which were able to explain desk-based employees' SB in the workplace. These themes were 1) '*Knowledge-deficit sitting', 2) 'Inadequate cognitive resources for action', 3) 'Organisational support and interpersonal influences', 4) 'Tied to the desk', 5) 'Willingness to Change', 6) 'Competing motivations', and 7) 'Emotional influences'.* These themes were then linked to five of the six COM-B elements *(Psychological Capability, Reflective Motivation, Automatic Motivation, Social Opportunity, Physical Opportunity [omitting Physical Capability])* and 12 of the TDF domains (*Knowledge, Skills, Beliefs about capabilities, Intentions, Beliefs about consequences, Environmental context and resources, Social influences, Reinforcement, Social/Professional role and identity, Emotion, Memory, attention and decision processes, Behavioural regulation [omitting Optimism and Goals])* presented below (with ***COM-B; [TDF shown in brackets below]***), and with an overview of barriers and facilitators in Table 14 and thematic map in Figure 9.

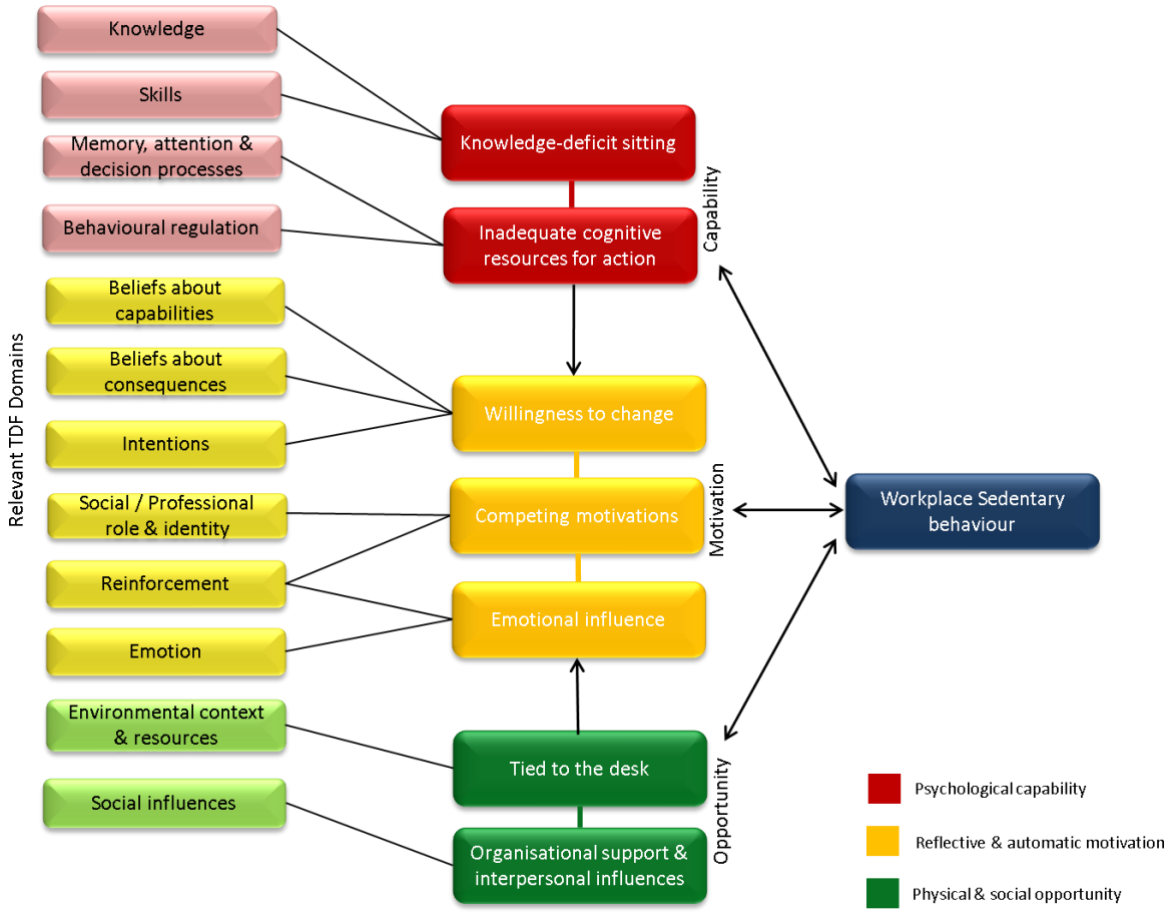

Figure 9: COM-B adapted determinants of workplace sedentary behaviour

Core themes from the interviews have been categorised into capability, opportunity and motivation in line with the COM-B model and the structure of the interview schedule.

Capability

The majority of participants said they are **physically capable** of breaking up their sitting time, although some highlighted that walking and standing trigger back problems. With respect to **psychological capability,** two themes emerged:

1. **Knowledge-deficit sitting** (***Psychological Capability; [Knowledge, Skills]***)

Lack of knowledge regarding sitting guidelines was unanimously cited as a reason for prolonged sitting in the workplace. The participants stated that it was important for them to understand how much sitting is acceptable or excessive, as well as the consequences of prolonged sitting and any benefits of breaking up sitting time. This highlighted *knowledge* and skills as important TDF domain that should be targeted in an intervention:

> *"If I'm really honest, I don't really know any current advice other than it's not good to sit down for too long… I think it would help if this is properly communicated" (Abi, 40).*

> *"Ahem, I really don't know what the advice is about total sitting time, the only advice I've seen is …, getting up regularly, but that's really more about screen time, time away from your computer screen. Not really aware of the general advice to the general population about sitting. Just that, it's not good to sit for too long" (Eunice, 47).*

> "*I actually have no idea what the recommended sitting time would be for a workplace environment or what the expert advice is, the right of length of time" (Jake, 37).*

However, a high number of participants knew their sitting at work was excessive, yet were also aware that knowledge does not always lead to action:

> *"There's a complete disconnect between what I do and what I know is good practice. Like I said, it's not done deliberately even though I know, you know it's good practice to get up and walk around" (David, 32).*

"Many times, I've had to stand up but wait for two seconds for my legs to wake up long enough before I walk along to the photocopier. My sitting time is horrendous. Knowing it and doing it are two different things" (Taher, 44).

2. **Inadequate cognitive resources for action (*Psychological Capability; [Memory, attention and decision processes, Behavioural regulation]*)**

Participants also stated having inadequate cognitive resources that support breaking up sitting time. For instance, they blamed their sitting behaviour on being engrossed in their daily tasks, and as a result, they forget to take micro-breaks. Being immersed in work also led to a neglect of physiological or psychological triggers to break up sitting time in order to meet a deadline.

"I get focused on work, erm, I don't notice the time so if I am writing a research paper or if I am writing a key document, I simply don't notice the time ……" (David, 32).

"I think because I'm concentrating either writing about something or maybe doing something technical on the website, rather than break the concentration even when tired, I often stick at it till I get the job done. And sometimes that can take longer than you would think" (Eunice, 47).

However, most of the participants believed that installing an application that flashes on their computer, known as computer on-screen prompts, would serve as a reminder for them to get up and take a short break from their work.

"Also doing some sort of algorithms for your computer, so that when your computer realises that you've been sat down it flashes up or something, a buzzer or something that tells me when I've sat still for X amount of time" (David, 32).

"I can't remember, but basically something that locks your screen and tells you, you have to move forward or something like that and then come back or my Fitbit, just charging it now… it's up to the individual, because am pretty sure about 90% of my office would like to have that app…" (Sophia, 26).

"It's just the amount of work, purely the amount of work that's there. Also, not remembering to, because sometimes you become engrossed in a project, or in a piece of work …, your head is just focused on that piece of work…. It's a case of the workload. Maybe something that flashes up on the computer; that flashes up at me saying: 'you've been working for this length of time, you know move now'…." (Taher, 44).

Despite the popularity, some participants believed computer on-screen prompts can easily be ignored or go unnoticed, especially when the users are in a meeting or working away from their desks and computers:

"Hmm, it is about how you sit if you will see the prompt. Sometimes you can be in a meeting or board meeting, so you might not be aware of the prompt as you are not sitting close to your computer at that time, so it depends on the nature of the office and how often people sit with their PC" (Cheryl, 31).

It was also perceived that older employees might be irritated seeing their screens locked automatically without warning.

> *"Might be a good one, but it might be annoying for other people. Like we obviously have old members in the team, so I think they might not appreciate locking their screens every half an hour" (Sophia, 26).*

Opportunity

Barriers and facilitators within the social and physical office work environment were identified to shape the office workers' opportunities to break up prolonged sitting time. Two themes; "organisational support and interpersonal influences" and "tied to the desk" linked to Social opportunity and Physical opportunity respectively emerged.

3. **Organisational support and interpersonal influences (*Social Opportunity; [Social influences]*)**

Several employees highlighted fear of being judged and condemned by their fellow colleagues, and of being penalised by their manager as a reason for not breaking up their sitting behaviour.

> *"The main inhibitor is if people think they was penalised because they think they've not been productive. I think the motivation will just come from knowing that they are supported by the manager" (Eunice, 47).*

"It's probably a matter of attitude because if you're just walking around, people think you're, you're wasting time; what are you doing? You know, chatting to people when you should be sitting at your desk working? Erm, and I think that's perhaps the biggest thing, is attitude towards you getting up and walking around" (Tina, 58).

However, it was revealed that the onus is not on individuals alone, but also on organisations. Participants were keen to break up their sitting if there was a policy or written statement that clearly shows that their organisations are supportive of the culture of micro-breaks at work and that there would not be any form of condemnation or judgment.

"I think it's not about what they can do but it's about the whole [organisation] being aware of true key messages, I think it's about promoting positive culture of movement, erm… And that comes through communication, variety of communication strategies, it's about communicating every opportunity about good practice about healthy movement…. and I guess it's about being given permission" (David, 32).

"Just knowing that my manager is okay with me getting up every half hour should be enough really. Apart from that, I'm okay but it's a busy period right now so I have to be on my desk …. I get that, so if my manager is okay with me standing up, going back and forth for two to three minutes then coming back, then it's fine" (Salma, 27).

"The only way really is becoming some sort of policy. Health and safety policy where it's implemented like a body in every office that reminds people" (Jude, 57).

In addition, other opportunities that come from the TDF domain *social influences* as identified by the participants include restricting their colleagues from making tea for them to encourage them to get up more often to do it themselves, being part of a team to provide collective support and ensure a collective target is set, appointing someone like a fire marshal to remind people, or having walking and standing meetings.

> *"Again I suppose it would have to come from another person to sort of tell me, that 'you have got to remember that you need to stand' I think someone like a fire marshal would get the job done (smiles)" (Jackie, 47)*.

> *"If it was a corporate activity, I am more likely to engage with it. If you are on your own, you are less likely to do it. Being encouraged by other people would help a great deal" (Becky, 58).*

4. Tied to the desk (*Physical Opportunity; [Environmental context and resources]*)

Most participants stated that the nature of their job impels them to work sitting down, without any structured breaks as it requires working on a computer, typing, responding to queries via emails, and making and receiving telephone calls.

> *"I think the general nature of my work mitigates against me being active at work because it's essentially sitting at a computer or sitting interviewing students or sitting in meetings." (Becky, 58).*

Moreover, irrespective of mindset, restriction due to heavy workload was seen as a hindrance to breaking up sitting time at regular intervals.

> *"Workload, theoretically I should be moving around different areas, looking at people, I have staff in different environments, I should be visiting them... People don't choose to want to sit all day, I think it's the work level that makes you sit all day at the desk. For crying out loud with my workload perhaps if I go for a coffee break I could probably do it on my laptop while I have my coffee …. "(Jude, 57).*

> *"Mmm, I guess work restrictions so, some people, if they're really busy, for example if they're customer facing and if they're really busy, they don't always get a chance to actually go and leave the desk to take a break and walk around and get some light exercise" (Sophia, 26).*

However, many believed they would be able to break up and reduce their sitting time by alternating between sitting and standing whilst carrying on working if they had access to height-adjustable workstations and if cost was not a concern.

> *"If you have those you know adjustable desks, absolutely that would make a huge difference for sure rather than moving around… If I had a desk, like one of those, like I said we've got a couple in the office that you can raise or lower, you were more inclined to be standing for most of the day than sitting for sure" (Abi, 40).*

> "*I think a raising desk is something that is worth exploring, but I understand that financially that is a huge investment for the [organisation] but there has been a lot of*

studies into that…. If money was not a problem, you can get raising desks, you can have it raised or seated and I will be happy to try that" (Terry, 37).

However, concerns were raised by some of the participants about the cost implication of a height-adjustable workstation, and whether organisations would be willing to invest in these.

"I've seen these desks where you can stand up and work; that was fantastic! Knowing about the cost implication in it, financial instability, may be too strong a word, of the organisation. Ahem, I don't think any money was put into that kind of motivation, but that was fantastic" (Eunice, 47).

Motivation

Participants stated that the intervention should target both **reflective** and **automatic motivation** for behaviour change to take place. With regards to reflective motivation, one theme emerged while two themes were linked to automatic motivation:

5. **Willingness to Change (*Reflective Motivation; [Beliefs about capabilities, Goals, Intentions, Beliefs about consequences]*)**

Around half of the participants reported that they felt in control of breaking up their sitting time, reflecting self-efficacy beliefs within the *beliefs about capabilities* TDF domain. For instance:

"On a scale of '1' to '10', with '10' being the most confident; I would say my confidence level is '8'" (Vickie, 58).

However, there was high variability with respect to beliefs about the health consequences of prolonged sitting, including weight gain, heart problems, lethargy, backaches, numbness, bad posture, tiredness, and mental drainage.

> *"Muscle wastage, exhaustion, not being alert, painful both mentally and physically, painful in the sense that you are not able to regulate your body temperature" (Farouq, 30).*

> *"For me, it's putting on weight and not just exercising enough so I can honestly say to you that if I came in 8am in the morning, sometimes I don't leave the office; I just walk down the corridor to make a cup of coffee until I leave by 4pm - that has got to be bad!" (Vickie, 59)*.

Apart from a perceived negative impact on health, it was also reported that prolonged sitting might result in a loss of productivity and concentration.

> *"I think that you become less productive because you are just sitting in the same spot so everything else is not firing quite the same way and eye strain, in particular with using the computer, and just not getting your heart rate going as much I suppose is another thing" (Julie, 37).*

Moreover, participants stated that they would respond to set goals if there was an expectation that they would be rewarded at the end, highlighting *goals* as important TDF domains.

"Well, I'm motivated by having a pound every time I get up, or, or a chocolate every time I get up… It wouldn't necessarily have to be money, it could be a, as I say, a kind of build credits for some sort of treats…" (Nikita, 41).

6. Competing motivations (*Automatic Motivation; [Reinforcement, Social/Professional role and identity]*)

Many participants identified existing habits and reinforced daily routines that inhibit them from breaking up their sitting time, some of which include eating at the desk and surfing the internet whilst sitting at the desk during lunch breaks.

"I actually work through my lunch; that is not good but I do work through my lunch time…… but you might be just surfing the net to look at what's on YouTube, such as the latest diet or, you know, whatever interests that you might see… checking social media and stuff like that and catching up with whatever BBC news stories might be" (Lilian, 55).

Several employees also reported laziness and lack of will power was seen as a counter argument that may prevent them from doing so. Some of them said they delay getting up until they have so many things to do. In response, the participants highlighted they will need to change their mindset for a stronger commitment towards integrating movement and standing into their work life, which corresponds to the *intention* TDF domain

"The right mindset! That's what I need to be able to stand up and walk at regular intervals" (Tiana, 47).

"Erm... I don't want to use this word but I'm going to say laziness. Do you know what I mean? There's sometimes I think, "Ahh, I could, I could go downstairs" but I'll wait until I've got more things I need to do downstairs and I'll go just once. So, I think laziness is, is a large bit of it" (Precious, 50).

"We are in an open office, so you don't have to necessarily get up and talk to somebody; you can just holler, it's laziness so yeah work environment we are in, is pretty lazy. It impacts quite a lot (Louisa, 41).

On the other hand, around half the participants admitted that they can engage in less sedentary time if they have a strong mindset and are mentally disciplined to break the habit in relation to their sitting time.

"I think it is more of a discipline thing actually. Right, you do need to get up, you need to stretch, you need to do something rather than just sitting here" (John, 27).

"Yeah, I need my mindset to change basically, I need to have, I need to get myself motivated to do something even if it's just making a point of going out every lunch time and just walking round the block" (Vickie, 59).

7. **Emotional influences (Automatic Motivation; [Emotion, Reinforcement])**

The feeling of not wanting to move was often linked to times when low in mood, while *participants reported moving more often when they felt happy.*

"When I'm more cheerful, happier more relaxed then I'll probably get up more because I will go and talk to somebody or spend a bit more time you know, not just sitting focusing on what I'm doing" (Julie, 37).

"Yeah, erm... I guess if I was in a low mood I would be more inclined to sit still and not get up because I don't want, I don't perhaps necessarily want to find somebody, no- not find somebody, I wouldn't want to bump into somebody who then is going to give me something I don't want, in terms of work or a problem or something, so I would probably more likely if I was in a low mood to kind of hide up here and just, just kind of keep my head down and keep it out the way" (Precious, 50).

In contrast, some participants believed that their job, rather than their mood, determines their sitting behaviour:

"No, not for me, my job determines my sitting behaviour and what I do determines my sitting behaviour, but my mood doesn't, no!" (Abi, 40).

"Regardless of if am upset or am happy it doesn't really affect how much I sit, if I have a requirement I will go. If I am allowed to move freely, I would go, it gives me better mind" (Farouq, 30).

"My job determines my sitting behaviour, but my mood doesn't – no!" (Abi, 40).

Participants who perceived sitting time could be influenced by mood expressed that their optimism and motivation could be improved by having access to empirical evidence regarding the negative consequence of prolonged sitting.

> *"Generally, people value research evidence, statistics, so in terms of increasing motivation and hope, informational literature on consequence of excessive sitting I guess will make a difference" (Becky, 58).*

Participants also reported that they are likely to overcome the habit of siting if there was competition among peers or if they were given incentives, underlining *Reinforcement* as an important TDF domain.

> *"You could develop some sort of challenge type thing. Erm, you know, people like games or competitions or even being given vouchers. People can find that quite motivating from that point of view" (John, 27)*.

6.4.3 Identification of intervention functions and policy categories

Seven out of nine intervention functions described in the BCW guide ((Michie, Atkins and West, 2014) were identified as relevant based on the outcomes of the semi-structured interviews, mapped from COM-B shown in Table 15. These intervention functions are; *Education* (defined as increasing knowledge and understanding), *Training* (defined as imparting skills), *Persuasion* (Defined as a way of using communication to stimulating positive or negative feeling or action), *Environmental restructuring* (defined as changing the physical or social context), *Enablement* (defined as increasing means and reducing barriers to increase

capability), *Incentivisation* (defined as creating an expectation of reward), and *Modelling* (defined as providing an example for imitation).

With respect to policy categories, only three out of the seven categories highlighted in the BCW guide (Michie, Atkins and West, 2014) were identified. These included *Communication/marketing* (for instance, using verbal, electronic communication or flyers to create awareness of benefits of breaking up sitting and health consequences of prolonged sitting), *Guidelines* (examples of which include informing employees of sitting time guidelines), and *Environmental/social planning* (e.g, designing and controlling the logistics of height-adjustable workstations within the office setting/office culture).

Table 14: Combined link between COM-B model, TDF domains, intervention functions, policy categories and BCT

COM-B Component	**Themes**	**TDF**	**What needs to happen for the target behaviour to occur**	**Evidence to support the need for change (Quotes from the interviews)**	**Intervention Functions**	**Policy Categories**	**Behaviour Change Techniques (BCTs)**
Psychological Capability	Knowledge-deficit sitting	Knowledge	Have access to empirical evidence that supports breaking up sitting time	*"Personally, I think I base my decisions on evidence, case studies and 'big shots'. Therefore, the more information we have about how it's beneficial to people and exactly what has happened, the intervention provided and the exact result"* (Participant 24, aged 47)	Education	Communication / Marketing, Guidelines	**9.1** Credible source **5.1** Information about health consequences **5.3** Information about social and environmental consequences
			Have an awareness of the health consequence of excessive sitting	*"I think you need to keep spreading the message that sitting for long periods of time actually isn't good for you"* (Participant 18, aged 59) *"I think, for me, possibly having a clearer understanding of the damage and negatives"* (Participant 6, aged 27)	Education	Communication / Marketing, Guidelines	**5.1** Information about health consequences

	Have an awareness of the benefit of breaking up sitting	*"I think it's about… education, I think it's about those key communication, and the positive, yes negative is important, but actually promoting the positive or focusing on the benefits rather than….."* (Participant 19, aged 32)	Education	Communication /Marketing, Guidelines	**5.1** Information about health consequences
	Have access to feedback about individual health behaviour	*"Erm, somebody from occupational health came out to see me, and pointed that I sit kind of wonky at my desk. I think if we have something or someone that tells us our progress, I'm sure everyone would be inclined to adjust"* *(*Participant 9, aged 34)	Education	Guidelines	**2.2** Feedback on behaviour
	Know other strategies to break up sitting	*"Maybe by reducing use of emails a bit more; instead stand up and talk to people rather than email when they are just there"* (Participant 11, aged 41)	Education	Communication / Marketing	**8.1** Behavioural practice/rehearsal **8.2** Behaviour substitution **8.3** Habit formation **8.4** Habit reversal

		Skills	Understand guidelines on sitting in the workplace	*"What do the experts say? Erm to be honest with you, I can't say I have any particular knowledge or guidance to it. I don't know what the recommendation is (smile) so I can't answer that…"* (Participant 22, aged 47) *"I'm not aware of any advice that says, 'Don't sit for longer than X amount"* (Participant 21, aged 58)	Training	Guidelines	**4.1** Instruction on how to perform the behaviour
	Inadequate cognitive resources for action	Memory, Attention & Decision Processes	Improve ability to remember to take breaks from sitting	*"Yea I would do a chair that buzzes or causes electric shock; shaking chair that's got a pressure pad on it so you know if it's been sat on it for a long time"* (Participant 19, aged 32) *"I think technology can be used for pop-up on peoples' computer every now and then, reminding them to get up and move or to get up and work once an hour or so"* (Participant 8, aged 37)	Environmental restructuring Enablement	Environmental/ Social planning	**7.1** Prompts/cues **12.5** Adding objects to the environment **12.1** Restructuring the physical environment

	Behavioural Regulation	Identify and develop strategies to break existing habits and for self-monitoring of sitting	*If I've got something that I can look at and I think 'oh I should be doing that'. The guilt factor always works… I would be willing to try if I know I'm being monitored* (Participant 10, aged 40) *"Getting drinks, getting water. For example, at the moment I do have a bottle on my desk, but I've actually decided on getting a small cup to allow me stand up as many times as possible..." (*Participant 6, aged 27)	Education Enablement	Communication / Marketing, Environmental/ Social planning	**2.3** Self-monitoring of behaviour 2.1 Monitoring of behaviour by others without feedback 2.2 Feedback on behaviour **1.2** Problem solving **1.4** Action planning **7.1** Prompts/cues **12.5** Adding objects to the environment
Physical Capability	Skills	Have physical strength to move more and sit less	*"Erm, if somebody was ill - I'm not personally, but - if somebody was, if they had a bad back or bad legs and it's difficult for them to walk around on a regular basis, I think they would benefit a lot from getting help from physio and weight training"* (Participant 4, aged 55)	Training Enablement	Environmental/ Social planning	**12.6** Body changes

Social Opportunity	Organisational support and interpersonal influences	Social influences	Have the enablement to make tea by oneself rather than by colleagues	*"Because they (colleagues) make my tea for me (laughs). We share the roles, we've got rota for making tea, so the four of us that drink tea take turns to get the drink. They are influencing my sitting time because they are making my drinks, so I'm not actually having to get up and do it myself"* (Participant 20, aged 44)	Enablement	Environmental / social planning	**6.3** Information about others' approval **1.2** Problem solving **1.4** Action planning
			Consider creating a team for peer support and comparison	*"I would feel uncomfortable doing it on my own, so I just kind of carry on as I am, but I think if we were doing it as a whole, we would not feel alone and can compare what we are doing with our colleagues'"* (Participant 10, aged 40)	Enablement	Environmental / social planning	**6.2** Social comparison **12.2** Restructuring the social environment **3.1** Social support (unspecified)
			Identify a timekeeper to get people moving	*"A possibility depends on whether I can get a Fire Marshall that would jump up and say 'common people, let's do stretches. I think there are people in our office who are well*	Modelling Enablement	Environmental/ Social planning	**3.2** Social support (practical) **6.1** Demonstration of the behaviour

		placed to do that kind of thing" (Participant 10, aged 40)			
	Encourage having walking or standing meetings	"Walking meeting would be nice. You know when you're just walking around, having a meeting instead of sitting in a place" (Participant 13, aged 26)	Enablement	Environmental/ Social planning	**8.1** Behavioural practice/rehearsal **8.2** Behaviour substitution **8.3** Habit formation **8.4** Habit reversal **12.2** Restructuring the social environment
	Consider stretching or walking for five minutes every hour	"*Go for a walk every hour or do the stretching kind of every half an hour for five min"* (Participant 9, aged 34)	Enablement	Environmental/ Social planning	**1.1** Goal setting (behaviour) **1.4** Action planning
	Encourage senior management to participate in breaking up sitting to ensure support	*"I guess a manager would be appropriate person, so that you don't feel you are doing something you should not do"* (Participant 24, aged 47)	Enablement	Environmental/ Social planning	**3.1** Social support (unspecified) **12.2** Restructuring the social environment

			Organisational support for moving more and sitting less	*"I think there can be some sort of support from management or line managers to make sure that, you are not just sitting there continuously… Cultural change at higher level, maybe via a training section, leaflet or booklet that go around or one of those online courses that we normally do - like fire awareness training, health and safety training …"* (Participant 7, aged 37)	Enablement	Environmental/ social planning	**3.1** Social support (unspecified) **12.2** Restructuring the social environment
Physical Opportunity	Tied to the desk	Environmental context and Resources	Provision of computer reminder system	*"I think technology can be used for pop-up on peoples' computer every now and then, reminding them to get up and move or to get up and work once an hour or so"* (Participant 8, aged 37)	Enablement	Environmental/ Social planning	**7.1** Prompts/cues **12.5** Adding objects to the environment
			Provide height-adjustable workstations to ensure employees continue working while standing up	*We probably do need our desks to be adjusted…. you know, at the right height. Well, I'm surprised this place doesn't have them, but I have worked in places where, hmm, where we*	Environmental restructuring	Environmental/ Social planning	**12.1** Restructuring the physical environment **12.5** Add object to the environment

		have actually had height-adjustable workstations. This place should have them, full stop" (Participant 4, aged 55)			
	Move printers, water dispensers away from employees' desks	*"Moving photocopiers and water dispenser further away…Same with toilet facilities. We've got to walk to them! Also, probably getting rid of all the rest of the printers, and we've only got one printer to use"* (Participant 20, aged 44)	Environmental restructuring	Environmental/ Social planning	**12.1** Restructuring the physical environment
	Provide treadmill/ stand up chairs or buzzing chairs	*"Yeah I would do a chair that goes up and down or a chair that buzzes or causes electric shock; shaking chair that's got a pressure pad on it so you know if it's been sat on it for a long time"* (Participant 19, aged 32) *"Mind you there are some brilliant chairs around, have you seen some of these new chairs, the stand-up ones, they are like rockers, and you've got to*	Environmental restructuring	Environmental/ Social planning	**12.1** Restructuring the physical environment **12.5** Adding objects to the environment **7.1** Prompts/cues

				keep your stability and your muscles working…. 'cause your legs are permanently keeping you stable and those flexing which are equivalent of walking, but you're not stood up" (Participant 8, aged 44)			
			Access to a standing hot desk	*"Yeah, possibly a hot-desking idea might be a good one, switching from my desk to a higher one. Yeah good use for that!"* (Participant 13, aged 26)	Environmental restructuring	Environmental/ Social planning	**12.1** Restructuring the physical environment **12.5** Adding objects to the environment
Reflective Motivation	Willingness to Change	Beliefs about Capabilities	Have a strong will and belief you can break up sitting	*"Somewhat confident, not massively… I hardly move until lunch break… I could break it up a little more and but not massively"* (Participant 8, aged 37) *"I am not making any excuse, but it is difficult for me at the moment to see how I can incorporate exercise into my day…"* (Participant 18, aged 59)	Education Persuasion	Communication / Marketing	**15.1** Verbal persuasion about capability **15.2** Mental rehearsal of successful performance **1.4** Action planning

		Acknowledge the need for self-discipline	*"If you discipline yourself to do something you can do it, if you have willpower…."* (Participant 3, aged 27)	Education Persuasion	Communication / Marketing	**8.3** Habit formation **4.2** Information about antecedents **8.1** Behavioural practice/rehearsal
	Goal	Have breaking up sitting goals with an expectation of reward	*Well I'm motivated by having a pound every time I get up, or, or a chocolate every time I get up… It wouldn't necessarily have to be money, it could be a kind of build credits for some sort of treat or, I don't know, half an hour of you know"* (Participant 25, aged 41) *"I think people could become quite motivated if you could develop some sort of challenge thing. Erm, you know, people like games or competitions, people can find motivation from that point of view"* (Participant 6, aged 27)	Incentivisation	Communication / Marketing	**1.1** Goal setting (behaviour) **1.2** Problem solving, **1.4** Action planning **10.1** Material incentive (behaviour) **10.2** Material reward (behaviour) **10.3** Non-specific reward **10.4** Social reward **10.5** Social incentive **10.6** Non-specific incentive **10.9** Self-reward

		Intention	Move from the state of contemplation to commitment to break up sitting	*"I just need to prioritize it really. It's prioritization, you need that reminder"* (Participant 13, aged 26)	Education Persuasion	Communication / Marketing	**1.1** Goal setting **1.4** Action Planning
Automatic Motivation	Emotional influences	Emotion	Discuss the risk involved in prolonged sitting to reduce the influence of mood	*"Because I'm low in mood I sit for a long time. Most times, when I leave, I'm tired, lethargic, and drained. I think getting up more would just make me better by the end of the day"* (Participant 10, aged 40)	Persuasion	Communication / Marketing	**5.6** Information about emotional consequences **11.2** Reduce negative emotions **2.4** Self-monitoring of outcome(s) of behaviour **4.4** Behavioural experiments
	Competing motivations	Reinforcement	Develop goals with incentives and reward to encourage employees to break up their sitting time	*"Maybe incentives, but I'm not sure what the incentive would be. Whether you do this, and you get a bag of apples at the end of the month"* (Participant 10, aged 40)	Incentivisation	Communication / Marketing	**10.8** Incentive (outcome) **10.1** Material incentive (behaviour) **10.2** Material reward (behaviour) **10.3** Non-specific reward

| | | |

6.4.4 Identification of behaviour change techniques

BCTs are considered as 'active components' when designing an intervention. In total, 39 out of the 93 BCTs in the BCT Taxonomy Version 1 (Michie *et al.*, 2013) were identified from the interview data (Table 14) (Michie, Atkins and West, 2014). The list of the possible BCTs were: 'Instruction on how to perform the behaviour', 'Credible source', 'Information about health consequences', 'Information about social and environmental consequences', 'Feedback on behaviour', 'Behavioural practice/rehearsal', 'Behaviour substitution', 'Habit formation', 'Habit reversal',' Prompts/cues', 'Adding objects to the environment', 'Restructuring the physical environment', 'Self-monitoring of behaviour', 'Monitoring of behaviour by others without feedback', ' Problem solving', 'Action planning', 'Body changes', 'Information about others' approval', 'Social comparison', 'Restructuring the social environment', 'Social support (unspecified)', 'Social support (practical)', 'Demonstration of the behaviour', 'Goal setting', 'Verbal persuasion about capability', 'Mental rehearsal of successful performance', 'Material incentive (behaviour)', 'Material reward (behaviour)', 'Non-specific reward', 'Social reward', Social incentive', 'Non-specific incentive', 'Self-reward', 'Information about emotional consequences', 'Reduce negative emotions', 'Self-monitoring of outcome(s) of behaviour', 'Behavioural experiments', 'Information about antecedents' and 'Incentive (outcome)'. Intervention designers will need to select BCTs that are mostly appropriate for the situation the intervention is being conducted. This can be achieved by considering the APEASE criteria or by first choosing BCTs that were most frequently used before those that were less frequently used as described in the BCW guide (Michie, Atkins and West, 2014).

6.4.5 ***Mode of delivery***

The appropriateness of mode of delivery depends on the target behaviour, target population and setting. Details on taxonomy of modes of delivery can be found in the BCW guide (Michie, Atkins and West, 2014). APEASE criteria should be used in selecting mode of delivery of choice. This could be either face-to-face or distance depending on setting. Where employees are spread over different offices and different locations, interventions could be delivered face-to-face, in clusters or individually. This can be achieved by giving out leaflets with detailed information about breaking up sitting, sitting guidelines for office workers and demonstrated using digital media.

6.5 Discussion

The aim of this work was to use qualitative interviews with desk-based employees to highlight aspects of the BCW that can be used to develop a tailored intervention package that could be employed in breaking up and reducing workplace sitting. This research describes the systematic process used to model determinants of workplace sitting behaviour by qualitatively analysing sources of behaviour with the COM-B/TDF model, linking to subsequent intervention functions and policy within the BCW, and finally, identifying the appropriate behaviour change techniques to use when developing a tailored intervention to break up office workers' sitting time.

Barriers to breaking up and reducing sitting time at work were attributed to the core themes of: '*Knowledge-deficit sitting', 'Inadequate cognitive resources for action', 'Organisational*

support and interpersonal influences', 'Tied to the desk', 'Willingness to Change', 'Competing motivations', and 'Emotional influences'. The majority of the participants in this study were not aware of any published recommendations for reducing sitting in the workplace (Buckley *et al.*, 2015). However, participants expressed a keen interest in changing their sitting behaviour, suggesting that a workplace intervention targeted at sitting patterns would be acceptable. The main reasons cited for prolonged sitting at work were the sedentary nature of the job, forgetfulness due to a heavy workload, an unsupportive physical workspace, and the organisational and social culture. These findings are consistent with previous studies that identified organisational cultural norms around "appropriate" workplace behaviour, environmental changes and workload pressures as barriers to breaking up workplace sedentary time (Cole, Tully and Cupples, 2015; Hadgraft *et al.*, 2016a; Waters *et al.*, 2016).

The interview responses suggested that interventions should include education about sitting guidelines, health and emotional consequences of prolonged sitting and the benefits of reducing sitting time; prompts to serve as reminders to break up sitting; environmental modification, such as the provision of height-adjustable workstations to alternate between sitting and standing without disrupting work; and changes to social and organisational support. However, concerns were raised about the cost implication of a height-adjustable workstation and whether organisations would be willing to invest in such a scheme to enhance the Physical Opportunity to sit less. There is evidence that suggests the long-term indirect costs of employees' presenteeism and absenteeism stemming from SB-associated illness might be higher than the cost of height-adjustable workstations. For instance, height-

adjustable workstations cost ≥£279 (US $375) per unit for a single display (Gardner *et al.,* 2017) and ≥£305 (US $400) per unit for a dual display (Healy *et al.,* 2013), which compares favourably with the indirect cost of presenteeism for businesses (which is far more than the cost of absenteeism) that was approximately £194 (US $255) per employee per annum (Goetzel *et al.,* 2004). Evidence has shown that organisational managers and employers are perceived as gatekeepers that determine the implementation of the recommendations to break up prolonged sitting in the workplace (Gardner, Smith and Mansfield, 2017), which was also identified in the current study. Similarly, previous studies (George *et al.*, 2014; McGuckin, Sealey and Barnett, 2017; Toomingas *et al.*, 2012) have reported similar findings that breaks from prolonged sitting need to be seen as a "normal" activity in the workplace in order to prevent perceived criticism from colleagues. Organisational support would address this change. This could be an important strategy to prevent SB-induced diseases, due to a probable connection between social support, role-modelling, and social norms and the development of chronic diseases associated with prolonged sedentary behaviour (Owen *et al.*, 2014).

The identified themes were linked to five of the six COM-B elements, including Psychological Capability, Social and Physical Opportunity as well as Reflective and Automatic Motivation as key targets for a behaviour change intervention for breaking up sitting time at work among office workers. However, there was no strong evidence for *Physical Capability* barriers in this data set. This is likely due to the exclusion of people with musculoskeletal problems in the study design. The use of the COM-B model (Michie, van Stralen and West, 2011) was instrumental in identifying an overview of factors contributing to prolonged sitting time in the

workplace. Mapping the data further to the TDF (Cane, O'Connor and Michie, 2012) ensured an exhaustive behavioural diagnosis of the determinants of the behaviour. Eleven of the TDF domains (*Knowledge,* Skills, *Beliefs about capabilities, Intentions, Beliefs about consequences, Environmental context and resources, Social influences, Reinforcement, Social/Professional role and identity, Emotion, Memory, attention and decision processes, Behavioural regulation)* were highlighted to be targeted in work-based sitting interventions following the inductively driven thematic analysis, without strong evidence for *Optimism and Goals.* This may again be linked to the inclusion criteria (free from musculoskeletal ill health) and the nature of the interviews investigating barriers as opposed to issues that may highlight optimistic views or goal setting.

The findings from the analysis of the interviews in this study suggest that the drivers of behaviour could be either intrinsic or extrinsic. Intrinsic drivers are those that are personal to employees, while extrinsic drivers are determined by the environment and employers. However, this implies that breaking up sitting time will require a more complex intervention using concerted behavioural planning that involves both office workers and their employers, as found in a previous study (Munir *et al.,* 2018). It was evident that there is currently no such collaborative scheme, where employees are knowledgeable, ready, willing and able, and feel supported to break up their sitting in the workplace. To trigger a change, there is an urgent need for intervention developers to focus on educating office workers about risks attached to prolonged sitting and what is currently considered as acceptable sitting time durations during a working day. To ensure such a change occurs would require a culture of collaborative

behavioural planning and the development of a complex intervention that would need to take Psychological Capability, Social and Physical Opportunity, and Reflective and Automatic Motivation into consideration. However, going by the 'less is more' principle of intervention design, only a fraction of target drivers of behaviour should be selected for rigorous intervention testing, instead of targeting several with no focus (Michie *et al.*, 2014).

Consequently, seven intervention functions including Education, Training, Modelling, Persuasion, Enablement, Environmental restructuring and Incentivisation were identified as relevant for a sedentary workplace intervention. These results are in alignment with the SMArT study by Munir *et al.* (2018) in which the BCW was also used to design a workplace sitting reduction intervention in hospital office workers. They identified the TDF domains of Knowledge, Social identity, Intentions, Beliefs about capabilities, and Self-regulation of behaviour, and consequently the key intervention functions of Education, Enablement, and Training. However, it should be noted that the present study identified a broader range of intervention functions due to the fact that the SMArT study applied the APEASE criteria to select the most relevant intervention function for the target population.

This study proposes 39 potential behaviour change techniques identified from this process. Several strategies that can be used to implement these behaviour change techniques include targeting cognitive memory by providing prompts and cues, offering rewards for successfully completing their target behaviour, providing information about breaking up sitting time and the consequences of prolonged sitting, providing access to height-adjustable workstations, or reassuring employees of management support. Modifying the work environment through the

introduction of active workstations has been found to effectively reduce SB in the workplace (Manini *et al.*, 2015) without detrimental effects on work performance (Ojo *et al.*, 2018).

Consistent with the findings of this present study, Gardner *et al.* (2016) in their systematic review sub analysis of workplace interventions found 6 BCTs that frequently appeared in effective interventions to reduce SB: Review behavioural goals, Self-monitoring (behaviour), Instruction on how to perform behaviour, Information on health consequences, Behaviour substitution, and Adding objects to the environment. All but one of these BCTs, Review behavioural goals, was also found in the present study. The BCTs identified in this present study were identified from the qualitative data and it may be that Review behavioural goals was a BCT identified by interventionists from psychological theory sources. Therefore, when tailoring future interventions, researchers should consider including theoretically derived BCTs as well as those generated from the target population.

6.5.1 Strengths of the study

This paper presents novel qualitative data following a detailed systematic process consistent with recommendations of the Medical Research Council, which requires every complex intervention development to undergo three different phases including theory, modelling and the experimental phase (Craig *et al.*, 2008; Medical Research Council, 2000; Michie *et al.*, 2008). This present study focuses on modelling, and statements from interviews have been theoretically-evaluated using COM-B/TDF as described in the BCW guide (Michie, Atkins and West, 2014). This ensured that the study was office worker-led, rather than researcher-led

(Barker, Atkins and de Lusignan, 2016; Greenhalgh *et al.,* 2004) and that any future implementation would be person-centred (Yardley *et al.,* 2015). The barriers to breaking up and reducing sitting time identified in this current study and previous studies (Cole, Tully and Cupples, 2015; Hadgraft *et al.*, 2016a; Waters *et al.*, 2016) are factors that operate at personal, social and environmental levels, which support a socio-ecological model of SB. This underlines the need for interventions to be targeted at multiple levels of influence on behaviour instead of targeting only individual, environmental or organisational factors. This current study goes beyond the socio-ecological model which only describes the levels at which to implement behaviour change strategies. Rather, this study identifies specific BCTs as 'active ingredients' which intervention designers can choose from and implement at relevant functional and policy levels in future workplace SB reduction interventions.

6.5.2 Limitations of the study

Worthy to note is the fact that people with a history of musculoskeletal problems were excluded from this study, which could mean that the findings are not relevant to those with such conditions. This limited an analysis of Physical Capability from COM-B, which is not present in the results. Second, the subjectivity of the analysis must be acknowledged, as with many qualitative studies in addition to concerns over external validity due to a small sample size. However, it is believed that the recruitment of participants from two different office settings as well as the rigour applied to the study process and data analysis, suggests that the findings might be transferable to other sedentary office settings. Differences in participants' demographics could introduce bias, however, a probable population heterogeneity effect

would have been minimised by purposively targeting participants who were all desk-based office workers with self-reported high level sitting of at least 5.5 hours. A further limitation is that PA of the participant was not considered during recruitment; however, as the focus of this study was on workplace sitting time, the time spent sitting during working hours was one of the criteria for inclusion rather than level of PA, which can be mutually exclusive. Furthermore, despite the clear framework and direction available on the use of the BCW, the process itself was lengthy and time-consuming, particularly the coding of BCTs from the qualitative interviews and the elements of COM-B and the TDF derived from the data. Whilst efficiency of use appears to be a limitation presently, developments in machine learning will soon mean the tool is more accessible (Michie *et al.*, 2017).

6.6 Conclusion

This study has identified possible components of a workplace intervention to break up and reduce sitting behaviour in the workplace based on the needs of office workers and this study emphasises the need for interventions to be targeted at multiple levels of influence on behaviour. Consequently, 39 BCTs have been identified and can be used as active ingredients in preparation for targeting the key determinants (Psychological Capability, Physical and Social Opportunity and Reflective and Automatic Motivation) of sitting behaviour in the workplace. SB intervention designers should apply the APEASE criteria to determine the most appropriate intervention functions, policy categories and BCTs to use, drawing on the evidence presented here that identifies what needs to change. Future research can use the insight and modelling from this paper to test the effectiveness of an intervention based on

the findings presented here, during an experimental phase as suggested by the Medical Research Council. This next phase could then provide an empirical basis for sitting behaviour policy implementation in the workplace.

CHAPTER 7 CONTEXTUALISING A TAILORED WORKPLACE INTERVENTION TO BREAK UP AND REDUCE SITTING TIME

Following the identification of possible intervention contents in the preceding chapter, this chapter describes the processes involved in developing a tailored workplace SB intervention in the context of this thesis.

7.1 Introduction

The Medical Research Council guidance outlined in section 2.4.1 recommends that the development of complex intervention must pass through three different phases which include a theory phase, followed by a modelling phase and then a series of experimental phases (Craig *et al.,* 2008; Medical Research Council, 2000; Michie *et al.,* 2008). Theories of behaviour change and a justification for the adoption of the BCW in developing a tailored intervention to break up and reduce sitting time in the workplace have been explored in section 2.4.2. A behavioural analysis for the identification of barriers and facilitators to breaking up workplace sitting in office workers was reported in chapter 6, and this helped in identifying what needs to change, as stated in step 4 of the BCW guide (Michie, Atkins and West, 2014). In the analysis, seven core inductive themes were identified including *'Knowledge-deficit sitting behaviour', 'Willingness to change', 'Inadequate cognitive resources for action', 'Tied to the desk', 'Competing motivations', 'Emotional influences', and 'Organisational support and interpersonal influences'(Ojo et al., 2019b),* and these themes were linked to five of the six COM-B constructs, without strong evidence for physical Capability barriers. Further mapping

shows a link with 12 of the 14 TDF domains. Subsequently, possible intervention functions, policy categories and behaviour change techniques (BCTs) that could be considered when developing intervention contents and strategies *(Ojo et al., 2019a)* were identified in the same chapter. The aim of this current chapter was to build on Chapter 6 to develop a context-based workplace intervention for breaking up or reducing siting time in office workers.

7.2 Screening with the APEASE Criteria

Following the identification of intervention functions, policy categories and probable BCTs listed in section 6.3. a choice was made about which intervention functions, policy categories and BCTs are most appropriate or have the highest possibility of success in delivering the desired change in this context as recommended in the BCW guide (Michie, Atkins and West, 2014). To achieve this the Acceptability, Practicability, Effectiveness/cost-effectiveness, Affordability, Safety/side-effects, Equity (APEASE) criteria, explained in Table 15, were employed in screening all the identified probable intervention functions, policy categories and BCTs that could be used in workplace sitting intervention development as. Initial judgments using the APEASE criteria were made by the PhD candidate (SO) and reviewed by members of the supervision team (AC, DB and DH) until consensus regarding acceptance or rejection was reached. This was important as it enabled the identification of intervention functions, policy categories, and BCTs that are affordable, practicable, effective, acceptable, safe, and equitable based on the context of this thesis as shown in Tables 16, 17 & 18 respectively

Table 15: APEASE criteria as a screening tool

Criterion	Description
Affordability	There is always an implicit or explicit budget that guides all interventions regardless of how effective or cost-effective it may be. An intervention is only affordable if it shows high level of effectiveness and can be easily delivered to or accessed by those it was intended for.
Practicality	An intervention is practicable to the extent that it can be delivered as designed through the means intended to the target population. For instance, an intervention may be effective when delivered by highly trained staff with extensive resources but in routine practice this may not be achievable.
Effectiveness and cost-effectiveness	Effectiveness simply refers to the effect size of the intervention with regards to the desired objectives in a real-world context. It is different from efficacy which refers to the effect size of the intervention when delivered under optimal conditions in comparative evaluations. Cost-effectiveness is defined as the ratio of effect to cost. However, if two interventions have an equally level of effectiveness, then clearly the most cost-effective should be chosen. If one is more effective but less cost-effective than another, other issues such as affordability should be considered during the decision-making process.
Acceptability	Acceptability refers to the extent to which an intervention is adjudicated to be appropriate by relevant stakeholders (public, professional and political). This may be different for different stakeholders.
Side effects/safety	An intervention may be effective and practicable but have unwanted side-effects or unintended consequences. These should be taken into consideration when deciding whether to proceed.
Equity	An important consideration is the extent to which an intervention may reduce or increase the disparities in standard of living, wellbeing or health between different sectors of society.

(Michie, Atkins and West, 2014)

7.3 Identification of context-based Intervention functions

Five intervention functions (Education, Persuasion, Enablement, Training and Environmental Restructuring) were considered upon screening with APEASE criteria as shown in Tables 16 (Michie, Atkins and West, 2014). Qualitative data in chapter 6 of this thesis revealed that office workers were not aware of sitting guidelines or have knowledge of health consequences of prolonged sitting. Education as a function is to foster a change in Psychological capability (by increasing awareness and understanding of sitting guidelines) and Reflective motivation (changing beliefs regarding the consequences of prolonged sitting time and benefits of breaking up prolonged periods of siting in the workplace). Persuasion further targets both Reflective and Automatic motivation by providing experts' advice based on evidence from reliable sources. Environmental restructuring is directed at Physical opportunity (by providing safe and readily accessible platforms that support frequent interruption to prolonged sitting), social opportunity (by increasing collective effort for breaking up sitting) and automatic motivation (by providing prompts or reminders to trigger behaviour). Enablement on the other hand triggers a change in Automatic motivation, Psychological capability as well as Physical and Social opportunities to ensure habitual engagement with adopted strategies for breaking up sitting in office workers. Training has been described as a function that can be used to enhance physical capability (e.g, strength training) and psychological capability, such as cognitive skills for planning and implementing) (Michie, Atkins and West, 2014). In this context, data mapping revealed that training will only be addressing psychological capability

due to the exclusion of to the exclusion of people with musculoskeletal problems in the study design.

Table 16: Selection of intervention functions to cause a change in office workers' sitting behaviour

Intervention function	**A**	**P**	**E**	**A**	**S**	**E**	**Comments**
Education	✓	✓	✓	✓	✓	✓	
Enablement	✓	✓	✓	✓	✓	✓	
Training	✓	✓	✓	✓	✓	✓	
Persuasion	✓	✓	✓	✓	✓	✓	
Incentivisation				✓		✓	No funds available, therefore it is not practicable or cost-effective.
Environmental restructuring	✓	✓	✓	✓	✓	✓	Made possible due to equipment donation.
Modelling	✓		✓	✓	✓	✓	Not practicable to identify a timekeeper who could get people moving as participants will be in clusters in different offices.

(L-R) A= Affordability, **P**=Practicality, **E**=Effectiveness/Cost-effectiveness, **A**=Acceptability, **S**=Side-effect/safety, **E**=Equity

Table 17: Screening and identification of policy categories to support the delivery of intervention

Policy categories	**A**	**P**	**E**	**A**	**S**	**E**	**Comments**
Communication /Marketing	✓	✓	✓	✓	✓	✓	
Guidelines	✓	✓	✓	✓	✓	✓	Although development of new guidelines is not warranted, participants' attention will be drawn to existing guidelines for sitting among office workers
Environmental planning	✓	✓	✓	✓	✓	✓	Permission will be obtained from the participating organisation management to modify the offices

(L-R) A= Affordability, **P**=Practicality, **E**=Effectiveness/Cost-effectiveness, **A**=Acceptability, **S**=Side-effect/safety, **E**=Equity

7.4 Identification of context-based policy categories

Three potential policy categories (referred to as broader population-level strategies that could enable the occurrence of selected intervention functions (Michie, Atkins and West, 2014) including Communication/marketing, Guidelines, and Environmental social Planning were identified in Chapter 6. However, the context through which change is implemented may limit choice of policy category. In the context of this research, upon application of the APEASE criteria, all the three policy categories are deemed to be practicable and likely to be effective as presented in Table 17. Communication/marketing could be used in providing education for office workers in order to increase awareness and knowledge of sitting guidelines. More emphasis will be placed on the current expert's suggestions for sitting among office workers to ensure compliance. Changes to Environmental planning will help in delivering the environmental restructuring changes needed to support a more conducive working environment for the behaviour changes that will be implemented.

7.5 Identification of context-based behaviour change techniques

In addition, following screening with APEASE criteria, it was not deemed possible to deliver all the identified 39 BCTS using the Behaviour Change Technique taxonomy version 1 (Table 18) (Michie, Atkins and West, 2014), therefore a subset of 14 BCTs were selected by the research team (SO, AC, DB and DH) as most probable to be effective in addressing the 12 most important TDF domains and thus in changing office workers' sitting behaviour in the

workplace. Therefore, these 14 BCTs will form the basis of recommendations for intervention and delivery in this thesis as presented in Table 19. For instance, in chapter 6, majority of the office workers admitted not knowing or having understanding of the guidelines for sitting in the workplace and stated that one main facilitator to undertake the target behaviour is to have access to empirical evidence (see Table 14). Therefore, *credible source* and *instruction on how to perform the behaviour* were selected to persuade and improve their understanding of the guidelines. This can be achieved by providing verbal information based on experts' recommendations for workplace sitting and definition of prolonged sitting stated in section 2.2.3 (Buckley *et al.*, 2015; Henson *et al.*, 2016a).

Also addressing persuasion and education, *provision of information about health* and *provision of information about emotional consequences* as discussed in section 2.2.5 could increase awareness; however, accentuating the benefits of breaking up sitting (section 2.3.3) may encourage and influence their belief and behaviour. *Goal setting, action planning* and *problem solving* were also identified as important BCTs to be included in the intervention, as these BCTs underline the importance of acting the present and making plans for the future. Office workers will be encouraged to take ownership of their sitting behaviour by setting bi-weekly goals for how much time they will need to reduce sitting time based on the education on what is considered as acceptable sitting time durations during a working day and training they have received as shown in Table 14.

Social support (unspecified) and *restructuring the social environment* were also identified as valuable BCTs and highlight the importance of organisational support and interpersonal

influence. Social support strategies involve obtaining permission from the management, to allow office workers break up their sitting time without fear of any consequences or punishment. Line managers will also be required to show support by sending (via email) tips on how to move more and sit less at work to their employees (Dunstan *et al.*, 2013).

The participants also stated (see Table 14) that they might feel uncomfortable if they were to break up their sitting alone, *restructuring the social environment* was designed to involve office workers to be clusterised in such a way that study participants in same arm of the intervention will be in the same offices to allow for peer support and comparisons, and at the same time reduce risk of contamination during the intervention studies. In addition, *prompts/cues, restructuring the physical environment, adding object to the environment* and *behavioural practice/rehearsal* involved providing office workers with a platform as well as prompt for cognitive action to regularly practice breaking up sitting in the workplace as majority of the office workers usually become tied to their desk in order to meet tight deadlines (Ojo *et al.*, 2019b). Finally, *demonstration of the behaviour* relates to modelling how to make use of all the different packages of the intervention to exhibit the desired behaviour (to break up sitting) to the participants. The MRC guidance underlines the need for the active ingredients of an intervention to be defined clearly and their active mechanisms made explicit (Moore *et al.*, 2015). The fact that the BCTTv1 gives clear definitions with examples for each of the BCTs makes it easy to succinctly describe all the active ingredients involved during intervention building using this approach. This can then be related back to the model that informed their choice, which makes it easier to replicate and judge whether each of the

intervention component is effective during evaluation of workplace SB and found significant effects (Edwardson *et al.*, 2018b; Munir *et al.*, 2018).

Table 18: Screening of the possible behaviour change techniques with APEASE criteria

BCT (code)	A	P	E	A	S	E	Comments
Goal setting (behaviour) (1.1)	✓	✓	✓	✓	✓	✓	
Problem solving (1.2)	✓	✓	✓	✓	✓	✓	
Action planning (1.4)	✓	✓	✓	✓	✓	✓	
Monitoring of behaviour by others without feedback (2.1)	✓	✓	✓	✓	✓	✓	Not practicable everyone will be busy with his/her primary responsibility.
Feedback on behaviour (2.2)			✓	✓	✓	✓	Not affordable and practicable in this context as a monitoring device needs be worn then retrieved before feedback can be provided.
Self-monitoring of behaviour (2.3)		✓	✓	✓	✓	✓	Not affordable in this context as a monitoring device (pedometer) will need to be worn by all the participants.
Self-monitoring of outcome(s) of behaviour (2.4)	✓		✓	✓		✓	The intervention will be short-termed due to time constraint. Therefore, it may be difficult to observe any noticeable change.
Social support (unspecified) (3.1)	✓	✓	✓	✓	✓	✓	
Social support (practical) (3.2)	✓		✓			✓	Practical help from other colleagues does not appear feasible due to the fact that everyone will be busy with his/her primary responsibility. Therefore, all participants need to take responsibility for their behaviour.
Instruction on how to perform the behaviour (4.1)	✓	✓	✓	✓	✓	✓	
Information about Antecedents (4.2)	✓		✓		✓	✓	Participants might feel overburdened from asking too much from taking records of all siting and events taking place before sitting.
Behavioural experiments (4.4)	✓				✓	✓	Although advice regarding consequences of prolonged siting behaviour will be provided based on existing

							evidence, it will be difficult in terms of cost-effectiveness and practicality to collect data to advise the participants prior to the intervention.
Information about health consequences (5.1)	✓	✓	✓	✓	✓	✓	
Information about social and environmental consequences (5.3)	✓			✓		✓	Not practicable as information is not known.
Information about emotional consequences (5.6)	✓	✓	✓	✓	✓	✓	
Demonstration of the behaviour (6.1)	✓	✓	✓	✓	✓	✓	
Social comparison (6.2)	✓		✓			✓	Revealing information about other people's sitting time/ behaviour would breach confidentiality.
Information about others' approval (6.3)	✓			✓	✓	✓	Not practicable. It is difficult to know what others think about sitting behaviour in the workplace.
Prompts/cues (7.1)	✓	✓	✓	✓	✓	✓	
Behavioural practice/rehearsal (8.1)	✓	✓	✓	✓	✓	✓	
Behaviour substitution (8.2)	✓		✓			✓	Participants are employees working at a desk. It is not practicable to keep prompting them to stand or go for a walk.
Habit formation (8.3)	✓		✓			✓	It is not practicable to repeatedly prompt them to rehearse standing or walking as this might be seen as a distraction.
Habit reversal (8.4)	✓		✓			✓	It is not practicable to repeatedly prompt them to rehearse standing or walking as this might be seen as a distraction.
Credible source (9.1)	✓	✓	✓	✓	✓	✓	
Material incentive (behaviour) (10.1)				✓	✓	✓	Not affordable.
Material reward (behaviour) (10.2)				✓	✓	✓	Not affordable.

Non-specific reward (10.3)				✓	✓	✓	Not affordable.
Social reward (10.4)				✓	✓	✓	Not practicable (time consuming).
Social incentive (10.5)				✓	✓	✓	Not practicable (time consuming).
Non-specific incentive (10.6)				✓	✓	✓	Not practicable or affordable.
Incentive (outcome) (10.8)				✓	✓	✓	Not affordable.
Self-reward (10.9)				✓	✓	✓	Not practicable or affordable.
Reduce negative emotions (11.2)	✓		✓	✓	✓	✓	Not practicable (time consuming)
Restructuring the physical environment (12.1)	✓	✓	✓	✓	✓	✓	Approval to modify work environment will be sought from the management.
Restructuring the social environment (12.2)	✓	✓	✓	✓	✓	✓	Participants' offices will be clustered to ensure those in the same office belong to the same group to promote peer support.
Adding object to the environment (12.5)	✓	✓	✓	✓	✓	✓	Donation of height-adjustable workstations has been received.
Body changes (12.6)				✓			Although a body massage or physiotherapy session may be acceptable for some participants, it does not seem affordable, practicable, safe or effective.
Verbal persuasion about capability (15.1)	✓				✓	✓	Participants do not need any special skill or strength to break up their sitting unless where an emotional problem is involved. As this cannot be ascertained so as not to pry into participants' privacy, it is considered not practicable.
Mental rehearsal of successful performance (15.2)	✓				✓	✓	Not practicable as it is difficult to ascertain if participants will have time to start imagining their ability to break up sitting while at work. It might be seen as a distraction.

(L-R) A= Affordability, **P**=Practicality, **E**=Effectiveness/Cost-effectiveness, **A**=Acceptability, **S**=Side-effect/safety, **E**=Equity

In summary, the intervention content shown in Table 19 has been developed based on the outcome of the qualitative study in chapter 6 in which the core determinants of workplace sitting behaviour were identified. This was achieved by adopting the COM-B model, TDF and systematically following the BCW stages in which the identified BCTs were contextualised using the APEASE criteria and evidence from the literature review (Danquah *et al.*, 2017; Henson *et al.*, 2016a). This was important as it ensured that the intervention content was theoretically-underpinned, office worker-led (Barker, Atkins and de Lusignan, 2016), person-centred (Yardley *et al.*, 2015) and evidence informed.

Table 19: Intervention content specified by behaviour change techniques and mapped onto components of TDF and COM-B model

Behaviour Change Techniques	**BCT Definition (Michie *et al.*, 2013)**	**COM-B construct targeted**	**TDF-construct targeted**	**Intervention Functions**	**Policy categories**	**Intervention content and mode of delivery**
1.1 Goal setting (behaviour)	Set or agree on a goal defined in terms of the behaviour to be achieved	Reflective motivation	Goals	Persuasion	Communication/ Marketing	Participants will be advised face-to-face to set bi-weekly goals for the duration of time spent sitting. This means that they will set different target for weeks 2, 4 & 6 to achieve both the minimum (2hrs) and maximum (4hrs) time for standing at work as advised by experts.
1.2 Problem solving	Analyse, or prompt the person to analyse, factors influencing the behaviour and generate or select strategies that include overcoming barriers and/or increasing facilitators	Psychological capability; reflective motivation	Behavioural regulation; goal	Persuasion	Communication/ Marketing	Participants will be met face-to-face and told to map out how they will use prompt software to break up their sitting time to actualise the incremental standing time targets. For instance, they could alternate between sitting and standing every 25 minutes with 5 min break in between depending on their choice. This is important as it would prevent prolonged sitting, defined as sitting for ≥ 30 min in one bout (Henson *et al.*, 2016a).
1.4 Action planning	Prompt detailed planning of performance of the behaviour (must include at least one of context, frequency,					

	duration and intensity).					
3.1 Social support (unspecified)	Advise on, arrange or provide social support (e.g. from friends, relatives, colleagues, buddies or staff) or non-contingent praise or reward for performance of the behaviour	Social opportunity; Physical opportunity; Reflective motivation	Social influences; Environmental context & resources; Social/Professional role and identity	Enablement, Environmental restructuring	Environmental/ Social planning, Service provision	Approval will be sought and obtained from the participating organisations. Participants will be assured via email that they will not be penalised for interrupting their working day by participating in the study. Line managers will send bi-weekly emails that contain tips for breaking up sitting, appreciating commitment of the participants towards breaking up prolonged sitting time and reminding them of their biweekly goals in week 2, 4 and 6 of the intervention (Dunstan *et al.,* 2013) (See Appendix 16).The programme will be designed in such a way that at least two people from the same office will participate in the intervention (See Appendix 13). This will provide the participants the opportunity to support one another and reduce the feeling of aloneness or being judged.

4.1 Instruction on how to perform the behaviour	Advise or agree on how to perform the behaviour (includes 'Skills training') Note: when the person attends classes	Psychological capability	Skills	Training	Guidelines	A face-to-face 10 min training session will be provided to the participants on how to break up sitting using prompt software and height-adjustable workstation. Definition of prolonged sitting (sitting > 30min) will be provided, and participants will be advised to not sit more than 30 min in one go (Danquah *et al.*, 2017; Henson *et al.*, 2016a). Participants will be provided with a leaflet containing information on the recommended sitting time guidelines, which states that office workers should be on their feet at work, for a minimum of two hours initially and subsequently increase to four hours (See Appendix 17).
5.1 Information about health consequence	Provide information (e.g. written, verbal, visual) about health consequences of performing the behaviour	Psychological capability; reflective motivation	Knowledge; beliefs about consequences	Education, Persuasion	Communication/ Marketing, Guidelines	A face-to-face, ten-minute information session will be organised, and participants will be educated about information regarding the health consequences of prolonged sitting and the benefits of breaking up sitting as found in scientific literature. A leaflet containing the information will be given to them.

5.6 Information about emotional consequence	Provide information (e.g. written, verbal, visual) about emotional consequences of performing the behaviour	Psychological capability; reflective motivation	Knowledge; beliefs about consequences	Education	Communication/ Marketing	Verbal information regarding some of the emotional consequences (such as loss of concentration, tiredness) of prolonged sitting will be provided during a ten-minute information session.
6.1 Demonstration of the behaviour	Provide an observable sample of the performance of the behaviour, directly in person or indirectly	Psychological capability	Skills; knowledge	Training Education Persuasion	Guidelines, Communication/ Marketing	A step-by-step guide on how all the intervention packages work will also be typed out and given to the participants to ensure they have something in hard copy to support them, and a five-minute demonstration of how each of the packages work will be delivered to the participants (Healy *et al.,* 2013).
7.1 Prompts/cues	Introduce or define environmental or social stimulus with the purpose of prompting or cueing the behaviour.	Physical opportunity; psychological capability	Environmental context and resources; memory, attention and decision processes	Environmental restructuring, Enablement	Environmental/ Social planning	Prompt software will be installed on participants' computers. This software will be used to provide reminders to change between sitting, standing, and taking short breaks (walking) based on the choice of the participants.
8.1 Behavioural practice/rehearsal	Prompt practice or rehearsal of the performance of the behaviour one or more	Physical opportunity	Environmental context and resources	Environmental restructuring	Environmental/ Social planning,	A Work-Fit-T Sit-Stand Desktop Workstation (Ergotron, St Paul, MN, USA) will be installed on participants' regular desk. This will provide them with the opportunity to alternate between

	times in a context or at a time when the performance may not be necessary, in order to increase habit and skill					sitting and standing while working.
9.1 Credible source	Present verbal or visual communication from a credible source in favour of or against the behaviour	Automatic motivation	Optimism	Education	Communication/ Marketing	A verbal communication based on expert statements (e.g (Buckley *et al.*, 2015)) about the need for office workers to reduce SB and how this could be achieved will be provided by the PhD researcher. The information will also available in a leaflet (See Appendix 17).
12.1 Restructuring the physical environment	Change, or advise to change the physical environment in order to facilitate performance of the wanted behaviour or create barriers to the unwanted behaviour	Physical opportunity	Environmental context and resources	Environmental restructuring	Environmental/ Social planning,	Height-adjustable workstations will be installed on participants' regular desk to afford them the opportunity to alternate between sitting and standing while working.
12.5 Adding object to the environment	Add objects to the environment in order to facilitate performance of the behaviour					
12.2 Restructuring the	Change, or advise to change the social	Social opportunity;	Social influences;	Enablement, Environmental restructuring	Environmental/ Social planning,	Intervention participants will be cluster randomised, which will help prevent feelings of being

social environment	environment in order to facilitate performance of the wanted behaviour or create barriers to the unwanted behaviour (other than prompts/cues, rewards and punishments)	Physical opportunity	Environmental context and resources		isolated or criticised and promote peer support. This will also ensure there is no contamination during clinical trials.

7.6 Discussion

This chapter described context-specific developmental research which sought to identify competent active ingredients of a multi-component workplace intervention to reduce and break-up sitting time in office workers. Five intervention functions, three policy categories and 14 BCTs were selected from the list reported in section 6.3 to target the determinants of sitting behaviour in the workplace. This was in agreement with 'less is more' principle by (Michie, Atkins and West, 2014) which states that only a fraction of target drivers of behaviour should be selected by intervention developers to ensure rigorous intervention testing takes place rather than targeting numerous with no focus. The effectiveness of these intervention functions in combination with BCTs to break up and reduce sitting time in office workers is not yet known; however, the SMArT study has examined some of these BCTs in the same context and found significant effects (Edwardson *et al.*, 2018b; Munir *et al.*, 2018).

It should be noted that, judgments regarding which BCTs to include in the intervention, were pragmatic and were based on feasibility and availability of resources to deliver the intervention. Consequently, there is a possibility that all the theoretical determinants of behaviour which were identified in chapter 6 (Table 14) for instance, material incentive and self-monitoring of behaviour, may not be addressed in the context of this intervention. This process is therefore considered to be subjective with possibility of introducing bias, and the intervention may not be transferrable to other contexts. For instance, the decision to include height-adjustable workstations in the intervention package despite concerns regarding cost implication. However, the use of APEASE criteria makes the process to be transparent (Michie,

Atkins and West, 2014) and efforts were made to ensure considerations were given to the views of the target users. This is one of the major strengths of this chapter as the developed intervention targets all the identified five COM-B elements required for a change regarding sitting behaviour to occur despite application of APEASE criteria as presented, and if found to be effective, the interventions could be adapted for broader use. The effectiveness of this current intervention will be examined in the next chapter.

CHAPTER 8 WORKPLACE INTERVENTION FOR REDUCING SITTING TIME IN SEDENTARY WORKERS: A PILOT STUDY

This chapter presents findings of a pilot study that tested the efficacy of the selected intervention package on workplace sitting time.

8.1 Introduction

SB was described in section 2.2.1, as any waking behaviour such as sitting, reclining or lying down, that has an energy expenditure of ≤ 1.5 metabolic equivalents (METs) (Tremblay *et al.*, 2017). Several health consequences associated with individuals who spend prolonged periods being sedentary have been reported in section 2.2.5 (Dunstan *et al.*, 2010; Healy *et al.*, 2011b; Teychenne, Costigan and Parker, 2015; Thorp *et al.*, 2012; Warburton, Nicol and Bredin, 2006; Wilmot *et al.*, 2012). The adverse consequences associated with high amounts of SB have led to changes in some PA guidelines to also include recommendations for sedentary time, which state that adults should reduce the amount of time spent being sedentary, and when physically possible should break prolonged periods of inactivity with at least light-intensity PA (UK Department of Health, 2019). Given that the workplace is a key setting for contributing to excessive SB (Bennie *et al.,* 2015), as stated in section 2.3.1, it is a crucial environment in which an intervention to decrease sitting time could be implemented to improve public health.

There is currently a concern for sickness absence in UK businesses, with an average of seven days sick leave per employee reported in 2015 at an estimated annual cost of £10.6 billion,

while presenteeism among employees was reported to cost £21.2 billion per annum (Centre for Mental Health, 2017). Evidence from previous cross-sectional studies has revealed that higher sitting times on workdays and higher occupational sitting could provoke a decrease in both mental wellbeing and subjective productivity (Puig-Ribera *et al.*, 2015). It is therefore paramount for interventions that target workplace SB to be developed.

A growing body of evidence, as presented in section 2.3.6, has shown that active workstations could be effective in decreasing SB in the workplace (Alkhajah *et al.*, 2012; Chau *et al.*, 2016; Edwardson *et al.*, 2018b; Koepp *et al.*, 2013; Manini *et al.*, 2015). Despite these interventions appearing promising, there is evidence to suggest that management of organisations might not be willing to implement them if there is concern over employees' productivity (Ben-Ner *et al.,* 2014), while a recent qualitative study identified hostility towards replacing sitting with standing in the workplace (Gardner, Smith and Mansfield, 2017). With respect to productivity concerns, a recent systematic review (see Chapter 4) found that productivity might not be affected by active workstation use (Ojo *et al.,* 2018). Issues of adherence when using active workstations have also been raised (Tudor-Locke *et al.,* 2014), although this could be caused by interventions not being tailored to meet employees' needs, as few studies have reported taking employees' perceptions on board when developing interventions to reduce sitting time (De Cocker *et al.,* 2015b; Gilson, Straker and Parry, 2012). Therefore, participants need to be involved in the development of interventions to ensure their needs are met and potentially to improve adherence (Straker *et al.,* 2004).

In Chapters 6 and 7, the Behaviour Change Wheel (BCW) (Michie, Atkins and West, 2014) was used to guide the systematic process of developing a participant-led intervention package by

first understanding the determinants of SB (Michie, van Stralen and West, 2011). This was followed by the identification of intervention functions and optimal behaviour change techniques (BCTs) for use in the intervention (Michie, Atkins and West, 2014).

Aims

Thus, the primary aim of this study was to pilot-test the effectiveness of a tailored workplace SB intervention to break up and reduce sitting time on workplace sitting time. The secondary aims were to determine adherence to the intervention as well as determine the preliminary effects of the intervention on other sitting and activity variables, work productivity, wellbeing and cardiometabolic health.

8.2 Method

8.2.1 Study Design

The study was registered on ClinicalTrials.Gov (NCT03560544). Ethical approval for the procedures detailed below was obtained from the University of Bedfordshire Institute for Health Research Ethics Committee (lHREC836) as shown in Appendix 10. Participants were given a participant information sheet and asked to provide written informed consent prior to any testing procedures (See Appendix 11 and 12). This study adopted an eight-week, two-arm cluster randomised control trial (RCT) design with the unit of randomisation being the workers' offices (Dunstan *et al.,* 2013). Participants were randomly allocated into clusters with each cluster being randomised to either the control or intervention group

8.2.2 Participant selection

Management approval was sought and obtained for the recruitment of the employees, changes to the workplace environment, and for study testing and communications to take place during work time (Healy *et al.,* 2013). The project was advertised to staff as part of a workplace wellbeing programme via internal mail, staff meetings, information fliers in offices and other strategic places within two different organisations (local council and University) in the East of England region.

8.2.3 Eligibility

Participants were full-time office desk-based employees between the ages of 18 and 60 years from any ethnic background and recruited from two worksites. Participants were excluded from the study if they were pregnant, had a history of musculoskeletal complaints, non-ambulatory, or had a planned holiday that would mean they would not be at work for more than two weeks during the 8-week intervention period.

8.2.4 Sample size

There is no standard procedure to determine sample size for a pilot study, since their main purpose is to obtain an estimate of the standard deviation that could be used to determine the likely effect size to inform the sample size of a full trial (Whitehead *et al.,* 2016). Thus, the proposed study recruited a total of 44 participants in two groups of 18 allowing for an attrition rate of 20%. This is in line with sample size recommendations for pilot studies (National

Institute for Health Research, 2018) and that used in a previous related pilot study (Healy *et al.,* 2013).

8.2.5 Randomisation

Offices (clusters) were randomised into either the intervention or control group in order to minimise problems of contamination between groups in open plan offices (Danquah *et al.,* 2017). There were 14 clusters with an average cluster size of three. Randomisation was carried out by assigning a cluster ID to each of the offices and clusters were then randomly allocated to intervention or control using online computer software (https://www.randomlists.com/team-generator) by an independent third-party researcher (See Appendix 13) (Kennedy *et al.,* 2017). Randomisation took place before the collection of baseline measurements and group allocation was disclosed to participants after the completion of baseline assessment (Danquah *et al.,* 2017). Given the nature of the intervention, blinding from participants or the core research team was not possible.

Control – usual practice

Participants in the control clusters were advised to continue their job as normal.

Intervention group

The intervention used in this pilot study was in compliance with stages of intervention development outlined in the Behaviour Change Wheel as described in earlier Chapters 6 and 7 (Michie *et al.*, 2014). The behaviour change strategies were based on the intervention content reported in Table 19 and delivered through the identified five intervention functions

in section 7.3 including: Enablement, Education, Training, Persuasion, and Environmental restructuring.

8.2.6 Outcome measures

Primary and secondary outcomes were assessed at baseline and at eight weeks. All questionnaires were completed online using Qualtrics survey software (Qualtrics, Provo, Utah, USA).

Primary outcome

The primary outcome measure was sitting time at work, which was measured using objective measures. An activPAL3 activity monitor (PAL Technologies Ltd., Glasgow, UK) was used to estimate the time spent sitting at work. The use of this device was informed by the review of literature in section 2.2.4.2. The activPAL has high reliability and validity for assessing sitting, standing, stepping and postural transitions (Grant *et al.,* 2006) (Kang and Rowe, 2015). As previously stated, there is conflicting evidence regarding how long activity monitors should be worn to be taken as representative of a person's typical activity. In this present study, the activPAL was worn on the right thigh for seven consecutive days (Edwardson *et al.,* 2017) at baseline and during the last week of the intervention. In addition, participants were given a daily diary to simultaneously keep record of their waking time, working hours and time they go to bed to aid with data processing (Edwardson *et al.,* 2017) as there is no validated or accurate method to segregate these periods of interest (Edwardson *et al.,* 2017). Data from the activPAL were considered valid only if the device was worn for a minimum of 75% of the monitoring time (Chau *et al.*, 2016; van der Ploeg *et al.*, 2010).

Data from the activPAL were downloaded using the PAL Software Suite (Version 7, PAL Technologies, Glasgow, UK). All downloaded data were saved as csv files, which included the time in seconds spent in different activities for each day. Data were subsequently processed using the validated Processing PAL software (v1.1, University of Leicester, Leicester, UK). A validated algorithm (Winkler *et al.*, 2016) identified valid waking wear data. Participants kept diaries in which times were recorded for waking and sleeping, as well as the start and end of the working day. Period heat maps were used to visually check classifications of waking wear-time against information provided in the participants' diaries and bout corrections made where errors were identified (Edwardson *et al.*, 2017) (See Appendix 15). The resulting data were averaged across all days. The sitting time at work variable was normalised by expressing it as a percentage of the duration of the working day for each participant.

Secondary outcomes

Adherence Analysis

The adherence of participants to the intervention was assessed using activPAL data for the working day for both standing time and the duration of sitting bouts. Adherence to each of these two components of the intervention was carried out independently using the methods reported below. Adherence to the intervention was only assessed for the intervention group, as the control group were given no guidelines to adhere to.

Sitting time

All participants in the intervention group were classified for SB in the workplace at both baseline and follow-up assessments based on expert statement guidelines (Buckley *et al.,* 2015). Participants were classified into one of three categories, which were sedentary (SED), meeting the minimal guidelines (MINIMAL) for standing or stepping at work of 2 h per working day, or meeting the recommended guidelines (MEETING) for standing or stepping at work of at least four hours per working day.

Other sitting and physical activity variables

Other sitting variables calculated were: total daily sitting time, time spent in sitting bouts <30 min and ≥30 min, the number of sitting bouts <30 min and ≥30 min, standing time, stepping time, and the number of sit-to-stand transitions, number of light and MVPA steps per day. A valid day for daily data was accepted if wear time was ≥ 10 hours per day; ≥ 500 steps per day and if not recording ≥95% data in one activity category (that is, sitting, standing or stepping). All valid days were visually compared with diary notes for quality control before summative variables were created. The resulting data were averaged across all days in each of the two categories used, which were the working day and total day. All other time variables from the activPAL for the working day were normalised by expressing them as percentage of the duration of the working day. All count variables, such as the number of sitting bouts, were normalised by expressing them as counts per hour.

Productivity

Work productivity was measured using measures of absenteeism, presenteeism, and ecological momentary assessment (EMA).

Absenteeism was measured using self-report at baseline and at the end of the eighth week. Three questions which have been previously used to assess unsanctioned absences in a study by Gaudine and Gregory (2010) were employed. These included the number of days off work in the last two weeks for sickness (colds, flu, etc), the number of days off work for mental health reasons (stress, burnout, etc), and the number of days excused work (e.g., compassionate leave, educational leave, parental leave, etc.). Self-reported absenteeism was calculated by adding the number of days reported for all the three questions.

Presenteeism was measured using the 8-item Work Limitations Questionnaire (WLQ), which is a short version of the original 25-item WLQ (Lerner *et al.*, 2001). This version of the WLQ has been shown to be a reliable and valid alternative to the longer questionnaire (Walker *et al.,* 2017). The WLQ requires participants to self-report their level of difficulty (or ability) to perform eight specific job demands in the last two weeks, with answers grouped into four work limitation scales on time management, physical, mental, and output demands.

The final measure of productivity used was *Ecological Momentary Assessment (EMA)*, which has been used previously in a variety of different contexts (Runyan *et al.,* 2013). EMA involves participants being prompted at random times throughout the day to respond about their current behaviour in as close to real time as possible, thus limiting recall bias (Moskowitz and Young, 2006). Prompt software was installed on participants' smartphones to deliver the EMA

(See Appendix 14). The software was only compatible with phones using Android operating systems, however, participants using iPhones were given an Android phone each to ensure that they were not excluded from the study. Prompts to complete the EMA occurred at random, four times each weekday between 9am to 5pm (Engelen *et al.,* 2016). In total, participants were requested to respond to and complete a maximum of 12 EMA surveys in a week. Once a participant had completed 12 surveys, the prompt software stopped prompting participants to respond (Engelen *et al.,* 2016). The questionnaire included items about posture, musculoskeletal issues, task being performed, social interactions, mood, and perception of engagement and productivity (Table 20). The time duration for completing the EMA questionnaire was less than one minute. The data from the EMA were averaged across all working days for sitting and standing separately. However, there were insufficient data for EMA while walking, so no analysis was performed.

Table 20: EMA productivity questions

Survey questions	**Responses**
What posture are you in?	Sitting/Standing/Walking
Are you experiencing musculoskeletal pain right now?	Yes/No
What are you currently doing?	In a meeting/Working at my desk/Working away from my desk/Eating/In transit/On a break/Other
How many people are you doing this with?	Alone / With 1 other person/ With 2-5 people/With 6+ people
On a scale of 1 to 10, 1 being not at all and 10 being extremely, please rate your emotions at this moment	
Happy	
Stressed	
Energised	
Anxious	
Productive	

Cardiometabolic risk biomarkers

All cardiometabolic risk biomarker measures were taken at baseline week and within five days post-intervention. Self-reported sedentary time has been consistently linked with cardiometabolic risk factors (Honda *et al.,* 2014). Cardiometabolic risk can be defined as any significant increase in the probability of developing cardiovascular (CV) disease and diabetes mellitus as a result of the presence of insulin resistance and atherogenic dyslipidemia (Ruilope, 2007). The biomarkers for identifying cardiometabolic risk used in this study were fasting glucose, lipid profile, blood pressure, waist circumference, and body mass index (BMI) (Chiang *et al.,* 2013; Ruilope, 2007).

Fasting blood glucose and lipid profile: Blood samples were collected in capillary tubes after an overnight fast of at least 10 hours using a finger prick method with a lancet (Alkhajah *et al*., 2012). Blood samples were analysed with a Cholestech LDX analyser (Cholestech Corp., Hayward, CA., USA), which provided measures of total cholesterol, high-density lipoprotein, low-density lipoprotein, triglycerides and blood glucose (Alkhajah *et al*., 2012).

Blood Pressure: Resting systolic and diastolic blood pressure were taken on the right arm after resting for at least 10 min in a seated position. Measurements were taken using an automated blood pressure monitor (Omron HEM705 CP, Omron Healthcare UK Limited, Milton Keynes, UK), which has been validated by the European Society of Hypertension (El Assaad,

Topouchian and Asmar, 2003). The average of two blood pressure readings with a two-min rest between each measure were used for all subsequent analysis (Celis-Morales *et al.,* 2013).

Anthropometry: The standardised procedure of Lohman *et al.* (1988) was used. Height was measured with a stadiometer (Horltain Ltd., Crymych, UK) to the nearest 0.1 cm, while mass was measured with an electronic weighing scale (Tanita Corp., Tokyo, Japan) to the nearest 0.1 kg. Waist circumference was recorded to the nearest 0.1 cm around the waist at navel-level while participants were standing (Boyle *et al.,* 2017; Jackson *et al.,* 2014). All measures were taken by the same investigator to avoid inter-investigator variability.

Stress and mental wellbeing

Perceived level of stress was measured using the *Cohen Perceived Stress Scale (PSS)* (Cohen and Williamson, 1988), which is a questionnaire that has been used widely for assessing the perception of stress. The PSS evaluates the unpredictability, uncontrollability and overload of an individual's life, and has high validity and reliability (Cohen and Williamson, 1988). The questionnaire requires participants to rank the frequency of feelings and thoughts using a five-point Likert scale ranging from 1 '*Never*' to 4 '*Very often'* (Mareva *et al.,* 2016). The Cohen Perceived Stress Scale (PSS) was processed following the scoring guidelines (Cohen and Williamson, 1988). Each of the 10 questions is scored from 0-4, with scores for the four negative items reversed, with the sum across all scale items used as a measure of perceived stress. Scores from 0-13 are considered as low stress, 14-26 as moderate stress, and 27-40 as high stress.

Participants' mood state was measured using the *Positive And Negative Affect Schedule (PANAS)*, which is a 20-item self-report measure of positive affect and negative affect, with 10 items in each subscale (Watson, Clark and Tellegen, 1988). The questionnaire makes use of words that describe feelings and emotions on a scale from 1 '*Very slightly or Not at all'* to 5 '*Extremely*'. The PANAS has high reliability (Crawford and Henry, 2004). Processing of the data for PANAS followed the guidelines of the original study (Watson, Clark and Tellegen, 1988). The PANAS has 10 items for positive affect and 10 items for negative affect with each item scored from 1-5. The sum of all responses for each of the subscales is used as a measure of the affect, with higher scores indicating higher levels of affect.

Changes in participants' mental wellbeing was assessed using the *Warwick-Edinburgh Mental Well-Being Scale (WEMWBS)* (Putz *et al.,* 2012), a 14-item scale that explores feelings and thoughts over the previous two weeks. This study was registered to obtain permission to use WEMWBS on warwick.ac.uk (ID: 448654978). The WEMWBS classifies individuals as having low, average or high mental wellbeing and can measure changes over time. The questionnaire asks questions such as 'I have been feeling confident' and participants rate themselves on a scale from 1 '*None of the time'* to 5 '*All of the time'.* It has been reported to have high test-retest reliability (Stewart-Brown *et al.,* 2011). The WEMWBS has 14 items, each of which is scored on a 5-point Likert scale, with all questions summed to give a total score that can range from 14-70 (Tennant *et al.,* 2007). Higher scores are indicative of better well-being, with norms available for the UK population (Putz *et al.,* 2012).

8.2.7 Statistical data analysis

All statistical analyses were performed using SPSS version 25 (IBM Corp, Armonk, New York, USA). Data were assessed for normality using the Shapiro-Wilk test owing to the small sample size. Linear mixed models were used with arm and time as fixed effects, participant ID and cluster ID as random effects, and the baseline value of each variable as a covariate. An additional linear mixed model was used to compare the effect of standing versus sitting posture for the EMA variables at follow-up with posture and arm as fixed effects, participant ID and cluster ID as random effects, and the baseline value of each variable as a covariate. To adjust for multiple comparisons in all linear mixed models, the Sidak post-hoc adjustment was used. Adjustments for missing data were made using the estimated marginal means procedure of the linear mixed models. Due to the large number of non-normally distributed variables, the bias-corrected and accelerated (BCa) bootstrap method was used to produce unbiased estimates of the confidence limits for all data (Kelley, 2005). Data are presented as means and 95% confidence intervals of the bootstrapping procedure. The level of statistical significance for the linear mixed models was taken to be $p \leq 0.05$ for two-tailed tests.

Magnitude of effects are reported as Hedges' *g*, which is a corrected effect size based on Cohen's *d* that is suitable for use in small sample sizes of 20 or less and produces an unbiased estimate of the population effect size (Lakens, 2013). The magnitude of the effect sizes was considered to be small if they were ≥ 0.2, moderate if ≥ 0.6, and large if they were ≥ 1.2, using the scale proposed by Hopkins *et al.* (2009), which adjusts for a misinterpretation in Cohen's scale for moderate and large effect sizes (Cohen, 1988). Adherence to the intervention was

assessed using the Wilcoxon signed rank test to compare baseline and follow-up scores. The standardised test statistic of the Wilcoxon test can be converted to an effect statistic by dividing it by the square root of N (Fritz, Morris and Richler, 2012), which can then be interpreted as *r* using the scales of Cohen (1988) and Hopkins (2009).

8.3 Results

Progression of participants through the study

The study was conducted in 2018, with participant recruitment beginning in April and all participants recruited by May. The trial began in June, with participation completed by August. An invitation to participate was sent to 73 participants by email, with the 61 people (84%) who expressed an interest to participate assessed for eligibility. In total, 44 participants were recruited and allocated into 14 clusters based on office location. The clusters were randomised 1:1 into the intervention or control arm (seven each). At baseline, participants were evenly distributed between intervention group (n= 22) and control group (n= 22). At the follow-up testing during the eighth week, 100% of clusters and 91% of participants were evaluated. In total, two participants withdrew from the trial due to illness, one in each group. Likewise, an additional participant withdrew from each group due to travelling abroad for work (experimental group) and changing jobs (control group). A CONSORT diagram of the progression of participants can be seen in Figure 10.

Of the remaining 40 participants, 100% of participants provided valid data for the activPAL and cardiometabolic data at both baseline and follow-up. With respect to data collected using

Qualtrics for the absenteeism, presenteeism, stress and wellbeing, all participants provided data at baseline, however only 19 of the remaining control participants (95%) and 15 of the remaining intervention participants (75%) provided data at follow-up. For EMA data, all intervention participants provided data at baseline, however, data was available for only 18 control participants (90%) due to software malfunctions. Similar problems were encountered at follow-up, with only 13 participants from each group (65%) providing EMA data.

Demographic data

Table 21 provides descriptive data for participants allocated to each study arm. No statistical comparisons of participant characteristics at baseline were made, in keeping with CONSORT guidelines for RCTs (de Boer *et al.,* 2015). Participants were middle-aged, mostly female, with around one-third from a BAME ethnic group, which is over twice as high as the 11.8% of the population of England and Wales in the 2011 census (Office for National Statistics, 2012). Just under half of the participants (47.5%) had a BMI in the normal range of 18.5-24.9 kg/m^2, with 25.0% overweight (BMI 25.0-29.9 kg/m^2), with the remaining 27.5% obese (BMI ≥ 30 kg/m^2). Participants were highly educated, with over eighty percent having completed tertiary education.

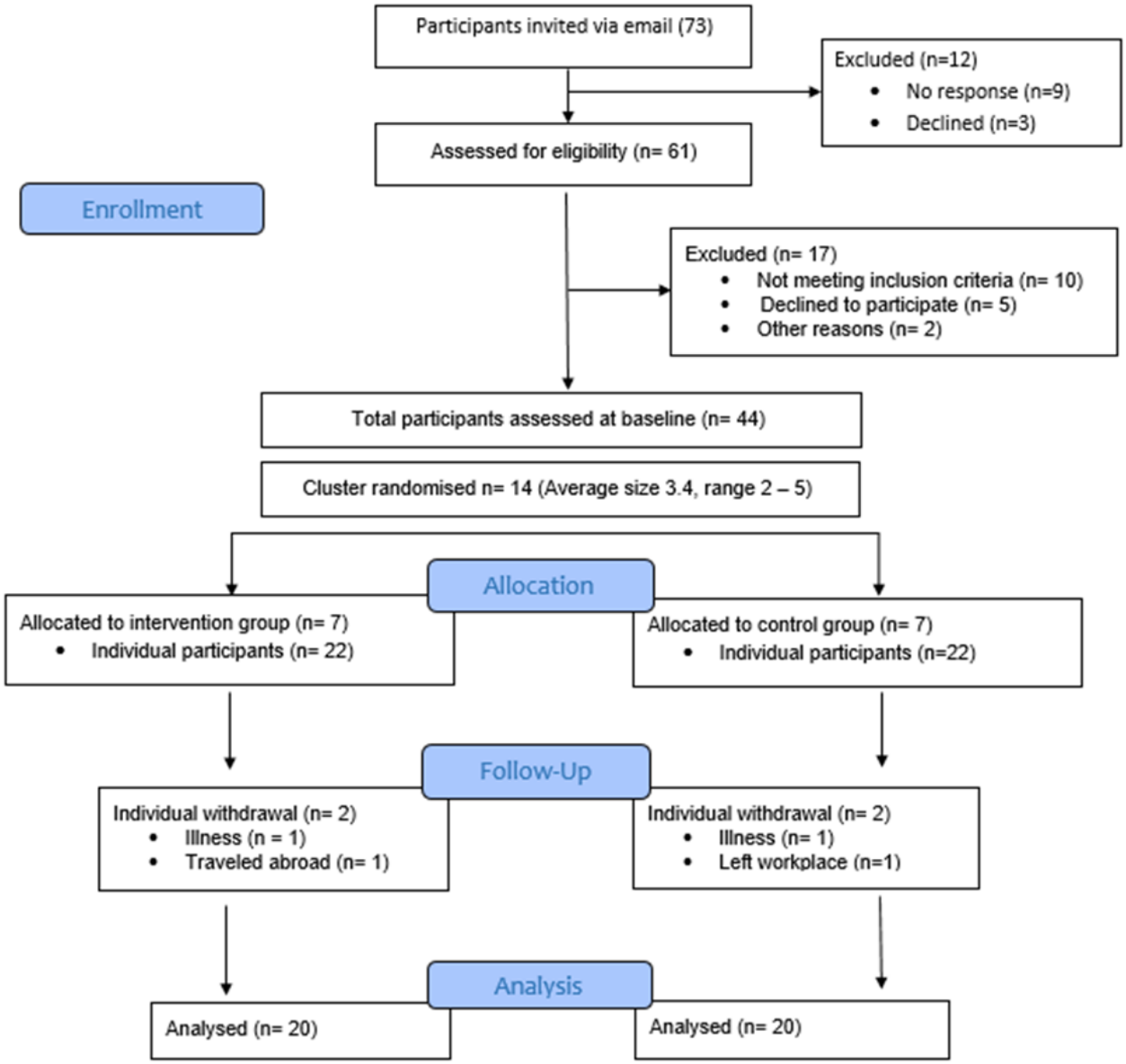

Figure 10: CONSORT diagram of progression of participants through the study

Table 21: Baseline characteristics of study participants

Characteristic	Control group	Intervention group	All
n	20	20	40
Age (years)	38.5 + 10.3	38.4 ± 11.2	38.4 ± 10.6
Sex (female)	17 (85.0%)	12 (60.0%)	29 (72.5%)
Ethnicity (BAME)	6 (30.0%)	6 (30.0%)	12 (30.0%)
Height (m)	1.65 ± 0.06	1.70 ± 0.10	1.68 ± 0.08
Weight (Kg)	76.7 ± 17.6	75.8 ± 16.2	76.2 ± 16.7
BMI (Kg/m^2)	27.9 ± 5.7	26.2 ± 5.0	27.1 ± 5.4
Married/cohabiting	13 (65.0%)	10 (50.0%)	23 (57.5%)
Education (Tertiary)	15 (75.0%)	18 (90.0%)	33 (82.5%)

BAME: Black and Asian Minority ethnic group
Age, Height, Weight, and BMI are presented as mean (95% CI)
Sex, Ethnicity, and Married/cohabiting/Education are presented as frequency (percentage).

Primary Outcome

Changes in normalised workplace sitting expressed as a percentage of the working day is presented in Table 22. Details of both working hours and absolute sitting time at work are also shown in Table 22. Participants in both control and intervention groups were highly sedentary at work at baseline. There was a significant difference between the groups at follow-up with the intervention group reducing their workplace sitting (moderate effect) relative to the control group.

Table 22: Changes in workplace sitting time

Variable	Control Group		Intervention Group		Adjusted Difference	Effect Size	P
	n	Mean (95% CI)	*n*	Mean (95% CI)	Mean (95% CI)		
Total working time (h)							
Baseline	20	8.11 (7.71 - 8.50)	20	7.41 (6.91, 7.93)			
After 8 weeks	20	7.91 (7.63 - 8.21)	20	8.33 (8.07, 8.62)	N/A		
Sitting time at work (h)							
Baseline	20	5.95 (5.49, 6.41)	20	5.62 (5.16, 6.09)			
After 8 weeks	20	5.55 (5.09, 6.01)	20	5.01 (4.55, 5.47)	-0.61 (-1.48, 0.27)	0.33	0.158
Sitting time at work (%)							
Baseline	20	73.5 (68.7, 78.3)	20	75.6 (70.9, 80.4)			
After 8 weeks	20	70.2 (65.4, 74.9)	20	60.4 (55.6, 65.2)	-11.01 (-20.71, -1.30)	0.54	**0.030**

Data are bootstrapped means and 95% confidence intervals
Effect sizes are Hedges' *g*
Bold text indicates a statistically significant effect of the intervention ($p \leq 0.05$)

Secondary Outcomes

Adherence to the intervention

At baseline, 50% of intervention participants were classified as SED, 45% were MINIMAL, with 5% classified as MEETING. After the intervention, 10% were SED, 50% MINIMAL, and 40% MEETING. When each participant was analysed individually, 70% of participants became less sedentary, 20% remained the same, while 10% became more sedentary. When the change in classification between baseline and follow-up was evaluated using the standardised test statistic of the Wilcoxon test, there was a significant effect of the intervention (Z=2.982, p=0.003, r=0.47), with this magnitude corresponding to a moderate effect.

Other workplace sitting and activity outcomes

The time spent in sitting bouts <30 min and ≥30 min, the number of sitting bouts <30 min and ≥30 min, standing time, stepping time, and the number of sit-to-stand transitions are shown in Table 23. There were significant differences in the time spent in sitting bouts < 30 min and standing at work, in favour of the intervention with large and medium effect sizes

respectively. However, there were no significant differences in the change between groups for time spent in prolonged sitting bouts, number of prolonged sitting bouts, stepping time, and number of sit-to stand transitions.

Table 23: Changes in workplace siting and activity outcomes at follow-up

	Control Group		Intervention Group		Adjusted Difference	Effect Size	P
Variable	***n***	**Mean (95% CI)**	***n***	**Mean (95% CI)**	**Mean (95% CI)**		
Number of sitting bouts <30 min at work per hour							
Baseline	20	3.74 (3.16, 4.29)	20	2.72 (2.10, 3.40)			
After 8 weeks	20	3.68 (2.98, 4.39)	20	2.83 (2.12, 3.53)	-0.20 (-1.20, 0.79)	0.10	0.666
Time in sitting bouts <30 min at work (%)							
Baseline	20	54.5 (51.2, 58.1)	20	51.9 (49.0, 54.2)			
After 8 weeks	20	51.3 (47.5, 55.1)	20	40.0 (36.2, 43.8)	-10.10 (-15.57, -4.63)	0.89	**0.002**
Number of sitting bouts ≥ 30 min at work per hour							
Baseline	20	0.38 (0.31, 0.45)	20	0.45 (0.40, 0.50)			
After 8 weeks	20	0.40 (0.32, 0.47)	20	0.44 (0.36, 0.52)	0.03 (-0.09, 0.15)	0.11	0.635
Time in sitting bouts ≥ 30 min at work (%)							
Baseline	20	19.2 (15.1, 23.3)	20	23.7 (20.2, 27.1)			
Change at 8 weeks	20	18.9 (14.8, 23.1)	20	20.4 (16.3, 24.6)	0.25 (-6.71, 7.21)	0.02	0.931
Standing time at work (%)							
Baseline	20	17.58 (13.14, 22.02)	20	15.47 (11.03, 19.91)			
After 8 weeks	20	20.98 (16.54, 25.42)	20	30.84 (26.40, 35.28)	10.94 (2.32, 19.56)	0.61	**0.017**
Stepping time at work (%)							
Baseline	20	8.91 (7.26, 10.57)	20	8.89 (7.23, 10.54)			
After 8 weeks	20	8.86 (7.21, 10.52)	20	8.77 (7.12, 10.42)	-0.07 (-1.94, 1.80)	0.02	0.936
Sit-to-stand transitions at work per hour							
Baseline	20	4.21 (3.64, 4.77)	20	3.18 (2.72, 3.72)			
After 8 weeks	20	3.93 (3.26, 4.60)	20	3.24 (2.57, 3.91)	-0.04 (-1.03, 0.95)	0.02	0.931

Data are bootstrapped means and 95% confidence intervals
Effect sizes are Hedges' *g*
Bold text indicates a statistically significant effect of the intervention ($p \leq 0.05$)

Daily sitting and activity variables

Absolute and relative values for daily sitting time, total waking time, the time spent in sitting bouts <30 min and ≥30 min, the number of sitting bouts <30 min and ≥30 min, absolute and relative values for total daily standing time, and the number of sit-to-stand transitions are shown in Table 24. Significant differences were found between groups for change in the time

spent in daily sitting bouts < 30 min and daily standing, in favour of the intervention with medium effect sizes. No other significant differences were observed.

Table 24: Changes in daily sitting and activity outcomes at follow-up

	Control Group		Intervention Group		Adjusted Difference	Effect Size	p
Variable	***n***	**Mean (95% CI)**	***n***	**Mean (95% CI)**	**Mean (95% CI)**		
Sitting time total day (h)							
Baseline	20	16.25 (15.81, 16.67)	20	15.98 (15.42, 16.61)			
After 8 weeks	20	15.88 (15.36, 16.40)	20	15.52 (15.07, 16.06)	N/A		
Sitting time total day (h)							
Baseline	20	10.43 (9.67, 11.06)	20	10.80 (10.18, 11.41)			
After 8 weeks	20	10.17 (9.55, 10.78)	20	9.47 (8.85, 10.09)	-0.89 (-1.89, 0.12)	0.43	0.078
Sitting time total day (%)							
Baseline	20	64.2 (60.5, 68.0)	20	67.7 (64.0, 71.5)			
After 8 weeks	20	64.1 (60.3, 67.8)	20	61.2 (57.4, 64.9)	-4.91 (-9.93, 0.11)	0.47	0.054
Number of sitting bouts <30 min total day							
Baseline	20	57.8 (48.1, 67.4)	20	45.2 (35.6, 54.9)			
After 8 weeks	20	56.9 (47.4, 66.6)	20	43.5 (33.9, 53.1)	-5.07 (-10.26, 0.11)	0.43	0.055
Time in sitting bouts <30 min total day							
Baseline	20	5.23 (4.66, 5.80)	20	4.55 (3.98, 5.12)			
After 8 weeks	20	5.26 (4.69, 5.83)	20	4.21 (3.64, 4.79)	-0.61 (-1.11, -0.11)	0.54	**0.019**
Number of sitting bouts ≥ 30 min total day							
Baseline	20	5.44 (4.82, 6.06)	20	6.10 (5.49, 6.73)			
After 8 weeks	20	5.48 (4.86, 6.10)	20	5.58 (4.96, 6.20)	-0.15 (-1.00, 0.70)	0.09	0.703
Time in sitting bouts ≥ 30 min total day							
Baseline	20	5.20 (4.49, 5.91)	20	6.26 (5.54, 6.97)			
Change at 8 weeks	20	4.90 (4.19, 5.62)	20	5.26 (4.54, 5.97)	-0.08 (-1.02, 0.86)	0.04	0.850
Standing time total day (h)							
Baseline	20	3.89 (3.37, 4.42)	20	3.38 (2.85, 3.90)			
After 8 weeks	20	3.87 (3.34, 4.39)	20	4.85 (3.83, 4.87)	0.82 (0.18, 1.62)	0.48	**0.046**
Standing time total day (%)							
Baseline	20	23.9 (20.8, 26.9)	20	21.1 (18.1, 24.1)			
After 8 weeks	20	24.3 (21.3, 27.3)	20	27.8 (24.8, 30.8)	5.3 (0.10, 10.40)	0.48	**0.045**
Sit to stand transitions total day							
Baseline	20	65.2 (55.5, 74.9)	20	52.7 (42.9, 62.4)			
After 8 weeks	20	64.5 (54.8, 74.2)	20	51.5 (41.8, 61.2)	-4.50 (-10.35, 1.36)	0.37	0.118

Data are bootstrapped means and 95% confidence intervals

Effect sizes are Hedges' *g*

Bold text indicates a statistically significant effect of the intervention ($p \leq 0.05$)

Daily stepping

The number of steps classified as light, MVPA, and time spent performing light and MVPA stepping are shown in Table 25. Total steps, as well as the total time spent stepping, are also included. There were no significant differences in any of the stepping variables.

Table 25: Changes in daily physical activity outcomes at follow up by randomisation group

	Control Group		Intervention Group		Adjusted Difference	Effect Size	P
Variable	***n***	**Mean (95% CI)**	***n***	**Mean (95% CI)**	**Mean (95% CI)**		
Number of light steps total day							
Baseline	20	873 (718, 1047)	20	674 (564, 804)			
After 8 weeks	20	799 (666, 931)	20	625 (492, 757)	-28.9 (-117.3, 59.5)	0.15	0.512
Number of MVPA steps total day							
Baseline	20	3867 (3192, 4592)	20	4034 (3542, 4633)			
After 8 weeks	20	3781 (3100, 4462)	20	3848 (3167, 4530)	68.0 (-638.9, 502.9)	0.05	0.811
Number of steps total day							
Baseline	20	4740 (3944, 5618)	20	4708 (4174, 5340)			
After 8 weeks	20	4580 (3807, 5352)	20	4473 (3700, 5246)	-80.5 (-677.1, 516.0)	0.06	0.786
Time light stepping (h)							
Baseline	20	0.76 (0.63, 0.91)	20	0.57 (0.48, 0.69)			
After 8 weeks	20	0.69 (0.58, 0.81)	20	0.53 (0.42, 0.65)	-0.02 (-0.09, 0.06)	0.11	0.627
Time MVPA stepping (h)							
Baseline	20	1.17 (0.96, 1.38)	20	1.23 (1.08, 1.40)			
After 8 weeks	20	1.16 (0.95, 1.37)	20	1.17 (0.96, 1.38)	-0.04 (-0.21, 0.13)	0.10	0.658
Time stepping (h)							
Baseline	20	1.93 (1.16, 2.27)	20	1.80 (1.58, 2.04)			
After 8 weeks	20	1.85 (1.56, 2.14)	20	1.70 (1.41, 2.00)	-0.04 (-0.24, 0.17)	0.08	0.709

Data are bootstrapped means and 95% confidence intervals

Effect sizes are Hedges' *g*

Bold text indicates a statistically significant effect of the intervention ($p \leq 0.05$)

Productivity

Presenteeism values and the number of days for absenteeism are presented in Table 26. There were no significant differences observed between groups for the two variables. In contrast, significant differences in the change from baseline to follow-up were observed between the intervention and control participants for three of the eight EMA outcome measures recorded when participants were in a seated position, as shown in Table 27. The

intervention participants reported being significantly more motivated, engaged, and productive when compared with control participants. However, there were no significant differences in the change between groups for the other five EMA outcome measures. In contrast, no differences were observed between groups for EMA outcome measures obtained when participants were standing when the EMA prompt was received (Table 28).

The final EMA analysis compared sitting and standing postures for the follow-up values only using arm and posture as main effects, and also including the interaction effect of arm x posture. When this was done, several significant differences were observed (Table 29). Firstly, there was a moderate effect of arm on reported productivity, with the intervention group being more productive than the control group, regardless of the position they were in. When the effects of posture were evaluated, participants reported feeling less stressed and more energised when standing, both of which were moderate effects. This effect was observed for both arms of the study. Finally, no interaction effects were observed between arm and posture with respect to EMA outcome measures (Table 29).

Table 26: Changes in absenteeism and presenteeism

	Control Group		Intervention Group		Adjusted Difference	Effect Size	P
Variable	***n***	**Mean (95% CI)**	***n***	**Mean (95% CI)**	**Mean (95% CI)**		
Absenteeism (days)							
Baseline	20	0.75 (-0.28, 1.78)	20	0.13 (-0.90, 1.15)			
After 8 weeks	19	1.53 (0.47, 2.58)	15	0.53 (-0.65, 1.72)	-1.43 (-4.75, 1.89)	0.21	0.357
Presenteeism (%)							
Baseline	20	32.4 (25.6, 39.2)	20	26.6 (19.8, 33.4)			
After 8 weeks	20	24.6 (17.6, 31.5)	15	28.8 (20.9, 36.6)	4.39 (-7.45, 16.24)	0.17	0.455

Data are bootstrapped means and 95% confidence intervals

Effect sizes are Hedges' *g*

Bold text indicates a statistically significant effect of the intervention ($p \leq 0.05$)

Table 27: Changes in EMA outcomes when sitting

	Control Group		Intervention Group		Adjusted Difference	Effect Size	P
Variable	***n***	**Mean (95% CI)**	***n***	**Mean (95% CI)**	**Mean (95% CI)**		
Anxious while sitting							
Baseline	18	2.44 (1.82, 3.07)	20	2.94 (2.35, 3.54)			
After 8 weeks	13	2.25 (1.51, 2.98)	13	2.31 (1.64, 2.97)	-0.02 (-0.68, 0.65)	0.02	0.955
Creative while sitting							
Baseline	18	4.19 (3.21, 5.17)	20	4.52 (3.59, 5.44)			
After 8 weeks	13	3.93 (2.87, 4.99)	13	5.42 (4.44, 6.40)	0.61 (-0.13, 1.35)	0.51	0.094
Energised while sitting							
Baseline	18	5.17 (4.48, 5.90)	20	6.33 (5.68, 6.99)			
After 8 weeks	13	5.51 (4.71, 6.30)	13	6.43 (5.71, 7.15)	0.27 (-0.23, 0.76)	0.29	0.285
Engaged while sitting							
Baseline	18	5.80 (5.10, 6.50)	20	6.52 (5.85, 7.18)			
After 8 weeks	13	5.66 (4.87, 6.46)	13	6.91 (6.19, 7.64)	0.46 (0.01, 0.91)	0.55	**0.044**
Happy while sitting							
Baseline	18	6.00 (5.40, 6.59)	20	6.90 (6.33, 7.46)			
After 8 weeks	13	6.58 (5.90, 7.26)	13	7.41 (6.79, 8.03)	0.25 (-0.18, 0.67)	0.31	0.249
Motivated while sitting							
Baseline	18	5.75 (5.03, 6.46)	20	6.46 (5.78, 7.14)			
After 8 weeks	13	5.56 (4.74, 6.37)	13	6.94 (6.20, 7.68)	0.55 (.08, 1.03)	0.62	**0.024**
Productive while sitting							
Baseline	18	5.75 (5.07, 6.43)	20	6.56 (5.91, 7.21)			
After 8 weeks	13	5.76 (4.98, 6.55)	13	7.22 (6.51, 7.94)	0.57 (0.11, 1.04)	0.66	**0.016**
Stressed while sitting							
Baseline	18	2.87 (2.18, 3.56)	20	3.62 (2.97, 4.27)			
After 8 weeks	13	2.73 (1.93, 3.54)	13	3.14 (2.42, 3.86)	0.08 (-0.47, 0.63)	0.08	0.769

Data are bootstrapped means and 95% confidence intervals

Effect sizes are Hedges' *g*

Bold text indicates a statistically significant effect of the intervention ($p \leq 0.05$)

Table 28: Changes in EMA outcomes when standing

	Control Group		Intervention Group		Adjusted Difference	Effect Size	P
Variable	***n***	**Mean (95% CI)**	***n***	**Mean (95% CI)**	**Mean (95% CI)**		
Anxious while standing							
Baseline	16	2.22 (1.56, 2.88)	17	2.40 (1.76, 3.04)			
After 8 weeks	10	2.04 (1.21, 2.87)	10	2.02 (1.22, 2.81)	0.03 (-0.69, 0.76)	0.03	0.919
Creative while standing							
Baseline	16	4.49 (3.37, 5.62)	17	4.90 (3.81, 5.99)			
After 8 weeks	10	5.76 (4.37, 7.14)	10	4.62 (3.30, 5.95)	-0.25 (-1.20, 0.70)	0.18	0.575
Energised while standing							
Baseline	16	5.33 (4.44, 6.21)	17	6.71 (5.85, 7.56)			
After 8 weeks	10	6.90 (5.79, 8.01)	10	6.77 (5.71, 7.83)	0.17 (-0.59, 0.92)	0.13	0.663
Engaged while standing							
Baseline	16	5.83 (4.89, 6.76)	17	6.90 (5.98, 7.80)			
After 8 weeks	10	6.79 (5.65, 7.94)	10	7.23 (6.14, 8.33)	0.25 (-0.37, 0.86)	0.24	0.428
Happy while standing							
Baseline	16	6.80 (6.12, 7.48)	17	7.28 (6.63, 7.94)			
After 8 weeks	10	7.32 (6.48, 8.16)	10	7.48 (6.68, 8.28)	0.13 (-0.32, 0.57)	0.17	0.572
Motivated while standing							
Baseline	16	6.02 (5.04, 6.99)	17	6.86 (5.91, 7.80)			
After 8 weeks	10	6.54 (5.31, 7.78)	10	7.02 (5.85, 8.19)	0.41 (-0.31, 1.13)	0.34	0.263
Productive while standing							
Baseline	16	5.70 (4.89, 6.52)	17	7.06 (6.27, 7.85)			
After 8 weeks	10	7.03 (6.02, 8.04)	10	7.54 (6.57, 8.50)	0.25 (-0.55, 1.04)	0.21	0.500
Stressed while standing							
Baseline	16	3.30 (2.53, 4.06)	17	3.00 (2.25, 3.75)			
After 8 weeks	10	2.25 (1.28, 3.22)	10	2.02 (1.09, 2.94)	-0.15 (-0.81, 0.51)	0.16	0.616

Data are bootstrapped means and 95% confidence intervals

Effect sizes are Hedges' *g*

Bold text indicates a statistically significant effect of the intervention ($p \leq 0.05$)

Table 29: Changes in EMA outcomes between sitting and standing for the intervention follow-up

	Control Group		Intervention Group		Adj. Diff. Arm	Effect Size	P	Adj. Diff. Posture	Effect Size	P	Interaction Effect	
Variable	***n***	**Mean (95% CI)**	***n***	**Mean (95% CI)**	**Mean (95% CI)**			**Mean (95% CI)**			**F**	**P**
Anxious												
Sitting	10	2.28 (1.76, 2.81)	11	2.24 (1.46, 3.02)								
Standing	10	2.02 (1.38, 2.65)	11	2.04 (1.15, 2.93)	0.01 (-0.67, 0.70)	0.01	0.978	-0.23 (-0.92, 0.45)	0.20	0.496	0.027	0.871
Creative												
Sitting	10	4.98 (4.00, 5.97)	11	3.98 (2.66, 5.29)								
Standing	10	4.62 (3.44, 5.81)	11	5.92 (4.42, 7.41)	-0.14 (-1.35, 1.06)	0.07	0.813	0.79 (-0.42, 1.99)	0.38	0.194	3.700	0.061
Energised												
Sitting	10	6.33 (5.62, 7.04)	11	5.57 (4.71, 6.44)								
Standing	10	6.73 (5.88, 7.58)	11	6.96 (5.97, 7.95)	0.26 (-0.57, 1.09)	0.18	0.529	0.89 (0.06, 1.72)	0.63	**0.036**	1.519	0.224
Engaged												
Sitting	10	6.83 (6.23, 7.42)	11	5.84 (4.89, 6.78)								
Standing	10	7.08 (6.36, 7.79)	11	6.94 (5.86, 8.02)	0.56 (-0.24, 1.37)	0.41	0.167	0.68 (-0.13, 1.49)	0.49	0.098	1.210	0.277
Happy												
Sitting	10	7.35 (6.71, 7.99)	11	6.69 (5.78, 6.79)								
Standing	10	7.52 (6.74, 8.29)	11	7.59 (6.95, 8.23)	0.66 (-0.23, 1.55)	0.26	0.368	0.53 (-0.12, 1.18)	0.47	0.108	1.443	0.236
Motivated												
Sitting	10	6.87 (6.26, 7.49)	11	5.70 (4.79, 6.60)								
Standing	10	6.98 (6.24, 7.72)	11	6.64 (5.60, 7.67)	0.76 (-0.04, 1.56)	0.47	0.062	0.52 (-0.28, 1.32)	0.38	0.194	1.177	0.284
Productive												
Sitting	10	7.18 (6.71, 7.66)	11	5.89 (5.00, 6.78)								
Standing	10	7.45 (6.87, 8.02)	11	7.03 (6.02, 8.05)	0.86 (0.13, 1.58)	0.69	**0.021**	0.71 (-0.02, 1.43)	0.57	0.055	1.750	0.193
Stressed												
Sitting	10	3.16 (2.63, 3.68)	11	2.72 (1.93, 3.52)								
Standing	10	2.02 (1.38, 2.65)	11	2.25 (1.35, 3.15)	0.10 (-0.59, 0.79)	0.08	0.773	-0.81 (-1.50, -0.12)	0.68	**0.023**	0.919	0.343

Data are bootstrapped means and 95% confidence intervals

Effect sizes are Hedges' *g*

Bold text indicates a statistically significant effect of the intervention ($p \leq 0.05$)

Other outcome measures

Data for cardiometabolic health outcomes are presented in Table 30. No significant differences were observed between groups for any cardiometabolic health outcome. Similarly, there were no significant differences observed between groups for stress or wellbeing (Table 31).

Table 30: Changes in cardiometabolic risk outcomes

	Control Group		Intervention Group		Adjusted Difference	Effect Size	p
Variable	***n***	**Mean (95% CI)**	***n***	**Mean (95% CI)**	**Mean (95% CI)**		
Weight (kg)							
Baseline	20	78.6 (69.1, 84.2)	20	75.8 (68.3, 83.3)			
After 8 weeks	20	73.6 (66.1, 81.1)	20	78.6 (71.1, 86.1)	5.27 (-5.13, 15.67)	0.23	0.311
BMI (kg/m2)							
Baseline	20	26.9 (24.1, 29.6)	20	26.2 (23.4, 29.0)			
After 8 weeks	20	26.8 (24.0, 29.5)	20	27.3 (24.6, 30.1)	1.12 (-2.20, 4.46)	0.15	0.501
Waist Circumference (cm)							
Baseline	20	91.1 (84.7, 97.5)	20	88.6 (82.2, 95.0)			
After 8 weeks	20	86.8 (80.4, 93.1)	20	90.5 (84.1, 96.9)	4.73 (-4.80, 14.26)	0.22	0.321
Systolic BP (mmHg)							
Baseline	20	115.2 (108.2, 122.3)	20	118.8 (111.7, 125.8)			
After 8 weeks	20	120.6 (113.5, 127.6)	20	117.0 (109.9, 124.0)	-3.74 (-14.41, 6.93)	0.16	0.482
Diastolic BP (mmHg)							
Baseline	20	77.5 (73.1, 82.0)	20	75.3 (70.9, 79.7)			
After 8 weeks	20	77.4 (73.0, 81.9)	20	75.6 (71.1, 80.0)	-1.23 (-7.04, 4.58)	0.09	0.670
Mean Arterial Pressure (mmHg)							
Baseline	20	96.4 (91.0, 101.8)	20	97.0 (91.7, 102.4)			
After 8 weeks	20	99.0 (93.6, 104.4)	20	96.3 (90.9, 101.6)	-2.83 (-10.55, 4.90)	0.16	0.463
Glucose (mmol/L)							
Baseline	20	5.01 (4.68, 5.34)	20	4.77 (4.44, 5.10)			
After 8 weeks	20	5.04 (4.71, 5.37)	20	5.42 (5.09, 5.75)	0.44 (-0.06, 0.94)	0.39	0.082
HDL (mmol/L)							
Baseline	20	1.31 (1.12, 1.49)	20	1.41 (1.22, 1.59)			
Change at 8 weeks	20	1.53 (1.34, 1.72)	20	1.37 (1.19, 1.56)	-0.17 (-0.45, 0.10)	0.28	0.200
LDL (mmol/L)							
Baseline	20	3.14 (2.74, 3.54)	20	2.99 (2.59, 3.39)			
Change at 8 weeks	20	2.85 (2.45, 3.25)	20	2.78 (2.39, 3.18)	-0.06 (-0.64, 0.52)	0.05	0.835
non-HDL (mmol/L)							
Baseline	20	3.63 (3.16, 4.11)	20	3.47 (3.00, 3.95)			
Change at 8 weeks	20	3.37 (2.90, 3.84)	20	3.48 (3.00, 3.95)	0.13 (-0.63, 0.88)	0.09	0.708
TC:HDL ratio							
Baseline	20	4.14 (3.47, 4.81)	20	3.79 (3.12, 4.45)			
Change at 8 weeks	20	3.39 (2.72, 4.06)	20	4.04 (3.37, 4.71)	0.70 (-0.21, 1.61)	0.34	0.128
Total Cholesterol (mmol/L)							
Baseline	20	4.94 (4.46, 5.42)	20	4.88 (4.40, 5.36)			
Change at 8 weeks	20	4.90 (4.42, 5.38)	20	4.93 (4.45, 5.41)	0.04 (-0.74, 0.83)	0.03	0.905
Triglycerides (mmol/L)							
Baseline	20	1.54 (1.02, 2.05)	20	1.10 (0.58, 1.61)			
Change at 8 weeks	20	1.15 (0.64, 1.67)	20	1.31 (0.79, 1.82)	0.13 (-0.42, 0.67)	0.10	0.638

Data are bootstrapped means and 95% confidence intervals

Effect sizes are Hedges' *g*

Bold text indicates a statistically significant effect of the intervention ($p \leq 0.05$)

Table 31: Changes in stress and wellbeing outcomes

	Control Group		Intervention Group		Adjusted Difference	Effect Size	P
Variable	***n***	**Mean (95% CI)**	***n***	**Mean (95% CI)**	**Mean (95% CI)**		
Cohen Perceived Stress							
Baseline	20	17.1 (14.1, 20.0)	20	15.9 (12.9, 18.8)			
After 8 weeks	19	14.0 (11.1, 17.0)	15	14.8 (11.6, 18.0)	1.29 (-2.43, 5.02)	0.17	0.457
Mental Wellbeing (WEMWBS)							
Baseline	20	46.2 (42.3, 50.1)	20	48.2 (44.3, 52.1)			
After 8 weeks	19	48.7 (44.7, 52.7)	15	47.3 (43.0, 51.7)	-2.11 (-7.92, 3.70)	0.18	0.440
PANAS (Positive Affect)							
Baseline	20	26.6 (24.9, 28.2)	20	25.3 (23.7, 26.9)			
After 8 weeks	19	25.7 (24.0, 27.3)	15	25.6 (23.8, 27.4)	0.52 (-1.43, 2.46)	0.12	0.590
PANAS (Negative Affect)							
Baseline	20	25.1 (23.5, 26.7)	20	23.6 (21.9, 25.2)			
Change at 8 weeks	19	24.7 (23.0, 26.4)	15	23.9 (22.0, 25.7)	-0.34 (-2.96, 2.28)	0.06	0.796

Data are bootstrapped means and 95% confidence intervals

Effect sizes are Hedges' *g*

Bold text indicates a statistically significant effect of the intervention ($p \leq 0.05$)

8.4 Discussion

The effect of the present intervention was assessed for a range of different outcomes. During working hours, the intervention significantly reduced desk-based office worker's sitting time in comparison with the control group. The overall effect of this multicomponent intervention on workplace sitting time was a reduction of 11%, which is equivalent to a 53-min reduction for an eight-hour working day. These findings indicate a step on the path to achieving the recommended time for light activity (light walking or standing) proposed by Buckley *et al.* (2015). This is evidenced by the significant change observed in standing time and in the number of participants meeting the initially recommended minimum 2 h of daily standing in the intervention group. Confidence in this finding was strengthened from reports of other studies in which sitting was replaced with standing, rather than ambulation (Healy *et al.*, 2016; Neuhaus *et al.*, 2014b). This suggests that most participants may have opted to reduce their sitting time by carrying out their work tasks while in a standing posture at their desk (Edwardson *et al.*, 2018b), which would be expected in interventions that provide height-adjustable workstations.

Some previous studies have reported comparatively higher effects of multicomponent interventions on workplace sitting time, with reported values ranging from 50-125 minute per day reductions (Carr *et al.*, 2013; Carr *et al.*, 2016a; Edwardson *et al.*, 2018b; Graves *et al.*, 2015; Neuhaus *et al.*, 2014b). Two of these studies also reported a decrease in the time spent in prolonged sitting, that is, sitting bouts lasting ≥30 min (Danquah *et al.,* 2017; Healy et al., 2013). In one study, the number of prolonged sitting periods per working day decreased in the intervention group (0.79 bouts; 95% CI 0.50-1.08 bouts) (Danquah *et al.,* 2017), while in another study the total amount of prolonged sitting decreased by over an hour per working

day (73 min; 95% CI 40-105 min) (Healy *et al.,* 2013). One measure that has been used to evaluate breaking up sitting is the number of sit-to-stand transitions, which are defined as a state of moving from a seated to a standing position (Jerome *et al.,* 2017). Studies have reported significant increases in sit-to-stand transitions associated with a reduction in prolonged sitting (Healy *et al.*, 2013; Neuhaus *et al.*, 2014b; Parry *et al.*, 2013). In this present study, it was expected that participants in the intervention group would have an increase in the number of sit-to-stand transitions as a result of the intervention. However, no difference in the number of sit-to-stand transitions was observed between groups after adjusting for the number of hours in the working day. The lack of change in the number of sit-to-stand transitions in spite of a reduction in sitting time is testament to the paradigm that decreasing sitting and increasing sit-to-stand transitions are independent behaviours that warrant distinct and specific approaches (Kerr *et al.,* 2016).

In addition, the number of sit-to-stand transitions might not be the best predictor of prolonged sitting time, with conflicting evidence from previous studies. For instance, one study found no change in the total number of sit-to-stand transitions despite decreased sitting time and increased standing and walking time (Judice *et al.*, 2015). Other studies have also reported that reduced sitting time and increased standing time had minimal impact on sit-to-stand transitions (Alkhajah *et al.,* 2012; Healy *et al.,* 2013). One reason for the differences between sitting time and sit-to-stand transitions might be due to an inherent flaw in using only the number sit-to-stand transitions as a parameter. For instance, it is possible for someone with many periods of prolonged sitting to also have a large number of sit-to-stand transitions provided they have a period in the day when they include many sit-to-stand transitions in a short space of time. In contrast, someone who breaks up their sitting every 25

min throughout the day but has no period with multiple sit-to-stand transitions in a short space of time, would have less transitions over the course of the day despite breaking up their sitting. With respect to the present study, it appears that the intervention arm participants did not get up from a sitting position more often, but instead stayed on their feet for a longer period of time during each of the non-sitting bouts (Judice *et al.,* 2015).

The present study did not find a significant effect of the intervention on prolonged sitting time (time in sitting bouts ≥ 30 min). This could be due to the fact that the study participants were free to set their prompts to break up sitting each day as they wished to. The implication could be that most participants focused on sitting reduction as opposed to breaking up sitting time. In contrast, Neuhaus *et al.* (2014b) made it compulsory for participants to stand up every 30 minutes, which resulted in a significant decrease of 31 min per working day in prolonged sitting (95% CI: 17-79 min). This suggests that future interventions should consider providing strategies to increase the regularity of breaking up sitting time. Thus, based on the finding that there was no increase in the number sit-to-stand transitions during this pilot trial. Future interventions should be cautious about the assumption that accumulated daily workplace sitting time is evenly spread during the working period and should include a focus on regularly breaking up sitting time.

The adherence of the intervention was assessed by evaluating the number of participants that met the intervention guidelines for standing up. With respect to standing up more at work, there was good adherence to the guideline, with 90% of intervention participants satisfying at least the minimum recommendation of two hours standing per day. Similar findings have been reported in the Take a Stand multicomponent study, which led to an increased standing time of 64 min (95% CI= 51, 77) (Danquah *et al.,* 2017). In addition, another multicomponent

study reported an increase in standing time of 93 min (Neuhaus *et al.*, 2014b). However, neither of these studies reported the percentage of participants meeting the guideline. The participants in the present study have shown greater compliance to the intervention in comparison with interventions reported in other studies. For instance, one study gave participants weekly tips on how to reduce sitting time that were provided on computers or smartphones using prompt software, asked participants to keep daily activity logs, and encouraged them to take 1-2 min walking short breaks every 30 min or two 15-min long breaks across an eight-week intervention duration. Better adherence to the recommended protocols was achieved by the short break group, with 69% adhering fully and 20% adhering partially, compared to the long break group which achieved 61% and 20% for full and partial adherence, respectively (Mailey *et al.*, 2016).

In another study, adherence was measured for an intervention that included access to a motivational website for tips and reminders on reducing SB and also a pedal machine and a pedometer for 12 weeks Carr *et al.* (2013). Participants' compliance with logging onto the website was 71%, with only 38% compliance with using the portable pedal machine. A similar compliance level was reported by Ryan *et al.* (2011) in a study in which office workers were evaluated for keeping their sitting bouts shorter than either 20 min, 30 min, or 55 min. Objective monitoring of participants identified none of the participants met the 20- or 30-min recommendations on every working day, however, 8% of participants met the 55 min recommendation. It should be noted, however, that no intervention was provided in the study by Ryan *et al.* (2011). The findings in the present study relative to previous work suggests that employees' knowledge of the sitting guidelines may have encouraged them to stand at their desks and work, rather than alternate between sitting and standing. Thus, it can

be argued that employees would be more compliant to workplace interventions to break up prolonged sitting if there was more emphasis on recommended guidelines for sitting time. In addition, there is a need for qualitative research work to be conducted to identify the best strategy to promote changes in ambulatory movement during working hours (Edwardson *et al.*, 2018b).

Some of the studies discussed above incorporated interventions lasting from one to three months (Carr *et al.*, 2013; Carr *et al.*, 2016a; Danquah *et al.*, 2017; Neuhaus *et al.*, 2014b) and were based on Social Cognitive Theory, which has self-efficacy as its main construct. This theory is based on the notion that behaviour is formed through the dynamic synergy that exists between personal, behavioural, and environmental influences (Bandura, 1986). The relatively short duration of these interventions would suggest that the majority of any changes observed could be attributable to the environmental component of the intervention (Healy *et al.*, 2013). For instance, a multicomponent study that involved the provision of high tables in meeting rooms, offices and corridors, in addition to scheduling walking meetings enabled participants to continue to stand and walk more (Danquah *et al.*, 2017). This could be an indication that provision of facilities that promote standing and walking meetings may be required in order to significantly reduce sitting time. In contrast, the intervention in the current study was guided by the BCW (Michie, Atkins and West, 2014) and tailored to meet the needs of employees, which led to high adherence and a large reduction in the number of participants failing to meet guidelines for standing up at work. Results similar to the findings of this present study have been reported in the SMArT Work intervention that also used the BCW in intervention development (Edwardson *et al.*, 2018b), with a reduction in workplace sitting of 50.6 min (95% CI= 78.7, 22.5) recorded at three months and 64.4 min (95% CI= 97.3,

31.5) at 12 months. This suggests that the BCW might be effective in developing workplace SB interventions to reduce sitting time.

With respect to PA, an objective evaluation was made to determine whether the intervention would have any effect on PA levels. The results showed no significant changes for any of the PA variables related to stepping. The lack of a meaningful change in PA levels could be a reflection of inadequate opportunities for PA in an office setting (Healy *et al*., 2013). Although the intervention asked participants to break up their sitting with either short walks or by standing up, participants appear to have spent more time standing up than walking (Healy *et al*., 2013). Therefore, future research should investigate how strategies to reduce sitting and increase PA can be used together successfully.

The present study also assessed the effect of the intervention on sitting and activity across the whole day, with no change found between groups for total daily sitting time, the number of steps, or the number of sitting bouts longer than 30 minutes. However, there were significant differences in the time spent in siting bouts less than 30 minutes and daily standing time. The fact that the intervention significantly increased standing time during working time could have led to the participants becoming tired and subsequently compensating by increasing their sitting time after work, thus resulting in an increased daily sitting time (Mansoubi *et al.*, 2016). Such assumptions would need to be evaluated in further research to determine the effect of workplace interventions to break up and reduce sitting both in and outside of work. Complementary intervention components that target behaviour changes outside of work may thus be required (Maylor *et al.,* 2018).

The intervention in this thesis did not have any significant effect on self-reported absenteeism or presenteeism. Evidence from other studies has also been equivocal. For instance, the

Walk@WorkSpain study, which was conducted among employees from six Spanish university campuses, reported no effect of the 19-week intervention on employees' mental wellbeing but identified an increase in presenteeism that remained present four weeks after the intervention (Puig-Ribera *et al.,* 2017). However, these changes were observed for both control and intervention groups, suggesting there was a factor other than the intervention explaining the increase in presenteeism observed. In another study, a five-month longitudinal intervention targeted at healthy behaviour in the workplace reported no effect on absenteeism, but a negative effect of the intervention was found for presenteeism (Hendriksen *et al.,* 2016). Although this study focused on improving PA levels rather than reducing sitting time, other studies have not reported any negative effects. For instance, the SMArT Work intervention study reported improved presenteeism at three months and 12 months post- intervention, although no change was observed for the number of absent days due to sickness (Edwardson *et al.*, 2018b). This suggests that a more positive outcome could be detected if the intervention was maintained over a longer period. Therefore, evidence from this study and the small number of studies identified above suggests that interventions to reduce sitting time in the workplace would not have any detrimental effect on employees' ability to cope with work and could potentially improve outcomes long-term.

In addition to simple measures of absenteeism and presenteeism, productivity was also assessed using data collected with the aid of EMA, which has been identified as an appropriate tool for measuring productivity due to its ability to limit recall bias (Yang *et al.,* 2018). The intervention led to a significant improvement in reported productivity while in a seated position for the intervention group in comparison with the control group at follow-up with a moderate effect size. Participants in the intervention group also reported being

significantly more motivated to do their work compared with those in the control group when assessed at follow-up, with this improvement also corresponding to a moderate effect. Although no changes were observed between groups for standing posture productivity, this was most likely due to the larger variability in results for the control group who had limited data for the standing condition in the follow-up evaluation owing to the absence of height-adjustable workstations for the control group. Similarly, there was limited data available for EMA when standing at baseline for both groups. When EMA was compared between seated and standing postures in the follow-up tests, participants felt significantly less stressed and more energised when standing in comparison with when they were sitting, regardless of the group they were in, with moderate effects observed.

In addition, this analysis identified participants in the intervention group as being significantly more productive than control group participants. No interaction effects were observed between the arm and posture for any of the EMA outcome measures. These results suggest that the multicomponent intervention that includes use of a height-adjustable workstation could decrease perceived stress and increase energy when standing, which might result in improved productivity. However, these results need to be considered with caution as a longer-duration trial with greater power, sufficient to detect any possible interaction effect, is needed to fully investigate this finding.

The EMA productivity findings are consistent with what was observed in an “Opt to Stand” pilot study among call centre staff (Chau *et al.*, 2016). This quasi-experimental study reported that the provision of height-adjustable workstations increased customer care workers’ standing time, without having any negative impact on their objectively measured productivity, including call handling time, time spent talking, time spent on hold, time spent

wrapping up calls, attendance, and sick leave. However, evidence from previous literature regarding the effect of interventions to break up or reduce sitting time in the workplace has been equivocal. For instance, in some studies, an objective assessment of work performance found no significant reductions (Ebara *et al.,* 2008; Hedge *et al*., 2005; Husemann *et al.,* 2009). However, these studies used laboratory tasks of activities such as data entry (Husemann et al., 2009) or transcription (Ebara *et al.,* 2008; Hedge *et al.,* 2005), rather than ecological assessment. In other studies using height-adjustable workstations, office workers expressed feeling more productive, focused, efficient, and alert (Alkhajah *et al.*, 2012; Chau *et al.*, 2014b; Grunseit *et al.*, 2013; Pronk *et al.*, 2012). In addition, a sustainable long-term effect of a sitting reduction intervention has been identified for job performance in a previously described workplace multicomponent study (Edwardson *et al.*, 2018b). Similarly, a recent systematic review of 63 studies investigating the effects of SB interventions on work-related productivity and performance in real and simulated office work found that workplace standing SB interventions showed a null effect on productivity and performance outcomes, which is in contrast to the negative effect shown by walking and cycling interventions for productivity but not for performance outcomes (Sui *et al.*, 2019). Thus, sitting reduction interventions incorporating height-adjustable workstations may thus have promise for improving workplace productivity and performance.

The intervention did not result in any significant difference in any of the cardiometabolic variables. Such a finding was not unexpected as the intervention was short-term and did not include any form of MVPA (Healy *et al.,* 2013). Other studies have also found no effect of reducing sitting on cardiometabolic biomarkers in a number of multicomponent interventions lasting 4 to 16 weeks, which decreased sitting by 59-125 minutes (Carr *et al.*, 2013; Carr *et al.*,

2016a; Healy *et al.*, 2013; Healy *et al.*, 2016). A probable reason for the lack of effect of such interventions on cardiometabolic biomarkers across all these studies and the present study could be that the study participants were reasonably healthy with respect to cardiometabolic risk. Previous studies have shown that the benefits of breaking up sitting are greater in obese and dysmetabolic populations (Benatti and Ried-Larsen, 2015; Dempsey *et al.,* 2016; Dunstan *et al.,* 2012; Healy e*t al.,* 2017).

However, some single-component intervention studies have reported beneficial changes in cardiometabolic outcomes such as total cholesterol and diastolic blood pressure after only 8 weeks of using a height-adjustable workstation (Graves *et al.,* 2015). Likewise, a 13-week prompt-only intervention resulted in a significant reduction in mean arterial pressure (Mainsbridge *et al.*, 2014). Significant reductions in waist circumference and diastolic blood pressure were also reported in a 12-week quasi experimental workplace intervention (Lin *et al*., 2017). Conversely, a long-term study conducted over 18-months to determine the effects of height-adjustable workstations reported no change of the intervention on cardiometabolic biomarkers (Zhu *et al.,* 2018), although improvements were observed in some cardiometabolic biomarkers in a 12-month Sit Less, Walk More workplace intervention (Lin *et al.,* 2018). It should be noted that due to the relatively small sample size of the present study it was not powered a priori to detect significant changes in these secondary outcomes. Therefore, the absence of significant differences should not be interpreted as ruling out possible important health benefits as reported in long-term interventions (Alkhajah *et al*., 2012). Thus, these findings should be explored in larger, sufficiently powered longer-term trials.

The intervention in this present study did not find any significant differences between groups for the change in mood, stress, or wellbeing. This finding is contrary to the findings recorded for EMA in which participants felt less stressed and more energised. This may have been due to differences in how and when stress was measured using questionnaires and EMA. Similarly, the SMArT Work intervention study reported no change in most mood affect variables except for anxiety at six and 12 months in favour of the intervention in comparison with the control (Edwardson *et al.*, 2018b). In contrast, a 4-week cross-over study by Dutta *et al.* (2014) reported that a workplace SB intervention using height-adjustable workstations led to an increase in participants' perceived well-being and mood. Corroborating this finding, the Take-a Stand Project in which the effectiveness of height-adjustable workstations was investigated, reported significant improvements in self-reported mood states for the intervention group compared with the control group (Pronk *et al.*, 2012). On the basis of these findings, the effects of SB reduction intervention on mood, stress and wellbeing should be investigated in longer-term studies sufficiently powered to detect changes in these outcomes.

Strengths and limitations

One of the strengths of this study is its real-world applicability, as the study was conducted in an ecological office environment. Secondly, this intervention was developed based on participants' needs, which explains why there was a high level of adherence and upper-level management support for participants during the intervention periods. Furthermore, this study adopted a robust cluster-randomised controlled design and thereby avoided or minimised contamination between the intervention and control groups. Moreover, the outcomes of this intervention have implications for evidence-based practice in workplace health and wellness promotion. Despite the lack of evidence from this study regarding health

benefits of this multicomponent intervention, employers or organisations considering improving the health of their employees through reduction of sitting time without adverse effect on their employees' productivity could adopt the strategies employed in this intervention. This includes environmental modification, education, prompting, and organisational support, coupled with self-monitoring and feedback on behaviour. As this pilot study was a complex intervention, there was a high likelihood that it would exert effects at several levels, thus a wide range of outcomes were included (Edwardson *et al.*, 2018b). However, this study had not been powered to detect differences in all the included outcomes.

Other limitations of the study were that participants' compliance with EMA and Qualtrics questionnaires declined at follow-up. Another limitation is that it was not possible to use a repeated measures analysis for the EMA outcome measures due to the number of missing data points. The EMA prompts were randomly generated, meaning that the responses of the participants occurred at different times of the day and on different days, with the prompts stopping after 12 responses had been recorded for each participant. This meant that the EMA data was collapsed into a single average for each outcome measure, which is a limited way of handling repeated measures data. A multilevel modelling approach has been proposed for handling unbalanced and hierarchical EMA data, which is often plagued by variations in the number and timing of observations between individuals (Kim *et al.*, 2018). Furthermore, the sample included in the study might not be truly representative of the general office worker population as the participants were mostly highly educated and white females. However, variation in confounding variables was adjusted for during data analysis. Lastly, the intervention took place during one of the busiest periods of the university in which several participants had to attend examination board meetings. This meant participants had many

meetings in which they were not using their height-adjustable workstations. Future interventions could control for this by adapting this current intervention.

In preparation for a full RCT, one of the key lessons learned from this pilot study is that recruitment rates were sufficient with 84% of participants who were initially invited to take part in the study. Furthermore, there was a high retention rate (91%) among those who participated in the study with only 9% attrition. However, this could have been influenced by the fact that the primary researcher is a member of staff and a student of one of the participating organisations. This would suggest that applying a more conservative dropout rate of 20% (Healy *et al.,* 2013) in a full RCT would be reasonable to maintain sufficient power for analysis.

There was a high completion rate for the outcomes measured in this study, other than the EMA assessment. Thus, it is suggested that all other outcome measures should be retained in a full trial despite the lack of change in some outcomes in this short 8-week intervention period. A longer intervention period (e.g. 12 months) should thus be considered. The Stand UP Victoria (Dunstan *et al.*, 2013), SMArT Work (Edwardson *et al.*, 2018b) and the Sit Less, Walk More (Lin *et al.*, 2018) studies have reported improvements in productivity, cardiometabolic risk markers and mental health outcomes in response to long-term interventions (Dunstan *et al.*, 2013; Edwardson *et al.*, 2018b; Lin *et al.*, 2018) . Based on the findings of the current pilot study, it would be reasonable to consider excluding EMA measures of productivity and performance as there were lots of missing data. However, this problem could be addressed through more rigorous testing and refinement of this tool prior to a full trial as the missing data was largely due to the EMA prompt software malfunctioning for some participants. Additionally, the EMA software could only function with Android

phones, and as a result, iPhone users were given an Android phone to respond to the EMA prompts. However, this might have reduced adherence to the EMA measures due to the iPhone not being their primary phone. In a full RCT, an EMA tool that is compatible with all phone operating systems should be developed.

The data generated from this pilot study can be used to inform a sample size calculation for a full trial. Therefore, sample size calculations were conducted using GPower (Faul *et al.*, 2007). A clinically meaningful difference of 30 min reduction in sitting time was used based on isotemporal substitution analyses that have shown that replacing this volume of sitting with standing and light physical activity is associated with significant improvements in cardiometabolic outcomes (such as fasting plasma glucose, insulin, and insulin resistance) (Buman *et al.*, 2014; Edwardson *et al.*, 2017a; Ekblom-Bak *et al.*, 2016). Based on the current pilot study, an SD of 22 min was found for change in workplace sitting in the intervention group relative to controls. Allowing for 90% power and 5% alpha, 17 participants would be required in each of the intervention and control groups to provide sufficient power for an individually randomised trial. In the full trial it is anticipated there would be 14 clusters with an average cluster size of six (higher cluster size relative to the current pilot study as there would be more resources and a longer timeframe for recruitment). With an intracluster correlation coefficient of 0.05 (Eldridge, Ashby and Kerry, 2006), this would give a design effect of 1.25. This means that 22 participants in each group would be needed to give enough power in the overall trial. The sample size for each cluster should then be increased by 20% to take into consideration participants not providing full primary outcome data (n=eight per cluster). This results in a total of 112 participants being required for a full trial.

8.5 Conclusion

This cluster randomised controlled trial detected a significant reduction in workplace sitting time with a simultaneous increase in standing time in office employees from two different work settings. This suggests that the intervention development approach used in this thesis in which the BCW, the TDF, the BCT taxonomy and the APEASE criteria were used in identifying and designing behaviour change intervention components, could be an effective approach to tailor an intervention to reduce sitting in office workers. However, further studies may be required to identify how the intervention can be adapted to increase the number of breaks in sitting time and the effects on health markers in a fully powered RCT.

CHAPTER 9 SUMMARY AND CONTRIBUTION OF THE THESIS

9.1 Chapter overview

This chapter closes the thesis by providing a summary of all the main findings reported in each chapter and discussing their significance and implications. The strengths and limitations of the thesis are also acknowledged as well as suggestions for future research.

9.1 Thesis summary

This thesis has contributed to the body of knowledge relating to SB, and in particular, the development of workplace interventions to break up and reduce sitting time in desk-based employees. The rationale that led to this thesis was conceived from the review of literature presented in Chapter Two. In this chapter, several adverse health consequences attributable to SB were discussed, such as obesity, cardiovascular disease, T2D, and poor mental wellbeing (Dunstan *et al.*, 2010; Gibson *et al.*, 2017; Healy *et al.*, 2011b; Petersen *et al.*, 2014; Teychenne, Costigan and Parker, 2015; Thorp *et al.*, 2012; Warburton, Nicol and Bredin, 2006; Wilmot *et al.*, 2012). Justification for targeting the workplace was provided (Bennie *et al.,* 2015; Evans *et al.,* 2012; Parry and Straker, 2013; Ryan *et al.,* 2011; Thorp *et al.,* 2012) as well as recommendations for a tailored SB intervention in the workplace. This thesis was based on the premise that breaking up and reducing sitting can be considered as a complex behaviour for desk-based office workers, which involves multiple actions (Cooley and Pedersen, 2013). Accordingly, the Medical Research Council framework for complex interventions was used to guide the rest of chapters within this thesis (Craig *et al.,* 2008; Craig *et al.,* 2013). This thesis

covers two stages of the framework, which are the development and piloting stages. This thesis comprises five different but intertwined studies which are developed from the thesis objectives and are presented in Chapters 4-8.

The systematic review in Chapter Four was carried out in keeping with the MRC framework, which recommends that all complex interventions, which are defined as interventions that comprise a wide range of interacting components, must start with a systematic review (Medical Research Council, 2006). This review was important as there is currently insufficient evidence regarding the acute and chronic effect of workplace SB interventions on productivity, and employers have shown reticence to implement such interventions due to a belief that it would negatively affect employees' productivity and performance (De Cocker *et al.*, 2015; Pereira *et al.*, 2015). This chapter also evaluated measures of productivity in the workplace, which was then used to choose the productivity assessment measures for the pilot study presented in Chapter Eight. This chapter revealed that the majority of the studies have assessed cognitive performance as a measure of productivity and that these studies were carried out during single-session trials, indicating that the chronic effect of SB interventions was not evaluated. Based on this review, evidence showed that height-adjustable workstations did not appear to have any detrimental effect on work performance, however, inadequate tools were used in assessing both productivity and performance. Therefore, further studies were recommended to investigate the impact of active workstations on employees' productivity and work performance in the workplace using ecological momentary assessment (EMA) to limit recall bias.

Chapter Five was a study to identify a specific population with high levels of occupational sitting that was selected for questioning to gain an insight into factors influencing their sitting

time in the workplace. This chapter was also used to identify magnitudes of differences in sitting time between ages, gender and ethnic groups to inform future powered studies in line with NICE (2008) recommendations for workplace PA interventions to be tailored to age, gender and ethnicity. This study assessed self-reported sitting time and PA levels of desk-based employees working in two different organisations using the WSQ and IPAQ questionnaires, respectively. The results of this study showed that employees had high levels of self-reported workplace sitting time, irrespective of age, gender and ethnicity. This study, therefore, concluded that workplace SB interventions should be targeted at all desk-based employees from any population regardless of age, gender and ethnicity, and such interventions should not be demographic-specific. The findings of this study should be interpreted with caution, as further sufficiently powered studies using objectives measures to compare sitting time between age groups, ethnic groups, and gender are warranted.

Chapter Six describes a qualitative study that used the BCW to develop an intervention to break up and reduce workplace sitting. Semi-structured interviews were conducted with 25 employees who reported a minimum of 5 h 30 min of sitting at work, which corresponds to around 75% of a working day. The interviews allowed the participants to be part of the processes involved in making decisions towards changing their behaviour (McGuckin, Sealey and Barnett, 2017). Based on the recommendation to use appropriate behaviour change interventions that consider specific preferences, work practices and settings (Cole, Tully and Cupples, 2015), the TDF and COM-B were respectively used to develop an interview schedule and explore the determinants of this behaviour and any potential barriers or facilitators to enactment. The analysis of the interview transcripts led to the identification of seven core themes, which were: *Knowledge-deficit sitting, Inadequate cognitive resources for action,*

Organisational support and interpersonal influences, Tied to the desk, Willingness to Change, Competing motivations, and Emotional influences. These linked *to* five of the six COM-B elements *(Psychological Capability, Reflective Motivation, Automatic Motivation, Social Opportunity, Physical Opportunity [omitting Physical Capability]) and* 12 TDF domains that should be targeted when aiming to break up sitting time in the workplace which are: *Knowledge, Skills Beliefs about capabilities, Intentions, Beliefs about consequences, Environmental context and resources, Social influences, Reinforcement, Social/Professional role and identity, Emotion, Memory, attention and decision processes, Behavioural regulation (omitting Optimism and Goals).*

Following the BCW, this led to the identification of seven intervention functions and four policy categories. Furthermore, from the interviews, 39 BCTs were identified as active ingredients that can be used as content for intervention development. Mining the interviews for BCTs was considered a novel approach to qualitative data analysis as there is currently no evidence of such an approach in the published literature. Evidence presented by this point provided an overview of the core barriers to breaking up and reducing sitting time based on behaviour change theory, a list of BCTs that could be used to adapt behaviour and the intervention functions and policy categories by which to deliver these. When developing workplace SB interventions, designers can choose from this list using APEASE criteria to decide what is affordable, practicable, effective, acceptable, safe, and equitable.

Chapter Seven describes the procedure used in the application of the APEASE criteria for the identification of context-specific intervention functions, policy categories and BCTs that were used in developing the intervention, with five intervention functions and three policy categories identified. A subset of 14 BCTs were selected as active ingredients upon application

of APEASE criteria including *'Goal setting (behaviour), 'Action planning', 'Problem solving', 'Instruction on how to perform the behaviour', 'Credible source', 'Information about health consequence', 'Information about emotional consequence', 'Prompts/cues', 'Social support (unspecified)', 'Restructuring the physical environment', 'Restructuring the social environment' 'Adding object to the environment', 'Behavioural practice/rehearsal', and 'Demonstration of the behaviour'*. The intervention programme was multicomponent, comprising several intervention functions including education, persuasion, enablement and environmental and social restructuring.

Finally, the intervention study was presented in Chapter Eight. The intervention group was educated about the recommended office workplace sitting guidelines, the health consequences of excess sitting and the benefit of breaking up sitting time. They were also given computer-prompt software and height-adjustable workstations, as well as support from their managers, while the control group did not receive any intervention. The primary outcome was objectively measured relative workplace sitting time, while secondary outcomes included productivity, which was assessed using EMA as suggested in the systematic review in Chapter Four (Ojo *et al.,* 2018). Finally, psychological variables and cardiometabolic risk biomarkers were also assessed to evaluate if the intervention would confer any health benefits. There was a high recruitment response rate as well as high intervention adherence, suggesting that the intervention was acceptable and potentially effective. The intervention significantly decreased sitting time and increased standing time, with all but two participants meeting at least the two-hour minimum recommendation for standing up during the workday (Buckley *et al.,* 2015). Both prolonged sitting and excessive sitting may need to be viewed as two distinct behaviours requiring two different

interventions. Future studies should consider how this present intervention can be adapted to target these two behaviours. The absence of consensus guidelines on breaking up sitting in the workplace could have made it difficult for participants to break up prolonged sitting, but the intervention worked well for the other aim of the study which was to reduce workplace sitting time. This was probably helped using a clearly defined guideline for sitting and standing up in the workplace. With respect to productivity, the EMA showed a significant improvement in the productivity of employees in the intervention, with no detrimental impact of standing on employees' productivity. There were also no adverse effects observed for either absenteeism or presenteeism. With respect to the outcome measures of wellbeing, stress and cardiometabolic biomarkers, no changes were observed, which might have been due to the short duration of the intervention. This present study further underlines the need for long-term effects of workplace SB interventions to be studied. In addition, evaluation through qualitative research is warranted to determine acceptability and how the participants felt about the intervention.

9.2 Significance of the thesis findings

The results of the four studies described in this thesis make a novel contribution to what is already known about workplace SB among desk-based employees. Findings from this thesis have already been disseminated to the wider audience through publications, as well as to a non-academic audience (to the study participants and participating organisations). Prior to these studies, there was insufficient evidence regarding the effect of active workstations on performance and productivity (Rhodes, Mark and Temmel, 2012), with the little evidence that was available being equivocal (Hadgraft *et al.*, 2016b). This thesis presented the first systematic review of the impact of active workstations on productivity based on studies

conducted in workplace settings. It also revealed that active workstations, height-adjustable workstations in particular, do not have any detrimental effect on productivity (Ojo *et al.,* 2018). This thesis revealed that workplace sitting time might not differ with age, gender, and ethnicity, and that workplace SB interventions should be targeted at all desk-based employees irrespective of their age, gender, and ethnicity, although this should be confirmed in a fully powered study.

Furthermore, no study had simultaneously sought to understand employees' perceived determinants of workplace SB thematically and deductively. However, this thesis showed that factors determining SB in the workplace are the same, irrespective of the method of analysis, as the themes obtained from thematic analysis perfectly mapped to the theory and all COM-B components except for *Physical capability* are predictors of workplace SB and should be targeted. From a theoretical perspective, previously, intervention developers could choose from a list of 93 BCTs to alter or redirect causal processes that regulate any behaviour. However, this thesis has taken SB research forward by reducing the long BCT list to 39 BCTs specific for workplace interventions based on the interviews conducted. This means that qualitative research studies might not be needed prior to the development of all future workplace SB interventions, with the list of BCTs able to be used to justify interventions as co-created and theory-led. In addition, past studies have mostly provided information about the effect of workplace SB interventions on cognitive performance (Ohlinger *et al.*, 2011; Russell *et al.*, 2015; Torbeyns *et al.*, 2016). However, this thesis has provided evidence on the actual effect of the intervention on work productivity using the EMA technique which can limit recall bias. The BCW guided workplace multicomponent intervention developed in this thesis was able to reduce sitting time and increase standing time at work without any negative effect on

productivity. This has an implication for practice, as it could serve as evidence for workplace managers, especially those holding strong opposing views, for the introduction of such interventions. Finally, this thesis provides evidence that further strengthens the need to tailor workplace interventions to meet employees' needs to improve adherence.

9.3 Limitations of the PhD

This thesis has some limitations that could have affected the findings reported. Firstly, the sample population of this thesis was limited to desk-based employees, which therefore casts doubts about the generalisability of results to other categories of workers who may equally be sitting for long periods of time. However, this is arguably not a limitation as it was the target audience for the PhD, which describes the development of an intervention for this specific group. In addition, a team of public health employees were part of the volunteers recruited for the study. It is possible that having participants who have a vested interest in the health outcome of an intervention might not be representative of the entire desk-based population (Li and Sung, 1999). Furthermore, this thesis could have included prolonged sitting time in the workplace in the criteria for recruitment of intervention participants. This probably would have excluded those who regularly break up their sitting despite having high levels of sitting during the working day, and might, therefore, have led to a greater effect of the intervention. The studies in this thesis also excluded people with musculoskeletal problems and those who had undergone recent surgeries, which means that the findings might not be applicable to such people and this is one possible reason that *Physical capability* was not an issue in terms of reducing SB. With respect to the study on the variation of sitting time with age, gender, and ethnicity, the main limitations were the absence of objective measures of sitting time and PA. Moreover, the overall sample size and the proportion of

BAME participants in the study population were small, meaning that potential differences due to ethnicity could not be definitively determined.

In addition, despite the rigorous process that led to the identification of possible BCTs, the measure employed in selecting BCTs for intervention was highly subjective and may not have given priority to employees' core needs. For instance, the qualitative study identified 'Feedback on behaviour' as an important BCT but this BCT was excluded using APEASE criteria due to time constraint for data processing and lack of access to wearable devices which provide instant feedback (Clemes, O'Connell and Edwardson, 2014). However, Edwardson *et al.* (2018b) underlined the importance of feedback and self-monitoring in sustaining the efficacy of their intervention. Finally, despite identifying the need for a long-term intervention in the systematic review, the pilot study only lasted eight weeks, meaning a longer study is needed to determine long-term adherence and efficacy of the intervention.

9.4 Future directions for workplace sedentary behaviour research

This thesis targeted both prolonged sitting and excessive sitting. There was a high level of adherence to the intervention resulting in a significant reduction in workplace sitting, which was similar to the effect of interventions reported in other studies (Carr *et al.*, 2013; Graves *et al.*, 2015; Mantzari *et al.*, 2019; Neuhaus *et al.*, 2014b). Research is limited regarding the long-term effect of workplace interventions, although, the SMArT intervention study reported chronic effects of 64 min and 83 min reductions in workplace sitting time at 6 and 12 months, respectively (Edwardson *et al.*, 2018b), which is similar to the 66 min reduction reported for an intervention in which sit-to-stand desks were used for a minimum of six

months (Carr *et al.*, 2016b). In contrast, elsewhere, a smaller sitting time reduction of 45 min per eight-hour workday was reported 12 months post-intervention (Healy *et al.*, 2016). It would be interesting for future research to investigate the effect of long-term use of this present intervention, similar to that carried out in the ongoing SMArT Work & Life intervention (Edwardson *et al.*, 2018a). The SMArT Work & Life intervention study in the UK seeks to determine the effectiveness of a 24-month intervention in local council workers at three different UK locations (Edwardson *et al.*, 2018a). Similarly, a European study entitled the 'Dynamic Work study' is also currently examining the effectiveness of the long-term use of a workplace multicomponent SB intervention in a 12-month cluster randomised controlled trial of 250 desk-based office workers of an insurance company at different locations in the Netherlands (Jelsma *et al.*, 2019). Collectively, these studies will provide important information regarding the effectiveness of SB workplace interventions and the long-term effects of the promising intervention presented in this thesis should also be evaluated.

In addition, the workplace needs to be further underlined as an important setting in which behaviours can have both detrimental (prolonged sitting) and favourable (breaking up sitting with bouts of light PA) influences on individuals' health (Bailey *et al.,* 2016; Bailey and Locke, 2015; Dunstan *et al.,* 2012). While it may appear ambitious to expect that awareness by itself will bring about the desired change in behaviour, dissemination of current experts' workplace sitting recommendations and knowledge of health consequences from prolonged sitting should be amplified.

There are concerns about possible detrimental effects of workplace SB interventions on productivity. Managers have a responsibility to keep businesses running smoothly and efficiently, without any financial losses, meaning there is a possibility that such concerns may

hinder managers' responsiveness towards changing workplace SB (Gilson, Straker and Parry, 2012). Bearing in mind that managers play an integral role in ensuring changes in the workplace are implemented and promoted, and that employees can be influenced accordingly (Gilson *et al.,* 2012; Pronk, 2011), more work is required on the impact of workplace SB interventions on productivity. More specifically, ensuring standardised outcome measures are used to assess both short-term and long-term effects on productivity is needed (Alkhajah *et al.,* 2012; Brown *et al.,* 2013).

Moreover, SB in the workplace should not be considered as a routine of behaviour that forms a habit, rather it may be viewed as a behaviour that is forced upon desk-based employees due to the nature of their job and expectations of superiors in meeting deadlines. Therefore, addressing healthy workplaces using a top-down approach to gain necessary support from management may constitute a vital component of an intervention to be considered. It is important that this is done by ensuring management plays a more active role and have a fuller understanding of their employees' perceived barriers to breaking up sitting time as well as their role in fostering changes in the workplace.

The updated PA guidelines from the UK Chief Medical Officers (UK Department of Health, 2019), which recommends that adults reduce the amount of time spent being sedentary, and when physically possible to break up prolonged periods of inactivity with at least light-intensity PA (UK Department of Health, 2019). The findings in this thesis could be used to inform occupational health and safety guidelines for employees who are desk-based to encourage a less sedentary, healthier and productive workforce.

A final lesson learnt from the findings of this thesis is that innovative techniques which comprise the components of the tested intervention should be developed to constantly

detach desk-based office workers from their chairs and to move more. To be specific, desk-based office workers should be educated about the sitting guidelines and possible health risks of prolonged sitting as well as the benefits of breaking up prolonged sitting time in the workplace. The provision of a physical environment that allows for sitting reduction and encourages breaking up sitting in the workplace should be given high priority and included in occupational health policies. This could include the provision of computer-prompt software and height-adjustable workstations. Finally, workers should be supported by the management, particularly their line managers. The findings from this thesis demonstrate a range of optimal BCTs that could be considered and included in future workplace health intervention strategies and policies. In addition to the intervention components of this thesis, future research work should consider investigating the efficacy of interventions that make provisions for walking and standing meetings. Such an approach might help reduce accumulated sitting from meetings, which was beyond the scope of this intervention.

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LIST OF APPENDICES

Appendix 1: Author contribution to overall thesis 334

Appendix 2: Ethical Approval for Chapter 4 338

Appendix 3: Black and Downs quality appraisal checklist 339

Appendix 4: Scoring of quality appraisal checklist.....342

Appendix 5: Ethical Approval for Chapter 5 - 7 343

Appendix 6: Flyer used in recruitment of participant for SB and PA survey 344

Appendix 7: Hopkin's scale for the magnitude of effect sizes.....345

Appendix 8: Participant Consent form for SB and PA survey 346

Appendix 9: Participants' consent form for Semi-structured interviews 347

Appendix 10: Ethical approval for pilot study 348

Appendix 11: Volunteers' information sheet 349

Appendix 12: Volunteers' informed consent form 351

Appendix 13: Cluster randomisation of participants.....352

Appendix 14: EMA software interface.....353

Appendix 15: Heat maps for bouts corrections 354

Appendix 16: Content of support emails from managers showing organisation-level component of the multicomponent intervention 355

Appendix 17: Leaflet used in educating the participants 356

Appendix 1: Author contribution to overall thesis

The author of this thesis, Samson Oluseye Ojo, solely wrote all the unpublished chapters of the thesis. These include Chapters One, Two, Three, Seven, Eight and Nine. Each of these chapters received feedback and comments from the supervision team (David Hewson [DH], Daniel Bailey [DB] and Angel Chater [AC]).

Work that has been published or is under review

Chapter Four: The Impact of Active Workstations on Workplace Productivity and Performance: A Systematic Review

- Obtained ethical approval.
- Drafted the rationale for the study.
- Conducted a systematic search for the identification of articles.
- Wrote the methods section.
- Conducted quality appraisal of the selected articles and compared with DP's and disagreements resolved by DH.
- Analysis conducted with help from DH.
- Interpreted data.
- Revised manuscript following comments from AC, DB, and DH.

Chapter Five: The effect of age, gender, and ethnicity on self-reported sitting time and physical activity in desk-based workers

- Obtained ethical approval.
- Set-up online questionnaires using Qualtrics.
- Contacted Qualtrics via email and telephone calls to fix some irregularities.

- Recruited 260 participants to complete the online questionnaires in two organisations. DB helped to gain contact with a gatekeeper at a local authority in the East of England.
- Monitored questionnaires for completion.
- Data downloaded, processed and analysed, with assistance from DH.
- Drafted the manuscript.
- Revised manuscript following comments from AC, DB, and DH.

Chapter Six: Identifying interventions to reduce and break up workplace sitting time using the behaviour change wheel

- Obtained ethical approval
- Sought knowledge on intervention design: contacted Professor Susan Michie who recommended using the BCW guidebook. Attended five workshop sessions on designing behaviour change interventions delivered by AC.
- Drafted the interview schedule and reviewed based on comments from AC, DB, and DH.
- Purposively identified eligible potential study participants with high sitting time based on datasets from the preceding study.
- Performed several administrative duties, such as developing invites and emailing invitation letters; re-scheduling interview appointments.
- Conducted 32 interviews with participants from two organisations.
- Conceived the idea of splitting qualitative work into two separate studies.
- Transcribed and thematically analysed 25 interviews using NVivo.

- Deductively analysed the 25 interviews reported above using both the COM-B model and TDF.
- Interpreted data with assistance from AC.
- Identified intervention functions, policy categories and BCTs with help from AC and Marsha Brierley (MB).
- Interpreted data and reviewed following comments from AC and MB.
- Draft of manuscript written and revised following input from AC, MB, DB, and DH.

Chapter Eight: Workplace intervention for reducing sitting time in sedentary workers: a pilot study

- Obtained ethical approval for the intervention study.
- Identified intervention techniques following screening with APEASE criteria with discussion with AC, DB, and DH (presented in Chapter Seven).
- Drafted the protocol sent to Ergotron for donation of height-adjustable workstations
- Performed several administrative duties, such as developing and sending invites to study participants.
- Identified eligible participants and arranged meetings for signing of informed consent forms based on office clusters.
- Identified online tools for randomisation.
- Compiled questionnaires using Qualtrics.
- Attended training sessions with laboratory technicians for series of tests for cardiometabolic biomarkers including finger prick blood collection and analysis, and on safety and protective measures.
- Attended activPAL training session with DB.

- Managed all logistics involved during the intervention including moving and installing all height-adjustable workstations to various offices in different locations with help from three students (2 BSc and 1 MSc).
- Designed a leaflet and a step-by-step guide for educating and giving instruction to the intervention group participants.
- Responsible for all laboratory tools used during the intervention.
- Collected finger prick blood samples and other cardiometabolic biomarkers with support from three students.
- Liaison with app developer for EMA productivity identified by DH.
- Sourced Android phones and installed Work productivity application on each of the phones using assigned IDs for each of the participants.
- Ensured activPALs were charged and rightly assigned to participants with help from the three students.
- Downloaded data from activPAL and Qualtrics.
- Read EMA data from Android phones using JSON Editor Online.
- Used newly developed Processing PAL software (Version 1.1) to generate data from the activPAL using daily log from the participants with support from DB.
- Processed all data with help from DH.
- Statistical analysis conducted with help from DH.
- Interpreted data with help from DH and DB.
- Discussion written with comments from DH, DB and AC

Appendix 2: Ethical Approval for Chapter 4

University of Bedfordshire
Institute for Health Research
Putteridge Bury
Hitchin Road
Luton
Beds LU2 8LE

28 April 2016

Samson Ojo
Student number: 1231176

Dear Samson Ojo

Re: IHREC Application No: IHREC611RS
Project Title: The effectiveness of workplace intervention to improve physical activity on productivity: a systematic review

The Ethics Committee of the Institute for Health Research has considered your application and has decided that the proposed research project should be approved as a systematic review.

Please note that if it becomes necessary to make any substantive change to the research design, the sampling approach or the data collection methods a further application will be required.

Yours sincerely



Dr Yannis Pappas
Head of PhD School, Institute for Health Research
Chair of Institute for Health Research Ethics Committee

Appendix 3: Black and Downs quality appraisal checklist

Appendix

Checklist for measuring study quality

Reporting

1. *Is the hypothesis/aim/objective of the study clearly described?*

yes	1
no	0

2. *Are the main outcomes to be measured clearly described in the Introduction or Methods section?*
   If the main outcomes are first mentioned in the Results section, the question should be answered no.

yes	1
no	0

3. *Are the characteristics of the patients included in the study clearly described ?*
   In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given.

yes	1
no	0

4. *Are the interventions of interest clearly described?*
   Treatments and placebo (where relevant) that are to be compared should be clearly described.

yes	1
no	0

5. *Are the distributions of principal confounders in each group of subjects to be compared clearly described?*
   A list of principal confounders is provided.

yes	2
partially	1
no	0

6. *Are the main findings of the study clearly described?*
   Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).

yes	1
no	0

7. *Does the study provide estimates of the random variability in the data for the main outcomes?*
   In non normally distributed data the inter-quartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.

yes	1
no	0

8. *Have all important adverse events that may be a consequence of the intervention been reported?*
   This should be answered yes if the study demonstrates that there was a comprehensive attempt to measure adverse events. (A list of possible adverse events is provided).

yes	1
no	0

9. *Have the characteristics of patients lost to follow-up been described?*
   This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.

yes	1
no	0

10. *Have actual probability values been reported(e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?*

yes	1
no	0

External validity

All the following criteria attempt to address the representativeness of the findings of the study and whether they may be generalised to the population from which the study subjects were derived.

11. *Were the subjects asked to participate in the study representative of the entire population from which they were recruited?*
    The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant

population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.

yes	1
no	0
unable to determine	0

12. *Were those subjects who were prepared to participate representative of the entire population from which they were recruited?*
The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.

yes	1
no	0
unable to determine	0

13. *Were the staff, places, and facilities where the patients were treated, representative of the treatment the majority of patients receive?*
For the question to be answered yes the study should demonstrate that the intervention was representative of that in use in the source population. The question should be answered no if, for example, the intervention was undertaken in a specialist centre unrepresentative of the hospitals most of the source population would attend.

yes	1
no	0
unable to determine	0

Internal validity - bias

14. *Was an attempt made to blind study subjects to the intervention they have received ?*
For studies where the patients would have no way of knowing which intervention they received, this should be answered yes.

yes	1
no	0
unable to determine	0

15. *Was an attempt made to blind those measuring the main outcomes of the intervention?*

yes	1
no	0
unable to determine	0

16. *If any of the results of the study were based on "data dredging", was this made clear?*
Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.

yes	1
no	0
unable to determine	0

17. *In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls ?*
Where follow-up was the same for all study patients the answer should yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.

yes	1
no	0
unable to determine	0

18. *Were the statistical tests used to assess the main outcomes appropriate?*
The statistical techniques used must be appropriate to the data. For example non-parametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.

yes	1
no	0
unable to determine	0

19. *Was compliance with the intervention/s reliable?*
Where there was non compliance with the allocated treatment or where there was contamination of one group, the question should be answered no. For studies where the effect of any misclassification was likely to bias any association to the null, the question should be answered yes.

yes	1
no	0
unable to determine	0

20. *Were the main outcome measures used accurate (valid and reliable)?*

For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.

yes	1
no	0
unable to determine	0

Internal validity - confounding (selection bias)

21. *Were the patients in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited from the same population?*
For example, patients for all comparison groups should be selected from the same hospital. The question should be answered unable to determine for cohort and case-control studies where there is no information concerning the source of patients included in the study.

yes	1
no	0
unable to determine	0

22. *Were study subjects in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited over the same period of time?*
For a study which does not specify the time period over which patients were recruited, the question should be answered as unable to determine.

yes	1
no	0
unable to determine	0

23. *Were study subjects randomised to intervention groups?*
Studies which state that subjects wererandomised should be answered yes except where method of randomisation would not ensure random allocation. For example alternate allocation would score no because it is predictable.

yes	1
no	0
unable to determine	0

24. *Was the randomised intervention assignment concealed from both patients and health care staff until recruitment was complete and irrevocable?*
All non-randomised studies should be answered no. If assignment was concealed from patients but not from staff, it should be answered no.

yes	1
no	0
unable to determine	0

25. *Was there adequate adjustment for confounding in the analyses from which the main findings were drawn?*
This question should be answered no for trials if: the main conclusions of the study were based on analyses of treatment rather than intention to treat; the distribution of known confounders in the different treatment groups was not described; or the distribution of known confounders differed between the treatment groups but was not taken into account in the analyses. In non-randomised studies if the effect of the main confounders was not investigated or confounding was demonstrated but no adjustment was made in the final analyses the question should be answered as no.

yes	1
no	0
unable to determine	0

26. *Were losses of patients to follow-up taken into account?*
If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.

yes	1
no	0
unable to determine	0

Power

27. *Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%?*
Sample sizes have been calculated to detect a difference of x% and y%.

	Size of *smaller* intervention group	
A	$<n_1$	0
B	n_1–n_2	1
C	n_3–n_4	2
D	n_5–n_6	3
E	n_7–n_8	4
F	n_9+	5

Appendix 4: Scoring of quality appraisal checklist

Down &Black checklist / **Articles**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27?	Total /24
Koren, Pisot and Simunic (2016)	1	1	1	1	0	1	1	1	1	1	0	0	0	NA	NA	1	1	1	1	1	1	0	1	NA	0	1		17
Ohlinger *et al.* (2011)	1	1	0	1	0	1	1	0	1	0	0	0	0	NA	NA	1	1	1	1	1	1	0	1	NA	1	0		14
Russell *et al.* (2015)	1	1	1	1	1	1	1	0	1	1	0	0	0	NA	NA	1	1	1	1	1	1	0	1	NA	1	0		17
Chau *et al.* (2016)	1	1	1	1	0	1	1	1	0	1	0	0	0	NA	NA	1	1	1	0	0	1	1	0	NA	0	0		13
Koepp *et al.* (2013)	1	1	1	1	0	1	1	1	1	0	0	0	0	NA	NA	1	1	1	1	1	1	0	0	NA	0	1		15
Donath *et al.* (2015)	1	1	1	1	2	1	1	1	1	1	0	0	0	NA	NA	1	1	1	0	1	1	0	1	NA	1	1		19
Torbeyns *et al.* (2016)	1	1	1	1	0	1	1	0	1	1	0	0	0	NA	NA	1	1	1	1	1	1	0	0	0	0	1		15

Highlighted in green means different ratings between SO and DB and resolved by DH while red indicates Not applicable

Appendix 5: Ethical Approval for Chapter 5 - 7

University of Bedfordshire
Institute for Health Research
Putteridge Bury
Hitchin Road
Luton
Beds LU2 8LE

4 April 2016

Samson Ojo
Student number: 1231176

Dear Samson Ojo

Re: IHREC Application No: IHREC610

Project Title: Determination of potentially acceptable workplace physical activity interventions among age, gender and culturally different desk-based employees

The Ethics Committee of the Institute for Health Research has considered your application and has decided that the proposed research project should be approved with no amendments.

Please note that if it becomes necessary to make any substantive change to the research design, the sampling approach or the data collection methods a further application will be required.

Yours sincerely



Dr Yannis Pappas
Head of PhD School, Institute for Health Research
Chair of Institute for Health Research Ethics Committee

Appendix 6: Flyer used in recruitment of participant for SB and PA survey

University of Bedfordshire

ARE YOU A UoB EMPLOYEE? DO YOU SPEND MOST OF YOUR DAY WORKING AT A DESK?

RESEARCH PARTCIPANTS URGENTLY WANTED!!!



- **We want to understand whether age, gender, and culture impacts on the physical activity and sedentary behaviour levels of office workers.**
- **This is important as low activity levels and high amounts of daily sitting time increase the risk of illness and disease.**
- **We only need you at this stage to complete a ten-minute online survey which can be found at:**

http://tiny.cc/kbdhgy

- **Participants will automatically be entered into a prize draw for 3 x £15 Amazon gift vouchers upon completion of the survey.**

This study has been approved by the Institute for Health Research Ethics Committee (#IHREC610)

Professor David Hewson, Dr Daniel Bailey and Mr Samson Ojo; a doctoral student, are conducting this study. Should you have more questions, please contact us at: david.hewson@beds.ac.uk, daniel.bailey@beds.ac.uk or samson.ojo@study.beds.ac.uk

Appendix 7: Hopkin's scale for the magnitude of effect sizes

	Correlation	Diff in means	Freq. diff.	Rel. risk	Odds ratio
Trivial	0.0	0.0	0	1.0	1.0
Small	0.1	0.2	10	1.2	1.5
Moderate	0.3	0.6	30	1.9	3.5
Large	0.5	1.2	50	3.0	9.0
Very large	0.7	2.0	70	5.7	32
Nearly perfect	0.9	4.0	90	19	360
Perfect	1	Infinite	100	Infinite	Infinite

(Source: Hopkins et al., 2009)

Appendix 8: Participant Consent form for SB and PA survey

ETHICAL APPROVAL NUMBER:



Institute for Health Research – University of Bedfordshire

Participant Consent Form

Determination of potentially acceptable workplace physical activity interventions among age, gender and culturally different desk-based employees

Principal Investigators: Samson Ojo, University of Bedfordshire
David Hewson, University of Bedfordshire
Daniel Bailey, University of Bedfordshire
Angel charter, University College London
Gail Kinman, University of Bedfordshire

Project date: Commencing April 2016

Email: Samson.ojo@study.beds.ac.uk

Telephone: Samson Ojo: 07735243981

Please circle as appropriate:

Have you received, read and understood a copy of the Information Letter?	Yes	No
Do you understand that your participation in this study is entirely voluntary?	Yes	No
Do you understand that you are free to refuse participation and have the right to withdraw at any time for any reason without it influencing your summative module grade, and that all data collected from you at that time will be removed?	Yes	No
Do you understand that the Universities name WILL NOT be shared and disclosed in the reporting of results?	Yes	No
Do you understand that your name will not be displayed in any reports, presentations or publications and you will be assigned a pseudonym for this purpose?	Yes	No
The study might require you to be audio recorded, are you happy with this?	Yes	No
Do you confirm that you have had an opportunity to ask questions and that your questions have been answered to you satisfaction?	Yes	No
Are you happy to be contacted to give further clarification to any of your data?	Yes	No
Are you happy to be contacted about taking part in future related research projects?	Yes	No

Name:_____

Signature _____ Date_____

I wish to receive the results of the study by email or post address at the following contact:

_____

Thank you for your participation!
Please complete and return this form to the research staff.

Appendix 9: Participants' consent form for Semi-structured interviews

University of Bedfordshire

Consent Form

Please read the following statements and **sign your initials in the box** to show that you have read and understood them and that you agree with them.

	Please initial Yes	No
I have read and understand the information about the study.	☐	☐
I understand that what I say will be used for this study but I will not be identified by name.	☐	☐
I am happy for the researcher to record anything that we say today (when recording has been typed up it will be destroyed).	☐	☐
I understand that I can stop the interview when I want to.	☐	☐
I am happy to take part in this project.	☐	☐
I am happy for anonymised information from the interview to be used in professional publications, further research and in the development of intervention	☐	☐

Please provide your information in the table below:

Gender	D.O.B	Ethnicity	Height	Weight

Participant statement:

I agree to take part in the study.

_____	_____	_____
Your name	Date	Your signature

Researcher's statement

I confirm that I have explained the nature, purposes and possible effects of the research study to the person whose name is printed above. They agreed to take part by signing and dating above.

_____	_____	_____
Name of Person taking consent	Date	Signature

Appendix 10: Ethical approval for pilot study

University of Bedfordshire
Institute for Health Research
Putteridge Bury
Hitchin Road
Luton
Beds LU2 8LE

23 March 2018

Samson Oluseye Ojo
Student number: 1231176

Dear Samson Oluseye Ojo

Re: IHREC Application No: IHREC836

Project Title: What is the effect of a tailored intervention to break up sitting in the workplace on cardiometabolic risk and worker productivity?

The Ethics Committee of the Institute for Health Research has considered your application and has decided that the proposed research project should be approved with no amendments.

Please note that if it becomes necessary to make any substantive change to the research design, the sampling approach or the data collection methods a further application will be required.

Yours sincerely

Dr Yannis Pappas
Head of PhD School, Institute for Health Research
Chair of Institute for Health Research Ethics Committee

Appendix 11: Volunteers' information sheet

University of Bedfordshire

Project Title: What is the effect of a tailored intervention to break up sitting in the workplace on cardiometabolic risk and worker productivity?

Investigators: Samson Ojo, Professor David Hewson, Dr Daniel Bailey, Dr Angel Chater

Volunteer's Information Sheet

You are being invited to take part in a research study. Before you decide to volunteer it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and feel free to discuss it with others if you wish.

What is the aim of the project?

The aim of this study is to examine the effect of a tailored workplace intervention to break up sitting on office workers' sitting time, work productivity, well-being, and cardiometabolic risk.

Why have you been chosen?

Participants needed for the study are office workers recruited from Bedford Borough Council and University of Bedfordshire aged 18 - 60 years. Participants excluded from this study include anyone with a major medical condition e.g. cardiovascular or respiratory, high or low blood pressure, arthritis, lower extremity musculoskeletal injury within the last 12 months.

What does the study involve?

You will be asked to provide informed consent and complete a health questionnaire. You will then be randomly allocated into either the control or intervention group, with the intervention group receiving height-adjustable desks and prompt software for both your computer and smartphone. You will be asked alternate between standing, sitting and walking throughout the working day. The control group will continue their day-to-day tasks as normal.

What do you have to do?

When you are at work you will be asked to wear an ActivPAL accelerometer to monitor your physical activity and sitting time. You will also receive random prompts on your smartphone up to four times a day to complete a brief productivity questionnaire (lasting

only 1 minute). The prompts will stop each week once 12 of questionnaires have been completed.

You will also be tested before the study starts and after the eight-week study period. Tests will include online questionnaires that take about 20 minutes to complete. These questionnaires will ask you about your physical activity and sitting time, your estimation of your presenteeism and absenteeism, work limitations, as well as psychological and mental wellbeing, and stress.

Your height, weight, and waist circumference will be also measured, along with blood pressure, while a finger finger-prick blood sample will be collected and analysed for fasting blood glucose, HDL, total cholesterol and triglycerides.

What are the possible disadvantages and risks of taking part?

A blood sample will be collected from you using the finger prick method twice. This might hurt for just a few minutes. You will receive prompts that will tell you what to do such as to walk for a few minutes, or to move your desk to the standing position and stand for 30 minutes. You can withdraw at any time from the experiment at any time if you wish.

What will happen to the data?

All information and results that are collected will be anonymised using a unique identifier and will be securely stored on a password protected computer. Only the researchers will have access to this data. Results of this study may be published, but your anonymity will be kept. All information and results will be deleted and destroyed upon completion of the study. If you wish to know your personal results, please provide your email address and these will be sent to you. A report detailing the results of the study will also be sent to all participants.

Who has reviewed the study?

The Institute for Health Research Ethics Committee (IHREC) has approved this study.

Contacts for Further Information

Samson Ojo
samson.ojo@study.beds.ac.uk
Dr Daniel Bailey
Daniel.bailey@beds.ac.uk

Professor David Hewson
david.hewson@.beds.ac.uk
Dr Angel Chater
angel.chater@beds.ac.uk

Appendix 12: Volunteers' informed consent form

University of Bedfordshire

I

Project Title: What is the effect of a tailored intervention to break up sitting in the workplace on cardiometabolic risk and worker productivity?

Investigators: Samson Ojo, Professor David Hewson, Dr Daniel Bailey, Dr Angel Chater

Volunteer's Informed Consent Form

Please read this form and sign next to each statement once you are satisfied that you are aware of what is required of you and have had the aims and procedures of this study fully explained to you.

- My participation in this study is voluntary and I understand that I am free to withdraw from the study at any time, without having to give a reason. ☐
- I understand that I will be required to break up my sitting at work and alternate with standing, and walking throughout the duration of this study. ☐
- I confirm that I have been given a full explanation of what is required of me and I have read and understand the information sheet which is attached. ☐
- I understand that all information and data will be held securely and if these results were to be published my anonymity will be kept. ☐
- I confirm that I have disclosed all relevant medical information. ☐
- I am fully aware of the risks involved with participating in this study. ☐

Name: ……

Signature: …… Date: ……

Email address (if you would like to receive your personal results):

……

Appendix 13: Cluster randomisation of participants

Clustering of participants

Cluster 1 BBC PH	Cluster 2 J107	Cluster 3 C101 b (a)	Cluster 4 H011	Cluster 5 B106	Cluster 6 BBC PH	Cluster 7 G113	Cluster 8 H204/F302	Cluster 9 Salaries	Cluster 10 AtL1	Cluster 11 BBC PH	Cluster 12 J103	Cluster 13 PM05 RGS	Cluster 14 H003
Beds 032	Beds 013	Beds 001	Beds 005	Beds 011	Beds 035	Beds 027	Beds 018	Beds 020	Beds 023	Beds 039	Beds 014	Beds 048	Beds 017
Beds 033	Beds 012	Beds 002	Beds 006	Beds 010	Beds 034	Beds 028	Beds 019	Beds 022	Beds 024	Beds 040	Beds 015	Beds 044	Beds 016
Beds 034		Beds 003	Beds 009		Beds 038	Beds 029		Beds 021	Beds 025	Beds 042		Beds 045	
		Beds 004	Beds 007			Beds 030			Beds 026	Beds 043			
			Beds 008			Beds 031							

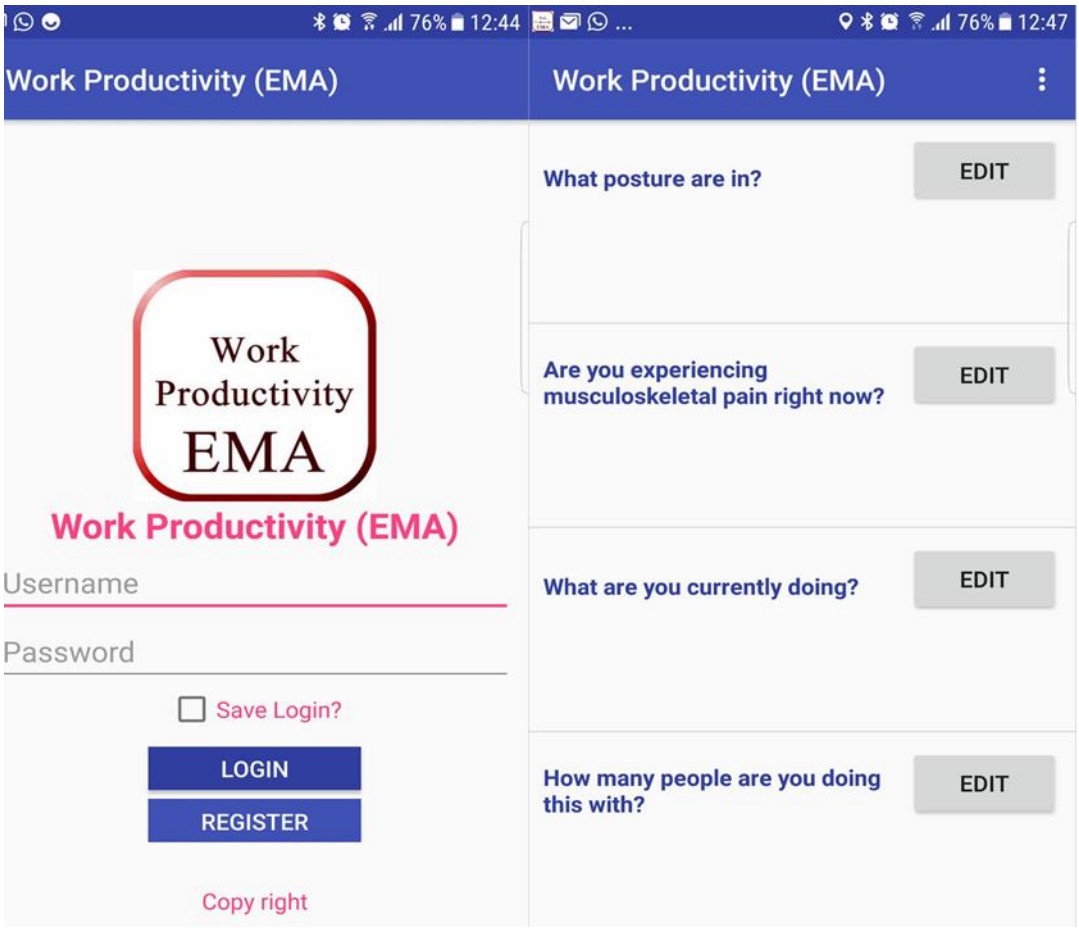
Random Team Generator



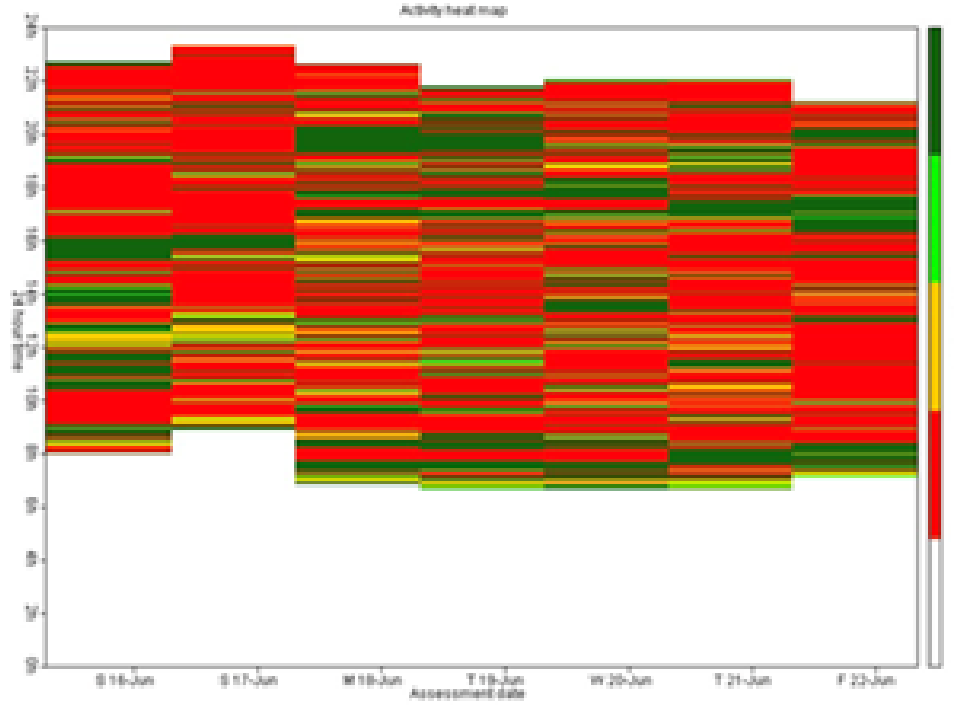
Randomisation can be found at:

https://www.randomlists.com/team-generator?items=Cluster1%0ACluster2%0ACluster3%0ACluster4%0Acluster5%0Acluster6%0Acluster7%0Acluster8%0Acluster9%0Acluster10%0Acluster11%0Acluster12%0Acluster13%0ACluster14&grp=2

Appendix 14: EMA software interface

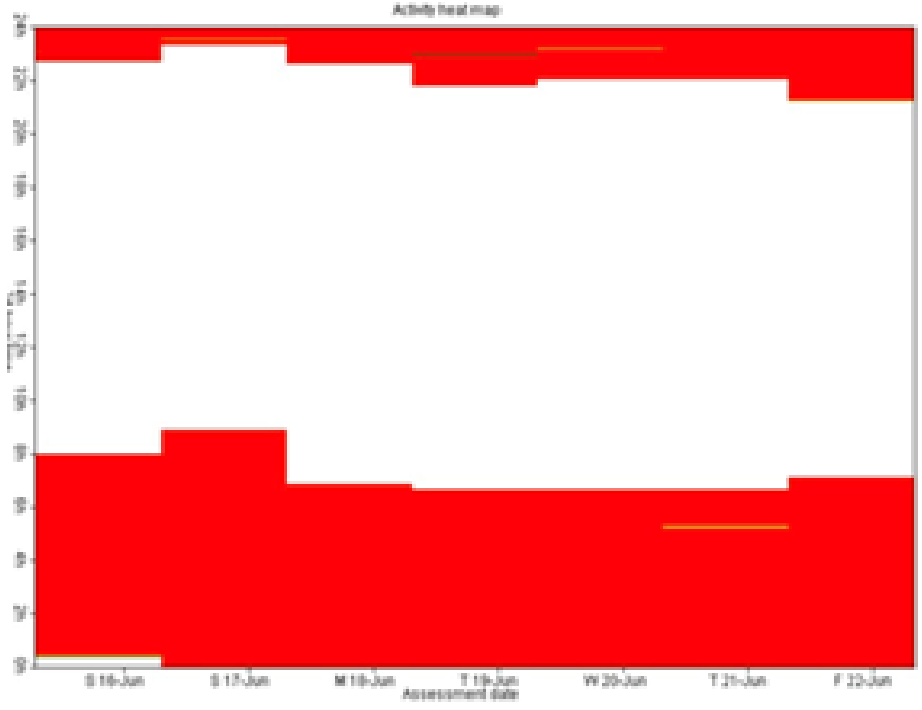


Appendix 15: Heat maps for bouts corrections



17 *Activity Colour Legends: WHITE: No Activity Information,RED: Sleeping, AMBER/ORANGE: Standing, LIGHT G*

Example of included data



*REEN: Light Stepping, DARK GREEN: MVPAs * besides the day/date implies that it is marked as INVALID, check summary tab for*

Example of excluded data

Appendix 16: Content of support emails from managers showing organisation-level component of the multicomponent intervention

Biweekly Support emails from managers to the participants

Dear ……,

This is **Week 2** of the intervention to make breaking up sitting in the workplace easier. I hope you are finding your new workstation helpful to stand more and are enjoying a healthier way to work. Remember the goal for this week is to increase your standing by 1 hour per day. Here is a tip for you:

Drink more water! It has the dual benefit of keeping you hydrated and encourages you to move to and from the tea room and bathroom.

Keep standing, keep moving

Management (signature)

Week 4

During my walk through the office this morning I have noticed that you have been standing. Great effort (team)! Just to let you know that, it is absolutely acceptable to take telephone calls whilst standing. You do not need to worry about being judged or penalised ☺

Keep standing, keep moving

Management (signature)

Week 6

It feels so amazing seeing your commitment towards achieving your sitting less, standing more goal. By now, it is expected that you would have increased the time spent standing up to 3 hours per day. As you continue to work towards this goal, remember to have lunch away from your desk, so you do not make others hungry ;-)

Keep standing, keep moving

Management (signature)

Appendix 17: Leaflet used in educating the participants

UNDERSTANDING SEDENTARY BEHAVIOUR

University of Bedfordshire

What is sedentary behaviour?

Sedentary behaviour (SB) is any waking behaviour that has a very low energy expenditure while in a sitting or lying posture.

In recent years, studies have emerged demonstrating that sitting is associated with an increased risk of type 2 diabetes and heart disease, regardless of how much exercise people do. So even if an individual goes for a 30 minute run every day this may not prevent the damaging effects of sitting down for long periods throughout the day.

In 2011, the UK Chief Medical Officers recommended that adults should minimise the amount of time spent sitting for long periods.

Where does excessive sitting take place?

Excessive sitting occurs in three major places. These include the workplace, when travelling (car, train), and during leisure periods (such as watching TV).

The office workplace is responsible for the highest levels of sitting. Office workers can spend over 80% of their working time sitting, which could be nearly 7 hours every day!

Health consequences of prolonged sitting

Regardless of how much someone exercises, too much sitting can result in the following conditions:

- Obesity
- Backache
- Type 2 Diabetes
- Cancer
- Heart Disease
- Osteoporosis
- Anxiety
- Depression
- Low self-esteem



Recent guidelines

Expert statement guidelines published in the British Journal of Sports Medicine in 2015 recommend that office workers need to decrease their sedentary behaviour, and should initially engage in at least 2 hours of standing or slow walking each day during their working hours, with this gradually increasing to 4 hours per work day.

The guidelines also recommend regularly breaking up seated-based work with standing or slow walking, which could be achieved using height-adjustable desks along with other tools such as computer prompts.

What can I do to reduce too much sitting in my workplace?

- Consider setting up an alarm on your phone or computer prompts to serve as a reminder to stand up at regular intervals.
- Adopt standing or walking meetings.
- Walk around to colleagues in close proximity, instead of communication via email.
- Consider taking telephone calls whilst standing
- Consider having lunch away from your desk.
- Collect printing from a machine further away from your desk.
- Alternate between sitting and standing using a height-adjustable desk.



Should you have any queries, please feel free to contact: Samson Ojo (Samson.ojo@study.beds.ac.uk) Professor David Hewson (david.hewson@beds.ac.uk)