Reducing Sedentary Behaviour in the Workplace: Using Digital Health Technology

Aoife Stephenson

BSc. (Hons) Physiotherapy, 2010

MSc Research, 2012

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Faculty of Life and Health Sciences of Ulster University

I confirm that the word count of this thesis is less than 100, 000 words

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Abbreviations and Acronyms

7-day SLIPA Log	7-day Sedentary and Light Intensity Physical Activity Log
APEASE	Acceptability, Practicability, Effectiveness and cost-effectiveness, Affordability, Safety/side-effects, Equity
AS	Ms. Aoife Stephenson
BCT	Behaviour Change Techniques
BCTTv1	Behaviour Change Techniques Taxonomy version 1
BCW	Behaviour Change Wheel
BHF	British Heart Foundation
BMI	Body Mass Index
BRUMS	Brunel Mood Scale
C	Control
CA	California
CI	Confidence Interval
CN	Prof Chris Nugent
COM-B	Capability, Opportunity, Motivation, Behaviour
EMA	Ecological momentary assessment
F	Female
Hr	Hour
I	Intervention
IB	Ian Bradbury
IBM	International Business Machines
IPAQ	International Physical Activity Questionnaire
IT	Information Technology
IW	Dr Iseult Wilson
JM	Dr Jacqueline Mair
LR	Ms. Leslie Rice
M	Male
MA	Mobile app group
MA+SSWD	Mobile app and stand desk work desk group
MD	Mean difference
MET	Metabolic Equivalent
MGC	Dr Matias Garcia Constantino
Mins	Minutes
MM	Prof Marie Murphy
MN	Minnesota

MOST	Multiphase Optimisation Strategy
N	Number
NCD	Non Communicable Diseases
NHS	National Health Service
NI	Northern Ireland
NICE	National Institute for Clinical Excellence
OSPAQ	Occupational Sitting and Physical Activity Questionnaire
PA	Physical activity
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses
RCT	Randomised Controlled Trial
RW	Mr. Robert Walker
SB	Sedentary Behaviour
SBRN	Sedentary Behaviour Research Network
SC	Ms. Samantha Cooke
SD	Standard Deviation
SH	Sarah Howes
SMART	Sequential Multiple Assignment Trials
SMcD	Prof Suzanne Mc Donough
SPSS	Statistical Package for the Social Sciences
SSWD	Sit Stand Work Desk
TDF	Theoretical Domains Framework
UCD	User Centred Design
UK	United Kingdom
US	United States
WSQ	Workforce Sitting Questionnaire

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Dissemination of Findings

Peer reviewed publications: (Appendix A)

Stephenson A, McDonough S, Murphy M, Nugent C, Mair J. Using computer, mobile and wearable technology enhanced interventions to reduce sedentary behaviour: a systematic review and meta-analysis. *IJBNPA*. 2017;14(1).

Oral Presentations

Stephenson A, McDonough S, Murphy M, Nugent C, Mair J. The effects of reducing occupational sedentary behaviour on employee mood and productivity. In proceedings: *International Society for Behavioural Nutrition and Physical Activity Conference*, Hong Kong, June 2018.

Stephenson A, McDonough S, Murphy M, Garcia-Constantino M, Nugent C, Mair J. The development and formative evaluation of the '"Worktivity"' app: a behaviour change theory-based mobile app to reduce occupational sedentary behaviour. In proceedings: *Health Enhancing Physical Activity Europe Conference,* Zagreb, Croatia, November 2017.

Poster Presentations

Stephenson A, McDonough S, Murphy M, Wilson I, Nugent C, Mair J. Facilitators, barriers and technology supported strategies to reduce workplace sitting: a focus group study. In proceedings: *Get-A-Move-On Symposium*, London, UK, May 2017.

Stephenson A, McDonough S, Murphy M, Nugent C, Mair J. Using computer, mobile and wearable technology interventions to change sedentary behaviours: a systematic review and meta-analysis. In proceedings: *Digital Behaviour Change Conference,* London, UK, February 2017.

Stephenson A, McDonough S, Murphy M, Nugent C, Mair J. A systematic review of computer based, wearable and mobile interventions to change sedentary behaviour in healthy adults. In proceedings: *Health Enhancing Physical Activity Europe Conference,* Belfast, UK, September 2016

Statement of contribution

Chapter 1: I provided a background to establish the scope, context, and significance of the research being conducted.

Chapter 2: I conducted the database searches, screened the titles and abstracts, assessed the articles for inclusion/exclusion, extracted the data, coded the Behaviour Change Techniques, assessed studies for risk of bias, synthesised the results and wrote up the chapter.

Chapter 3: I was responsible for the development of the semi structured interview script, recruiting and screening of participants, conduct of the focus groups and interviews, qualitative data analysis, drafting results and study write up.

Chapter 4: I coordinated the research team meetings and workshops. I provided intellectual contribution to app and chapter. I conducted in house testing of the app, conducted the think aloud interviews and their analysis and completed write up of the chapter.

Chapter 5: I assisted with the developing the study protocol, design and selection of outcome measures. I was responsible for participant recruitment and screening. I conducted and scheduled the outcome measures assessments. I completed the data entry, analysis of results an write up of the chapter.

Chapter 6: I summarised each of the chapters and described how the results of this thesis fits in the current scientific literature and what it means for future research.

Thesis Abstract

Introduction

Office work generally consists of high amounts of sedentary behaviour (SB) which has been associated with negative health consequences (Van Uffelen et al., 2010; Hadgraft et al., 2016 a). To reduce this risk there is a need for workplace SB reduction interventions (De Cocker et al., 2015). Considering the opportunities afforded by digital technologies, the aim of this thesis was to develop, evaluate and assess the feasibility of a theory-informed, digital intervention to reduce occupational SB.

Methods

Phase one involved a systematic review and meta-analysis exploring the effectiveness of technology-enhanced interventions to reduce SB. This led to phase two which explored office workers' perceptions on barriers and facilitators via focus groups and interviews (n=48) to reducing occupational SB and beliefs regarding technology-supported approaches. These phases informed the development of a mobile application (app) intervention - "Worktivity" (phase three), which incorporated behaviour change techniques to help reduce occupational SB. Phase four explored the feasibility of using "Worktivity" to promote occupational SB reductions. The randomized controlled feasibility study and process evaluation (n=56) consisted of the "Worktivity" intervention to promote occupational SB reductions in office workers tested over an 8-week period, with or without a sit stand work desk (SSWD), relative to a comparison condition.

Results

Findings from phase one indicated that it may be possible to reduce occupational SB using technology-enhanced interventions by approximately 40 minutes per day. Phase two revealed the main barrier to reducing sitting at work was the requirement to complete job tasks. Technology was seen to be valuable in providing prompts and to allow behavioural self-monitoring. Phase three led to the development of "Worktivity", a theory based and user informed mobile app intervention to reduce occupational SB. The findings of phase four suggest it is feasible to implement "Worktivity" with the addition of a SSWD for desk-based office workers, with potential to evoke change in SB.

Conclusion

The resulting app "Worktivity" is the first of its kind developed with the primary aim of reducing occupational SB using digital self-monitoring. This thesis presents a formative, iterative, participatory approach to developing and evaluating a digital intervention to reduce workplace SB, which may be used as a template for other intervention developers.

Key Words

Sedentary behaviour, digital technology, behaviour change, systematic review, focus group, feasibility, mobile app

Chapter 1 - Introduction

1.1 Overview

Societal changes have resulted in sitting being the dominant posture during most activities of daily life, such as travelling, working, learning, and leisure time (De Craemer et al., 2018). Major structural, societal, economic and technological changes, particularly since the middle of the 20th century, have been associated with significantly reduced demands for physical activity (PA) (Owen et al., 2010). According to Public Health England, the English population is 60% less active than in the 1960s and if current trends continue, it will be a further 35% less active by 2030 (Public Health England, 2016).

Today our environment fosters sedentariness, however, a sedentary lifestyle is not innate to the human condition (Levine, 2015). People were designed to move and our biochemistry and physiology have evolved to function optimally under such circumstances (Levine, 2015; Zhu and Owen, 2017). It is the mismatch between our modern lifestyles and our ancestral hunter-gatherer genome which is playing a substantial role in the on-going epidemic of non-communicable disease (NCD) (O'Keefe and Cordain, 2004). Advances in modern society have brought about an increase in life expectancy (Lichtenberg, 2015), although people are living longer, they are living with a sequelae of diseases, many of which are attributable to NCDs in which inactivity and sedentary lifestyles are implicated (Vos et al., 2015).

Sedentary behaviour (SB) has been defined as any waking behaviour characterised by an energy expenditure ≤1.5 metabolic equivalents (METs), while in a sitting, reclining or lying posture (Sedentary Behaviour Research Network, 2012; Tremblay et al., 2017). Common SBs include computer use, TV viewing, driving automobiles, and reading (Sedentary Behaviour Research Network, 2012). Evidence suggests SB is a highly prevalent behaviour in today's society with the majority of people's time (55–69% of the day) spent sedentary (Healy et al., 2007; Matthews et al., 2008; Colley et al., 2011; Hansen et al., 2012). In 2017, the British Heart Foundation (BHF) produced a report containing a comprehensive overview of levels of physical inactivity and SB in adults across the United Kingdom (UK). The report estimates that the average UK adult spends 76 days per year sitting (British Heart Foundation, 2017). Given its high prevalence and its potential health effects, the amount of time spent sitting should be a concern for the majority of the population (Munir et al., 2018).

The impact of physical inactivity and sedentary lifestyles weigh heavily on the UK healthcare system and is estimated to cost as much as £1.2 billion per year (Townsend et al., 2015). A recent study exploring the all-cause mortality attributable to sitting time across 54 countries suggests that high sitting time is responsible for 4% of all deaths (433,000 deaths/year) (De Rezende et al., 2016). With the high prevalence of SB and its apparent associations with several negative health concerns, research on SB has rapidly gained prominence within the scientific community (Straker et al., 2016). Furthermore, SB has also received considerable public and media attention (Van der Ploeg and Hillsdon, 2017).

It has been suggested that the deleterious outcomes associated with sedentary time generally decrease in magnitude among persons who participate in higher levels of PA compared with lower levels (Biswas et al., 2015). A recent meta-analysis of over one million people shows high levels of moderate intensity PA (i.e., about 60-75 min per day) seem to eliminate the increased risk of death associated with high sitting time (Ekelund et al., 2016). However the levels of PA required to eliminate the risk are high (420-525 minutes of moderate intensity PA per week), which may be unrealistic for most people. This is over three times the recommended amount of PA as based on the current UK PA guidelines (150 mins moderate intensity PA per week). In Northern Ireland (NI), 39% of men and 49% of women fail to meet these guidelines (Department of Health, 2017). This underlines the importance of attempting to reduce sedentary behaviour at a population level.

Inactivity and SB are often considered as two distinct constructs (Van der Ploeg and Hillsdon, 2017). Inactivity has been defined as “An insufficient physical activity level to meet present physical activity recommendations” (Tremblay et al., 2017). The differences between SB and inactivity are reflected by way of additional inclusion of recommendations for SB into the PA guidelines of a number of countries including the

UK and Australia (UK Government, Department of Health and Social Care, 2011; Australian Government, Department of Health, 2017). However, as SB research is in its infancy the guidelines are vague. Currently, the SB evidence base is insufficiently developed to inform quantitative public health guidance (Stamtakis et al., 2018). The current UK guidelines suggest adults should minimise the amount of time spent being sedentary (sitting) for extended periods (UK Government, Department of Health and Social Care, 2011). The Australian guidelines add a recommendation to break up long periods of sitting as often as possible (Australian Government, Department of Health, 2017).

1.2 Occupational SB

Modern society is filled with opportunities for SB, and the workplace setting is no exception. Office work is generally characterised by sustained sedentary time and contributes significantly to overall sedentary exposure of office workers (Parry and Straker, 2013). Occupational sitting has been defined as SB that is accrued as part of, or relating to, work (Straker et al., 2016). Traditionally, this has concerned activities within a workplace, including productive tasks and lunch/morning/afternoon breaks from productive tasks (Straker et al., 2016). Sedentary activities have been shown to comprise 65-82% of time at work in industrialised countries (Ryan et al., 2011, Parry and Straker, 2013, Ryde et al., 2013, Clemes et al., 2014, Hadgraft et al., 2016 a) with a large proportion (54-77%) of office workers total daily sitting time occurring during their “working day” (Clemes et al., 2014, Kazi et al., 2014, Waters et al., 2016). This high occupational exposure to SB may have broad implications for population health (Hadgraft et al., 2016 a) and is likely to be a major contributor to the poor health outcomes associated with overall SB exposure (Parry and Straker, 2013). Therefore, occupational SB has become an emergent workplace health and safety issue (Straker et al., 2016).

Recent reviews and meta-analyses have linked SB to all-cause mortality (Wilmot et al., 2012; Chau et al., 2013; De Rezende et al., 2014; Biswas et al., 2015), cardiovascular disease (Wilmot et al., 2012; De Rezende et al., 2014; Biswas et al., 2015), type 2 diabetes (Wilmot et al., 2012; De Rezende et al., 2014), metabolic syndrome (De Rezende et al., 2014), ovarian cancer (De Rezende et al., 2014; Biswas et al., 2015), colon cancer (De Rezende et al., 2014; Biswas et al., 2015), endometrial cancer (De Rezende et al., 2014; Biswas et al., 2015) and breast cancer (Biswas et al., 2015). Increased breaks in sedentary time have been beneficially associated with waist circumference, serum triglycerides and plasma glucose (Healy et al., 2008). Although the precise physiological mechanisms by which SB is detrimental to health are not fully known, a sedentary lifestyle is associated with biomarkers of cardiovascular disease, increased telomere length, defects in lipoprotein metabolism, early atherosclerosis, insulin resistance, and the development of metabolic syndrome (Hamilton, Hamilton and Zderic, 2007; Frydenlund et al., 2011; Sjögren et al., 2014; Same et al., 2015).

The evidence base linking occupational sitting, in particular, with health outcomes is scarce (Straker et al., 2016). Results of a systematic review show limited evidence to support a positive relationship between occupational sitting and health risks (Van Uffelen et al., 2010). There was an association between occupational sitting and body mass index (BMI), cancer, diabetes and mortality however, the heterogeneity of study designs, measures, and findings make it difficult to draw definitive conclusions. Other meta-analyses showed time spent in occupational sedentary pursuits to be associated with increased risks of colon cancer (Schmid and Leitzmann, 2014) and breast cancer in women (Zhou, Zhao and Peng, 2015).

In recent years, there has been a marked interest in identifying ways to reduce sedentary time and promote breaks in sitting (Mantzari et al., 2016). Emerging evidence suggests that it is possible to intervene to reduce adult SB in both occupational and non-occupational settings through activity permissive work stations, sit-stand desks, television control devices, health coaching, activity monitors, and prompts to break up sitting (Prince et al., 2014; Martin et al., 2015; Shrestha et al., 2016; Shrestha et al., 2018).

In term of reducing occupational SB, a Cochrane systematic review and meta-analysis (Shrestha et al., 2016; Shrestha et al., 2018) evaluated the effectiveness of physical workplace interventions (sit-stand desks), workplace policy changes, information/counselling and multi-component interventions to reduce sitting at work compared to either alternative interventions or control. Results suggest that there is currently only low-quality evidence that the use of physical workplace interventions (sit-stand desks) can reduce workplace sitting at short-term (-100 min/workday) and medium-term follow-ups (-57 min/workday). Effects of other types of interventions, including workplace policy changes, provision of information/counselling, and multi-component interventions (combined educational/behavioural and environmental interventions), are largely inconsistent.

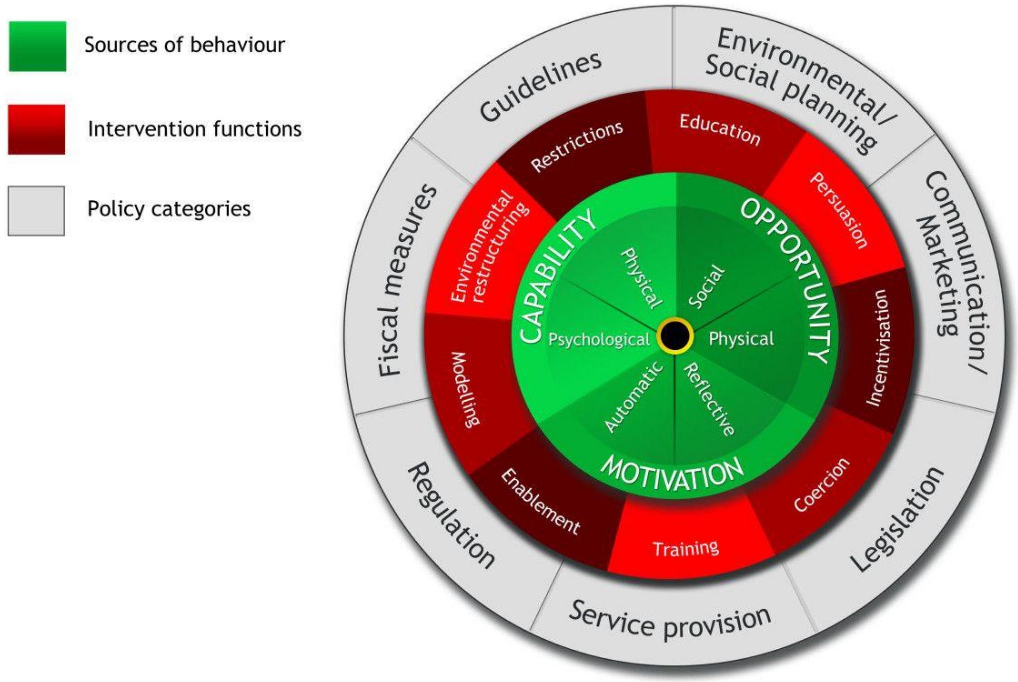
Another systematic review by Chu and colleagues (2016) exploring the effectiveness of interventions to reduce workplace SB found multi-component interventions to have the greatest workplace sitting reduction (-88.8 min/workday), followed by environmental (-72.8 min/workday); and educational/behavioural strategies (-15.5 min/workday). Whilst environmental changes to the workplace, such as sit-stand work desks (SSWD), appear effective at reducing workplace sitting time, cost is a likely barrier for many workplaces (Chau et al., 2014). There were 34 studies included in the review by Shrestha et al. (2018) and 26 included by Chu et al. (2016), with 15 of these studies included in both reviews. The difference in findings between Chu et al. (2016) and Shrestha et al. (2018) is most likely explained by the heterogeneity of inclusion criteria, databases searched and timeframes explored. The review by Shrestha and colleagues (2018) was a Cochrane systematic review which searched a wider range of databases, had slightly different inclusion criteria and also was published two years later than the review by Chu and colleagues (2016).

Technology has recently been implemented in healthcare interventions and has potential to be a low cost, high reach, effective and acceptable way to bring about behaviour change (West and Michie, 2016). While technological advancements have contributed to a rise in SB (Inyang and Stella, 2015), it also provides opportunities for innovative delivery of health-related information (Partridge et al., 2015). There is encouraging evidence to support digital technologies as intervention tools to improve health behaviours (McIntosh et al., 2017; Oosterveen et al., 2017). Using technology to manage health is growing in popularity. A consumer survey on digital health in England showed that in 2018, 44% of respondents used websites, 48% used mobile phones and 31% used wearables to manage their health and lifestyle, all of which have risen since 2016 (Accenture, 2018 a). There has also been increasing interest from researchers and clinicians in harnessing digital technology as a means of delivering behavioural interventions for health (Dennison et al., 2013). The ability to use digital platforms to change behaviour has many advantages for researchers and users alike; notably, personalisation of material, increased scalability, and reduced expenses (Hartin et al., 2016).

1.3 The Behaviour Change Wheel

Recent recommendations on prevention and management of NCDs highlight the need for research focused on behaviour change as the core component (Matheson et al., 2013). The importance of behaviour change theories in digital technologies has also been stressed (West and Michie, 2016). Research suggests that digital interventions with more extensive use of theory are associated with larger effect sizes than those without (Webb et al., 2010). The Behaviour Change Wheel (BCW) (Michie, van Stralen and West, 2011) provides a structured, theoretical framework for designing behaviour change interventions and strategies (Atkins and Michie, 2015) and is presented in Figure 1-1. The framework was developed from a synthesis of 19 frameworks of behaviour change (Michie, van Stralen and West, 2011).

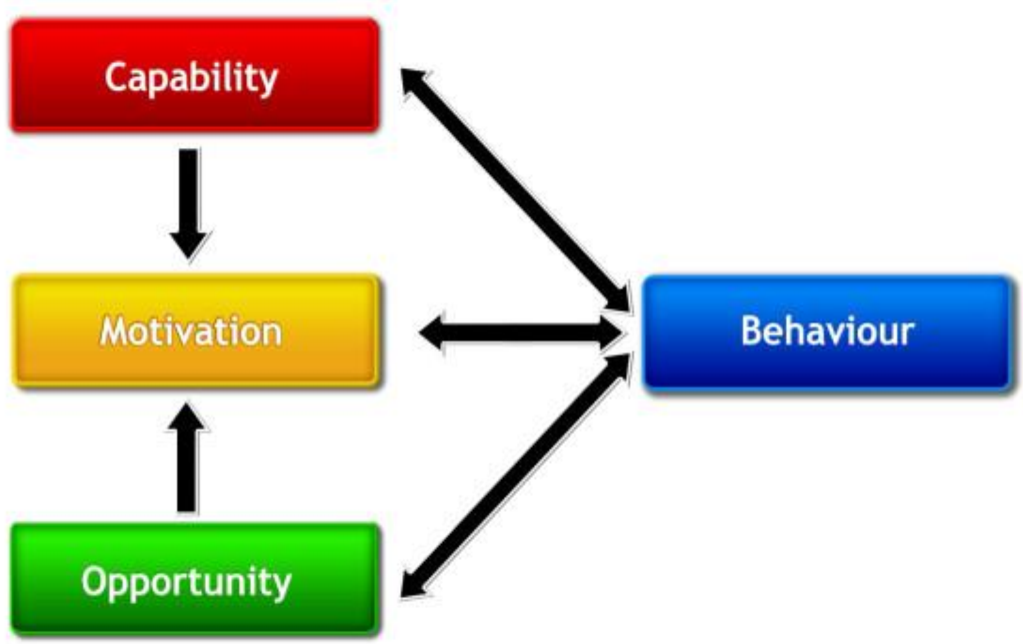
Figure 1-1 The Behaviour Change Wheel



Source: Michie, van Stralen and West, 2011

The hub of the wheel identifies the sources of the behaviour that could prove fruitful targets for intervention. It uses the COM-B ('Capability', 'Opportunity', 'Motivation' and 'Behaviour') model (Michie, Atkins and West, 2014), displayed in Figure 1-2 (Michie, Atkins and West, 2014).

Figure 1-2 The COM-B system



Source: Michie, van Stralen and West, 2011

Capability is defined as the individual's psychological and physical capacity to engage in the activity concerned and includes having the necessary knowledge and skills. Motivation is defined as all those brain processes that energise and direct behaviour, not just goals and conscious decision making. It includes habitual processes, emotional responding, as well as analytical decision making. Opportunity is defined as all the factors that lie outside the individual that make the behaviour possible or prompt it (Michie, van Stralen and West, 2011). This model recognises that behaviour is part of an interacting system involving all these components. Interventions need to change one or more of them in such a way as to put the system into a new configuration and minimise the risk of it reverting (Michie, Atkins and West, 2014). Surrounding the hub is a layer of nine intervention functions based on the particular COM-B analysis one has undertaken (Michie, Atkins and West, 2014). The outer layer, the rim of the wheel, identifies seven policy level categories that can support the delivery of these intervention functions (Michie, Atkins and West, 2014).

The Behaviour Change Technique Taxonomy (BCTT v1) is an extensive hierarchically organised taxonomy of 93 distinct behaviour change techniques (BCT) (Michie et al., 2013) (Appendix B) which is linked to the BCW, but gives more specific description of the intervention options in the BCW and provides a way of characterising the content of behaviour change interventions at a finer grain level than in the BCW (Michie, Atkins and West, 2014; West and Michie, 2016). The BCTT v1 was developed in a series of consensus exercises involving 55 experts in delivering and/or designing behaviour change interventions (Michie et al., 2013). A BCT is defined as an observable and replicable component designed to change behaviour (Michie et al., 2015). It is the smallest component compatible with retaining the postulated active ingredients and can be used alone or in combination with other BCTs (Michie et al., 2015). Using the BCW and BCTT v1 approach to intervention design encourages intervention designers to consider a full range of options and choose those more promising through a systematic evaluation of theory and evidence (Michie, Atkins and West, 2014).

It is clear that SB is a highly prevalent behaviour in office work and this exposure has been linked to several negative health consequences. Research relating to how interventions can be harnessed to reduce SB is in its infancy. There has been an increased interest in using digital technology to reduce SB. A small number of studies exploring the use of technologies such as activity trackers (Brakenridge et al., 2016; Guitar et al., 2017), computer prompts (Evans et al., 2012) and smartphones (Bond et al., 2014, King et al., 2016 and Arroggi et al., 2017) to reduce SB have demonstrated some promising results. However, there is a lack of evidence examining their role in reducing SB. A recent Cochrane review and meta-analysis of interventions to reduce occupational SB has further highlighted the lack of studies using digital technology (Shrestha et al., 2018).

Designing efficacious, feasible, and theory-based workplace SB reduction interventions is of public health interest (Mullane et al., 2017). To progress the knowledge in this area, there is a need to develop and evaluate digital technology tools to reduce occupational SB. Little is known about how best to meet the needs of desk-based office workers and their employers in order to reduce SB. Information is also lacking regarding factors that may influence acceptability and engagement of digital interventions in the workplace. The most appropriate BCTs to be used in these interventions also remains unclear. Adopting a formative approach, grounded in behaviour change theory to design and evaluate the digital intervention can help ensure that the final product meets user needs with promise to incur positive behaviour change (Buller et al., 2013).

1.4 Thesis Aims

The overall aim of this PhD was to develop and assess the feasibility of a theory-informed digital intervention to reduce occupational SB.

1.5 Thesis Objectives

1. To iteratively develop a digital technology-based intervention to reduce occupational sitting, designed using the BCW, and specifically to meet the needs and preferences of occupational desk-based office workers.

2. To assess the feasibility of using a mobile app-based intervention with or without the use of a SSWD to reduce occupational SB. The mobile app used was the result of the development phases of this thesis.

These aims and objectives have informed the chapters within this thesis. Specific aims of each stage of the research are presented within their respective chapters.

1. Thesis Organisation

This thesis consists of six chapters describing the stages of development of a digital intervention to reduce occupational SB and the feasibility testing of the resulting mobile app, ““Worktivity””. The combined output from Chapters 2 and 3 informed the development of a mobile app to reduce occupational SB (Chapter 4), which underwent feasibility testing (Chapter 5).

- The current chapter (Chapter 1), details the background to and rationale for this project.

- Chapter 2 details a systematic review and meta-analysis exploring the effectiveness of behaviour change interventions using computer, mobile and/or wearable technologies aimed at reducing SB in healthy adults. This chapter also presents information on the types of technology used in SB reduction interventions and identifies the BCTs used.

- Chapter 3 presents qualitative work from focus groups and interviews with desk-based employees and their employers. The chapter aims to explore their perceptions on the barriers and facilitators to reducing sitting at work and ascertain the practicality of strategies with an emphasis on technology supported approaches.

- Chapter 4 describes the design, development and usability evaluation of a digital intervention to reduce occupational SB. The development process involved the following steps: (1) identifying the theoretical basis, (2) understanding the behaviour and what needs to change, (3) selecting mode of delivery, (4) selecting intervention components and BCTs, (5) designing a prototype intervention and (6) “think-aloud” usability testing, (7) characterisation of the resulting intervention, a mobile app ““Worktivity””.

- Chapter 5 presents the findings from a feasibility study of a mobile app intervention to promote sitting time reductions in office workers tested over an 8 week period intervention, with or without SSWD, relative to a comparison condition. This chapter also describes a process evaluation of recruitment procedures and how interventions were delivered and received, and a preliminary evaluation of responses to the interventions/control conditions in terms of sitting time, productivity and mood.

- Chapter 6 summarises the main findings from each stage of work and its contribution to the literature. It highlights the strengths and limitations of this thesis and potential avenues for further research.

Chapter 2 - Using computer, mobile and wearable technology enhanced interventions to reduce SB: a systematic review and meta-analysis

2.1 Introduction

As described in Chapter 1, SB is a highly prevalent behaviour (Healy et al., 2007; Matthews et al., 2008; Colley et al., 2011; Hansen et al., 2012). Mechanised transportation, sedentary jobs and labour-saving technologies have led to SBs prevailing in industrialised postmodern societies (Kirchengast, 2014). This is concerning as prolonged SB is positively associated with a range of health concerns including all-cause mortality, cardiovascular disease, type 2 diabetes, metabolic syndrome and several types of cancers (Wilmot et al., 2012; Chau et al., 2013; De Rezende et al., 2014; Biswas et al., 2015).

Previous systematic reviews and meta-analyses suggest that it is possible to intervene to reduce SBs in adults through activity permissive work stations, height adjustable desks, health coaching, activity monitors, and prompts to break up sitting (Prince et al., 2014; Martin et al., 2015). Pooled results from these interventions range from 22 to 91 min/day reduction in sedentary time in the intervention groups compared with the controls.

While technological advancements have contributed to a rise in SB (Inyang and Stella, 2015) these reviews (Prince et al., 2014; Martin et al., 2015), have identified that they are also being harnessed to reduce SB. Digital tools such as mobile phones, internet, text-messaging and wearable sensors can be used to change health behaviours, however, there is a lack of evidence examining their role in reducing SB. For example, these have been successfully applied to improve diet/PA (Broekhuizen et al., 2012; Oosterveen et al., 2017), sexual health behaviours (Noar, Black and Pierce, 2009), weight management (Neve et al., 2010), alcohol reduction (Oosterveen et al., 2017) and smoking cessation (Free et al., 2013; Whittaker et al., 2016). However only one systematic review and meta-analysis to date has investigated the use of mobile phone-based interventions on outcomes of PA and SB (Direito et al., 2016). The main findings were that interventions targeting PA and SB promote small reductions in free-living individuals' sitting time. However, only 5 of the 21 included studies reported a measure of SB.

Recommendations on prevention and management of NCDs stress the need for research focused on behaviour change as the core component (Matheson et al., 2013). The BCTT v1 is linked to the BCW and described in Chapter 1. The BCT is the smallest component compatible with retaining the postulated active ingredients (Michie et al., 2015), and provides a way of characterising the content of behaviour change interventions at a finer grain level than in the BCW (Michie, Atkins and West, 2014; West and Michie, 2016). The identification and characterisation of BCTs allows for an understanding of mechanisms of behaviour change, leading to enhanced replication and implementation of effective interventions (Michie et al., 2013).

Reviews of SB interventions and the BCTs used within these interventions have started to emerge. In a systematic review targeting PA and/or SB (Gardner et al., 2015), BCTs identified as particularly promising to change sitting time include “self-monitoring”, “problem solving”, and “restructuring the social or physical environment”. Another systematic review (Direito et al., 2016), focusing on mobile phone based technologies to influence PA and/or SB identified “goal setting (behaviour)”, “self-monitoring of behaviour”, “social support (unspecified)”, “feedback on behaviour”, as the most frequently employed BCTs in intervention groups. However, these interventions were not explicitly aimed at reducing SB, nor did they explore the BCTs specific to digital technology. There is evidence to suggest that interventions specifically targeting SB (as opposed to PA) are more effective in reducing SB (Prince et al., 2014; Martin et al., 2015). Therefore, an exploration of BCTs used in interventions specifically focused on reducing SB, and how BCTs are incorporated into technology enhanced interventions is required.

The effectiveness of interventions supported by computer, mobile and/or wearable technology aimed specifically at reducing SB, and the BCTs used within, have not yet been explored. The objectives of this systematic review and meta-analysis are to evaluate the effectiveness of behaviour change interventions using computer, mobile and/or wearable technologies aimed at reducing SB in healthy adults and to identify the BCTs used within these interventions.

2.2 Methods

The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) Guidelines and Cochrane Handbook for Systematic Reviews of Interventions were used as a methodological template for this review (Moher, 2009; Higgins and Green, 2011).

2.2.1 Inclusion Criteria

- Adults aged 18 years and over,
- Published randomised controlled trials (RCT) of any duration with a main aim of reducing SB and with computer, mobile or wearable technology as any part of the intervention,
- RCTs with a comparison or control arm that consisted of no intervention control, usual care, or alternative treatment conditions,
- Pre-post objective, subjective or proxy measure of SB.

2.2.2 Exclusion Criteria

- RCTs not published in English,

- Comparator intervention using computer, mobile or wearable technology to reduce SB or increase PA,
- RCTs where the main aim of the intervention was to increase PA,
- Interventions delivered in a hospital setting,
- Clinically diagnosed populations, with the exception of those who are overweight or obese.

2.2.3 Information Sources and Search Strategy

Search strategies were developed for each electronic database; MEDLINE, EMBASE, CINAHL, PsycINFO and PubMed. The searches were based on the strategy developed for MEDLINE (Appendix C) and revised appropriately for the other databases. The search dates were from data base inception to June 2016, when the searches were conducted.

The search results were imported into EndNote X7 bibliographic software (Thompson Reuters, San Francisco, CA, USA) and duplicate studies were removed. The titles and abstracts of all identified studies were screened to identify potentially relevant papers. Studies that did not meet the inclusion criteria and titles/abstracts obviously not related to the topic of interest were excluded. Full text papers of potentially relevant studies were retrieved and assessed for eligibility by one member of the research team (AS).

Where uncertainties arose regarding study inclusion, consensus was achieved through discussion amongst the research team.

2.2.4 Data Extraction

The following data were independently extracted from each article using a standardised form: author, year, study design, participants, intervention description, comparator description, SB outcome measures and longest follow-up.

2.2.5 Assessment of Risk of Bias in Included Studies

The risk of bias for each study was assessed using the Cochrane Collaboration's risk of bias tool (Higgins and Green, 2011). Initially, a small sample of studies (n=3) were assessed by two members of the research team (AS and MM), inconsistency in scoring was reviewed, and a consensus reached prior to the analysis of the remaining studies. The remainder of the risk of bias assessment was carried out independently by one member of the research team (AS).

Studies that used an objective measure to assess SB were judged as being at low risk of bias for blinding of outcome assessment. Studies assessing SB with subjective and proxy measures were judged as being at high risk of bias, as there was potential for misreporting of time spent sitting. Where greater than 20% dropout in any group for outcomes up to one year and greater than 30% for outcomes greater than one year was reported, studies were judged as being at high risk of bias for incomplete outcome data. Studies were judged as being at low risk of bias for selective outcome reporting if the final publication of the trial followed what had been planned in a published protocol paper. In the case where no protocol paper was publicly available, studies were deemed as being at low risk for selective outcome reporting if they had reported all the outcomes mentioned in the methodology. A study was judged to be at low risk of bias overall when all domains had a low risk of bias. Conversely, a study was judged to have a high risk of bias when it reported a feature that would be judged as having a high risk of bias in any domain. As it is not possible to blind either in studies of this nature, we did not assess blinding of participants or personnel for overall risk of bias (Shrestha et al., 2016).

Coding of behaviour change techniques

All intervention procedures were coded using the BCTT v1 (Michie et al., 2013), Content was coded using the information reported within the methodology sections of identified studies and their protocol papers (where available) to identify the specific BCTs used in each intervention. BCTs targeting SB were coded for the entire intervention and then separately for the computer, mobile and wearable technology components by AS. To minimise bias in interpretation of the tool, a small sample of studies were first assessed by two trained BCT coders (AS and SH). Inconsistency in coding was reviewed and a consensus reached, prior to the analysis of the remaining studies, by one researcher (AS).

Where uncertainties later arose, the example was discussed with the wider remaining research team to achieve consensus.

2.2.6 Measures of Treatment Effect

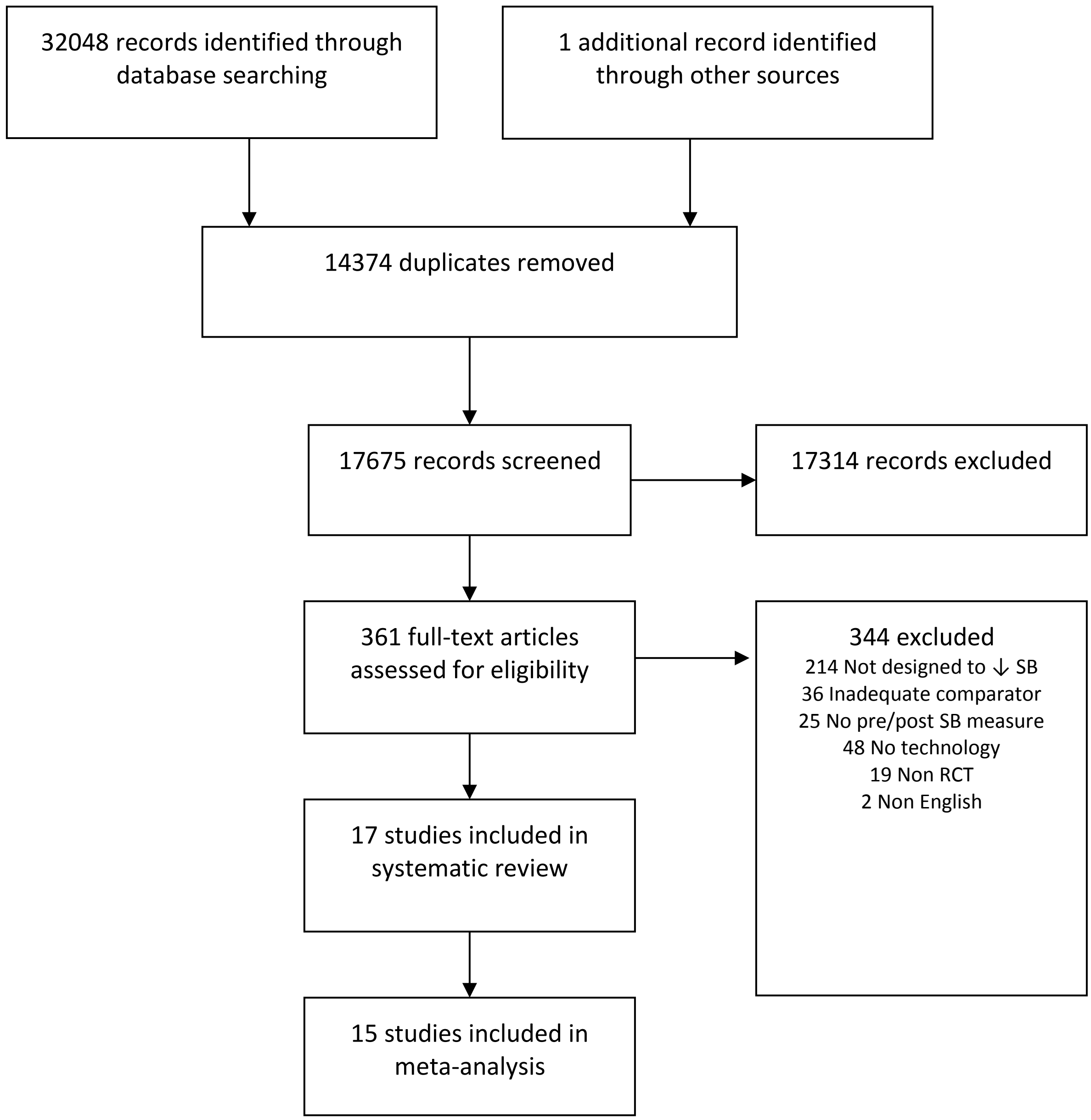
Fifteen studies reported continuous outcomes for measures of SB across the same scale allowing meta-analysis of mean differences (MD). Statistical analysis was conducted in accordance with guidelines from the Cochrane Handbook for Systematic Reviews of Interventions (Higgins and Green, 2011). SB data were transformed into minutes per day (e.g. 5 hr/day = 300 min/day). Data were pooled to compare the post intervention mean differences and 95% confidence intervals (CIs) in sitting time (min/day) between intervention and comparison groups. Authors of the studies included were contacted by email up to three times for further information where required. Studies where the information was unavailable or that reported units which could not be converted to min/day were not included in the meta-analyses.

Where studies reported multiple follow-up points of the same outcome, data were extracted for subgroup analyses at the following time points: short-term ($\leq$3 months), medium-term (>3 to 6 months), and long-term follow-up (>6 months). In studies where two data sets fell within one of these time points, the longest time point was used for data extraction. Where more than one measure of SB was available, objective data were given priority over subjective or proxy data. If more than one proxy measure of SB was available, the measure most representative of overall SB was given preference. If a study focused on reducing workplace SB, workplace SB data were prioritised over SB in other domains or overall SB. Conversely, where an intervention targeted overall daily SB, full day SB data were used in the analysis. Separate subgroup analyses were run for interventions targeting workplace sitting and overall daily SB for short-term ($\leq$3 months), medium-term (>3 to 6 months), and long-term follow-up (>6 months) periods. Subgroup analyses were also conducted for objective and subjective outcome measures. Data were assessed for statistical heterogeneity. Values of the I^2 statistic that were 30% to 60% were considered to represent moderate heterogeneity and 50% to 90% substantial heterogeneity. Studies were pooled using a random effects model where heterogeneity was moderate to substantial; otherwise a fixed effects model was used.

2.3 Results

Figure 2-1 displays the PRISMA flow diagram of the literature search. Inclusion criteria were met by 17 studies, 15 of which provided adequate data to be included in a meta-analysis.

Figure 2-1 PRISMA flow diagram



2.3.1 Study Characteristics

Study and participant characteristics are summarised in Table 2-1. Of the 17 included studies (n= 1,967 participants), 1,323 participants (67%) reported being female. Four studies stated the ratio of male to female participants for the sample analysed and not the sample randomised (Evans et al., 2012; Dutta et al., 2014; Donath et al., 2015; Maher and Conroy, 2015). Fifteen studies were carried out in mixed gender populations. Two studies were carried out amongst female participants only (Ashe et al., 2015; Urda et al., 2016). Thirteen studies included any participants aged 18 years or over. One study targeted females aged 55–70 years (Ashe et al., 2015). The target population in two studies were young adults with an age range of 18-40 years (Biddle et al., 2015, Laska et al., 2016). One study targeted undergraduate university students (Maher and Conroy, 2015).

All studies were published between 2012 and 2016. Ten interventions were designed to reduce SB in the workplace and seven interventions aimed to reduce overall daily SB. Eleven studies were SB interventions alone (Evans et al., 2012; Carr et al., 2013; Dutta et al., 2014; Mainsbridge et al., 2014; Pedersen, Cooley and Mainsbridge, 2014; Biddle et al., 2015; Donath et al., 2015; Júdice et al., 2015; Maher and Conroy, 2015; Danquah et al., 2016; De Cocker et al., 2016), and both PA and SB were targeted in three studies (Barwais, Cuddihy and Tomson, 2013; Schuna et al., 2014; Ashe et al., 2015). The remaining three were lifestyle interventions that included a SB reduction component (Van Berkel et al., 2014 a; Laska et al., 2016; Urda et al., 2016).

All studies targeted SB using a mix of intervention approaches. Table 2-1 details the overall components of the interventions in addition to computer, mobile and wearable technology components. The studies targeting workplace SB utilised the following tools: software/computer prompts were used in seven studies (Evans et al., 2012; Mainsbridge et al., 2014; Pedersen, Cooley and Mainsbridge, 2014; Schuna et al., 2014; Donath et al., 2015; Júdice et al., 2015; Urda et al., 2016); emails were used in five studies (Dutta et al., 2014; Schuna et al., 2014; Van Berkel et al., 2014 a; Donath et al., 2015; Danquah et al., 2016); websites to relay information and provide feedback to participants were used in three studies (Van Berkel et al., 2014 a; Danquah et al., 2016; De Cocker et al., 2016); and text messages were used in one study (Danquah et al., 2016). In those interventions targeting overall sitting, emails were used in three studies (Barwais, Cuddihy and Tomson, 2013; Carr et al., 2013; Maher and Conroy, 2015), websites were used in two studies (Carr et al., 2013; Laska et al., 2016), and text messages were sent to participants in three studies (Biddle et al., 2015; Júdice et al., 2015; Laska et al., 2016). Activity monitors with an online companion were used in three studies (Barwais, Cuddihy and Tomson, 2013; Ashe et al., 2015; Biddle et al., 2015). One study used a mobile app intervention, and this was an optional component of the intervention (Ashe et al., 2015).

The duration and intensity of the interventions varied. The intervention time ranged from five days (Evans et al., 2012; Urda et al., 2016) to 24 months (Laska et al., 2016). The type of control groups also varied between studies. Two studies used a wait-list control (Carr et al., 2013; De Cocker et al., 2016), seven studies used a no intervention control group (Barwais, Cuddihy and Tomson, 2013; Dutta et al., 2014; Schuna et al., 2014; Júdice et al., 2015; Maher and Conroy, 2015; Danquah et al., 2016; Urda et al., 2016) and one study compared a stand-up desk combined with prompts with a stand-up desk alone (Donath et al., 2015). Seven studies provided their control group with basic health information (Evans et al., 2012; Mainsbridge et al., 2014; Pedersen, Cooley and Mainsbridge, 2014; Van Berkel et al., 2014 a; Ashe et al., 2015; Biddle et al., 2015; Laska et al., 2016).

A variety of SB measurement tools were used. Three studies used more than one measurement tool (Dutta et al., 2014; Biddle et al., 2015; De Cocker et al., 2016). Eleven studies used objective measures including; accelerometers (Carr et al., 2013; Dutta et al., 2014; Schuna et al., 2014; Ashe et al., 2015; Biddle et al., 2015; Donath et al., 2015; Danquah et al., 2016) and inclinometers (Evans et al., 2012; Biddle et al., 2015; Júdice et al., 2015; De Cocker et al., 2016; Urda et al., 2016). Subjective questionnaires were used in five studies (Barwais, Cuddihy and Tomson, 2013; Dutta et al., 2014; Biddle et al., 2015; Maher and Conroy, 2015; De Cocker et al., 2016). Four studies used proxy measures where participants were asked to record the time they spent in the domains they were interested in for example computer time/TV time (Mainsbridge et al., 2014; Pedersen, Cooley and Mainsbridge, 2014; Van Berkel et al., 2014 a; Laska et al., 2016).

Table 2-1: Summary Table of Included Studies

Author/ Year	Study design	Sample Size	Sex	Age	Health Risk	Setting	Aim	Intervention	Technology tool(s)	Comparison group	Outcome Measure	Longest follow-up
Ashe 2015	Pilot RCT	25	25F 0M	All: 64.1±4.6 I: 64.8±4.6 C: 63.1±4.8	Healthy, not meeting PA guidelines	Community / home	SB+ PA	Group health education, PA/SB, PA prescription, online activity monitor (Fitbit), Fitbit app, public transport tickets	Activity monitor (Fitbit) with online companion and app	Health information	ActiGraph™	6 months
Barwais 2013	RCT	33	11F 22M	All:27 ± 4.0 I:9.0 ± 4.4 C:26.4 ± 3.0	Self-report >7 hours/day sitting	Community / home	SB+ PA	Gruve activity tracker with online companion, motivational emails	Gruve activity tracker with online companion, motivational emails	No intervention	7-day SLIPA Log	4 weeks

Author/ Year	Study design	Sample Size	Sex	Age	Health Risk	Setting	Aim	Intervention	Technology tool(s)	Comparison group	Outcome Measure	Longest follow-up
Biddle 2015	RCT	187	128F 59M	All:32.8 ±5.6 I:32.4 ±5.4 C:33.3 ±5.8	Obese/ overweight plus additional risk factor for diabetes	Community / home	SB	Group education, Gruve activity tracker with online companion, motivational texts/calls	Gruve activity tracker with online companion, motivational texts	Health information + SB information	ActiGraph™, ActivPAL™ , IPAQ, Marshall sitting questionna-ire	12 months
Carr 2013	RCT	40	36F 4M	All:44.7 ±9.6 I:47.6 ±9.9 C:42.6 ±8.9	Apparently healthy, Self-reporting < 60 min of moderate to vigorous PA/week, overweight, reporting a minimum of 75% of their work day sitting	Workplace+ community/ home	SB	Pedal machine, commercial website (Walker Tracker, Portland, Oregon, USA), pedometer, motivational emails	Commercial website (Walker Tracker, Portland, Oregon, USA), motivational emails	Waitlist	StepWatch ™	12 weeks

Author/ Year	Study design	Sample Size	Sex	Age	Health Risk	Setting	Aim	Intervention	Technology tool(s)	Comparison group	Outcome Measure	Longest follow-up
Danquah* 2016	Cluster RCT	317	210F 107M	All:46 ±10 I:46 ±10 C:45 ±11	Employees who sit most of the workday	Workplace	SB	Active meetings, lecture, workshop, educational emails/texts, project website	Emails/text, project website	No intervention	ActiGraph™	12 weeks
De Cocker* 2016	RCT	213	146F 67M	All:40.3 ±9.1 I:40.5 ±8.6 C:39.3 ±9.0	All employees	Workplace	SB	Web based feedback from project website	Web based feedback from project website	Waitlist	ActivPAL™, WSQ	12 weeks
Donath* 2015	RCT	38	23F 8M 7 no data	All:42.42 I:45 ±12 C:40 ±10	Free from cardio-vascular disease	Workplace	SB	Standing desks, computer prompts	Computer prompts	Standing desk	ActiGraph™	12 weeks
Dutta* 2014	Cross-over RCT	29	19F 9M 1 no data	All: 40.4 (no SD reported)	Employees who sit most of the workday	Workplace	SB	Standing desks, reminder emails	Reminder emails	No intervention	Modular Signal Recorder	4 weeks

Author/ Year	Study design	Sample Size	Sex	Age	Health Risk	Setting	Aim	Intervention	Technology tool(s)	Comparison group	Outcome Measure	Longest follow-up
											145, Gruve, OSPAQ	
Evans* 2012	RCT	30	22F 6M 2 no data	All: 44 I:49 ± 8 C: 39± 10	Healthy employees	Workplace	SB	Individual education session, software prompts	Software prompts	Health information + SB information	ActivPAL™	5 days
Júdice 2015	Cross-over RCT	10	5F 5M	All:50.4 ±11.5	BMI < 25.0 kg m−2; not taking medication, not meeting PA guidelines, free from any major disease	Workplace+ community/ home	SB	Computer prompts, step monitoring, motivational calls/texts	Computer prompts, motivational texts	No intervention	ActivPAL™	1 week

Author/ Year	Study design	Sample Size	Sex	Age	Health Risk	Setting	Aim	Intervention	Technology tool(s)	Comparison group	Outcome Measure	Longest follow-up
Laska 2016	RCT	441	298F 143M	All: 22.8 (no SD reported) I:22.9 C:22.8	BMI: 20–34.9 kg/ m2	Community / home	Life style + SB	Educational course (online/face to face/hybrid), project website, motivational texts/calls	Educational course (online/ face to face/hybrid), project website, motivational texts	Health information	Self-reported screen time behaviours	24 months
Maher 2015	RCT	195	89F 95M 11 no data	All: 20.4 (no SD reported)	All undergraduates	Community / home	SB	SB planning via email	SB planning via email	No intervention	IPAQ	7 days
Mainsbridge * 2014	RCT	29	24F 5M	All: 40.10 I: 36.73 ± 12.38 C: 42.28 ± 9.59	Employees who sit most of workday, medically cleared to perform	Workplace	SB	Group education, prompting software	Prompting software	Health information + SB information	Self-reported sitting	13 weeks

Author/ Year	Study design	Sample Size	Sex	Age	Health Risk	Setting	Aim	Intervention	Technology tool(s)	Comparison group	Outcome Measure	Longest follow-up
					short PA bouts							
Pedersen* 2014	RCT	34	26F 8M	All: 43 I:41.50±12.39 C: 43.88±9.65	Employees who sit most of the workday, free from existing health conditions	Workplace	SB	Group education, prompting software	Prompting software	Health information + SB information	Self-reported SB	13 weeks
Schuna* 2014	RCT	41	40F 1M	All: 40.1 ±10.1 I:40.0 ±9.5 C: 40.3 ±10.9	Overweight /obese office workers.	Workplace	SB+ PA	Treadmill desk, computer prompts	Computer prompts, email	No intervention	ActiGraph™	12 weeks
Urda* 2016	RCT	48	48F 0M	All: 48±10	Employees who sit most of the workday	Workplace	Life style + SB	Educational handout, computer prompt	Computer prompts	No intervention	ActivPAL™	5 days

Author/ Year	Study design	Sample Size	Sex	Age	Health Risk	Setting	Aim	Intervention	Technology tool(s)	Comparison group	Outcome Measure	Longest follow-up
Van Berkel* 2014 a	RCT	257	173F 84M	All: 45.5 I: 46.0 ±9.4 C: 45.1 ±9.6	All employees	Workplace	Life style + SB	Mindfulness sessions, nutrition support, e-coaching, intranet webpage	E-coaching (email), intranet webpage	Health information	Self-reported SB	12 months

* denotes interventions targeting workplace sitting
F=female, M=male, SB= sedentary behavior, PA= physical activity, I= intervention, C= control, IPAQ= International Physical Activity Questionnaire, WSQ=Workforce Sitting Questionnaire , OSPAQ= Occupational Sitting and Physical Activity Questionnaire

2.3.2 Risk of Bias of Included Studies

The assessment for each risk of bias item across all included studies, plus the additional domains assessed for cross over and cluster RCTs are presented in Figures 2-2 and 2-3.

2.3.2.1 Selection Bias

Fourteen studies were considered at low risk of random sequence generation bias due to adequate randomisation procedures. Three studies were deemed to be at an unclear risk of bias due to insufficient reporting of the method of randomisation. Five studies were considered to be at low risk of bias through allocation concealment. Allocation concealment was considered unclear in 11 studies due to a lack of information regarding the methods used to conceal intervention versus control group allocation. One study was deemed to be at a high risk of bias through allocation bias as it reported within the paper that it was not possible to conceal allocation.

2.3.2.2 Performance Bias

Since blinding of participants to the interventions was not possible all 17 studies had a high risk of bias due to lack of blinding.

2.3.2.3 Detection Bias

SB measures used to determine intervention effects in this analysis were measured through subjective/proxy measures in seven studies and thus were at high risk for detection bias. The risk of bias was deemed low for the other ten studies due to objective measurement of the SB outcome.

2.3.2.4 Attrition Bias

Eight studies were deemed to be at low risk of attrition bias due to low attrition rates. Six studies were at high risk of attrition bias due to high dropout levels. Three studies were considered to be at an unclear risk of attrition bias due to insufficient reporting.

2.3.2.5 Reporting Bias

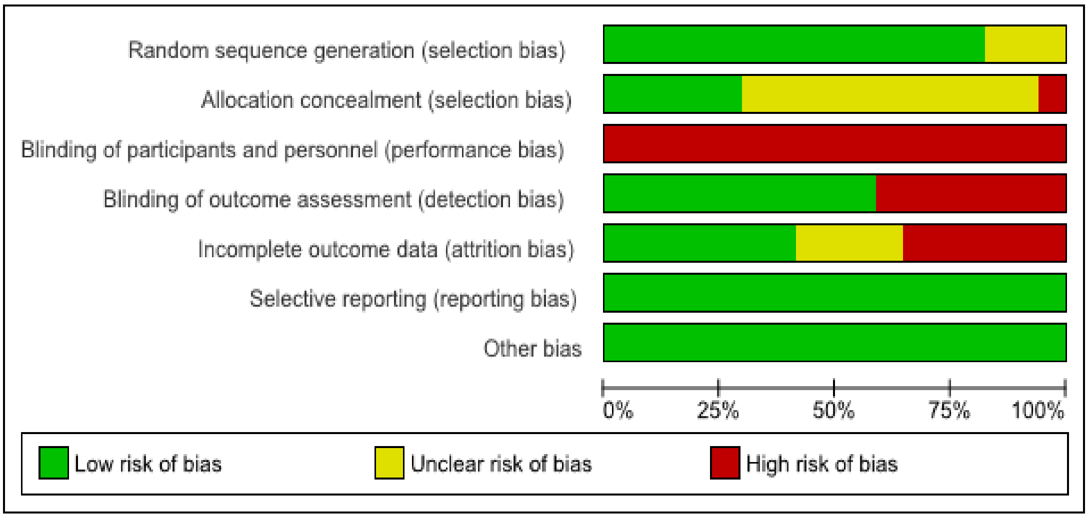
All 17 studies were deemed to be of low risk of reporting bias. Authors reported all the SB outcome measures mentioned in methods and protocol papers.

2.3.2.6 Other Bias

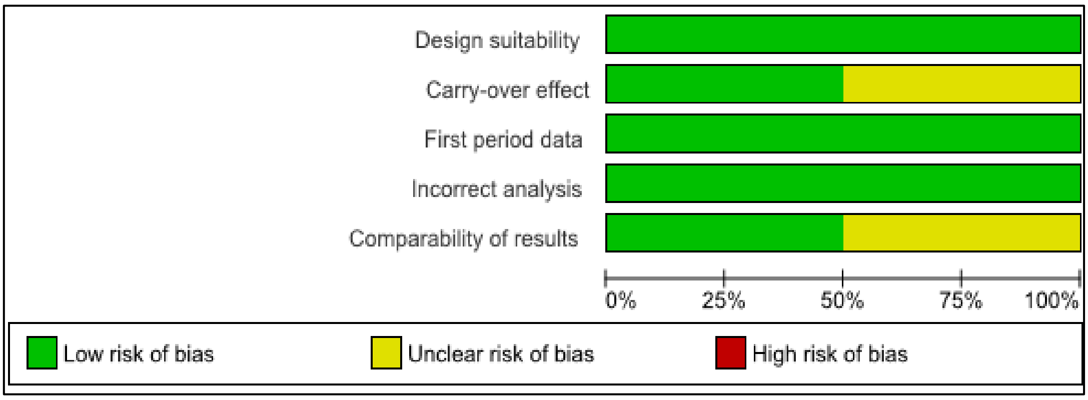
All 17 studies were considered to be of low risk for other bias. All additional domains for the cluster RCT, were deemed to be at low risk of bias, with the exception of two domains. This study was considered to be of an unclear risk of bias for “Loss of clusters” and “Comparability with individually randomised trials”, as neither domain was sufficiently addressed in the study reports. Additional domains for the crossover studies were also assessed. All additional domains for Júdice et al. (2015) were considered to be at a low risk of bias. All domains for Dutta et al. (2014) were low risk of bias with the exception of “Carry over effect” and “Comparability with parallel-group trials”. These domains were considered to be at unclear risk of bias due to insufficient reporting.

Figure 2-2 Risk of bias graph

Risk of bias graph (all studies n=17)



Cross over RCT additional domains (n=2)



Cluster RCT additional domains (n=1)

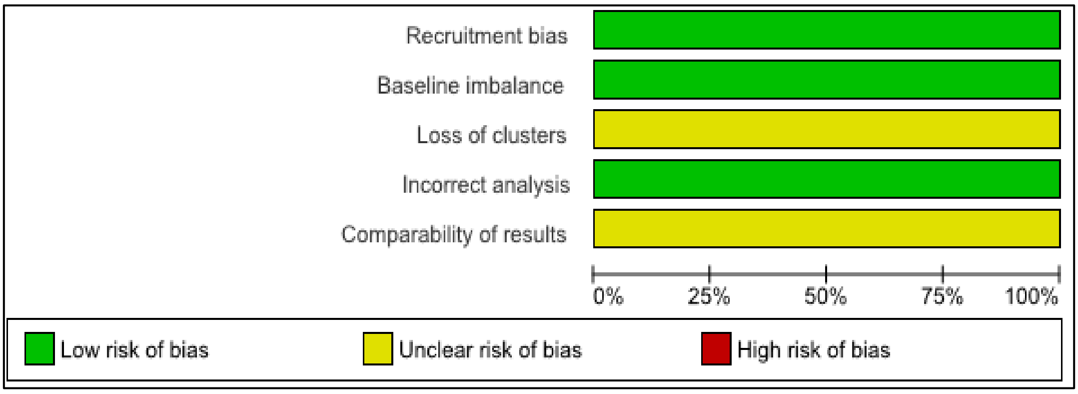


Figure 2-3 Risk of Bias Summary

Risk of bias summary (all studies)

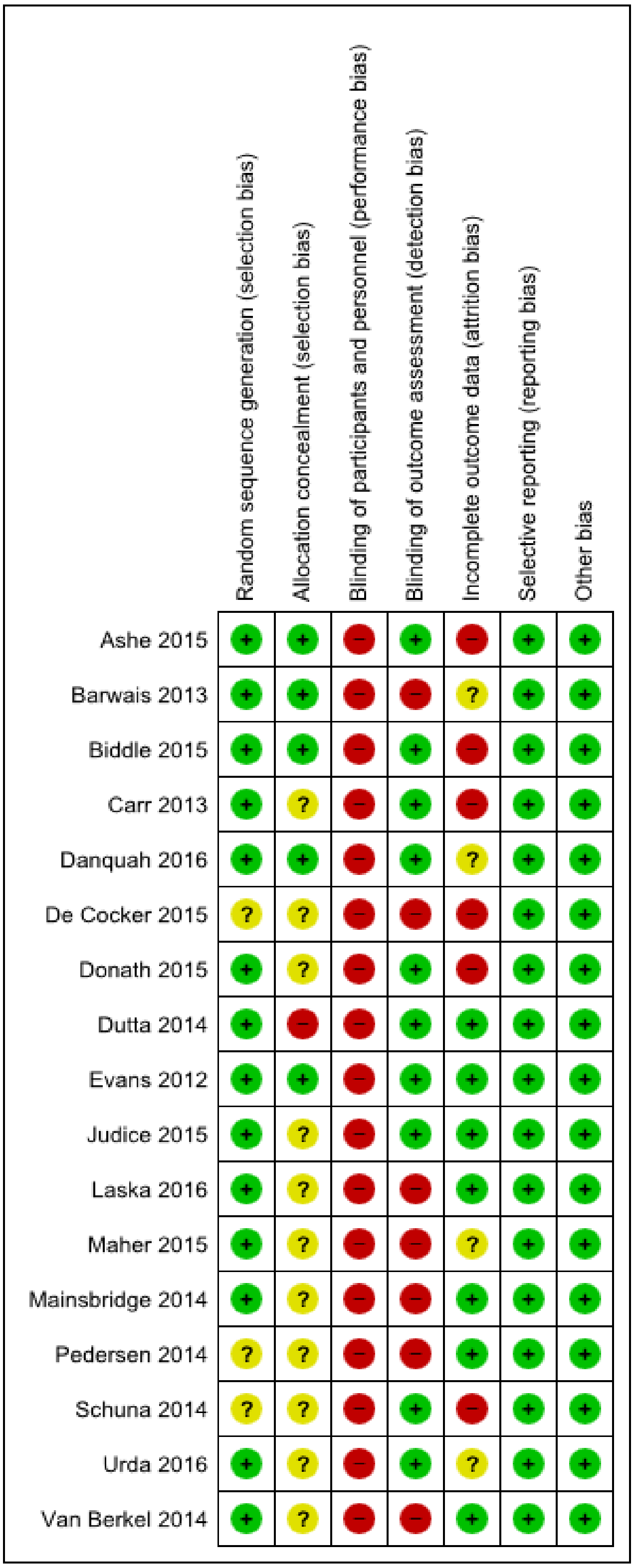
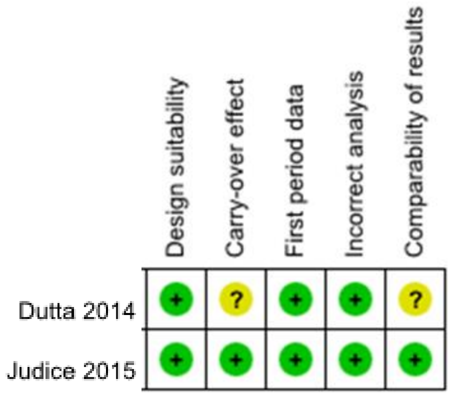
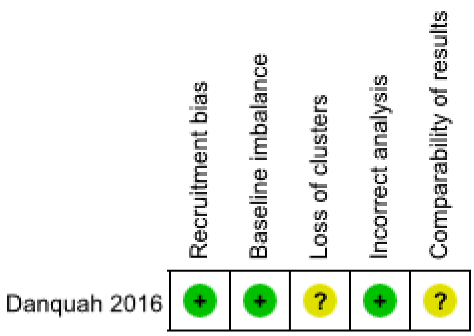


Figure 2-3 continued

Cross over additional domains



Cluster RCT additional domains



2.3.2.6 Overall Risk of Bias Assessment

Overall, 13 studies were judged to have a high risk of bias based on: allocation concealment (Dutta et al., 2014) blinding of outcome assessment (Barwais, Cuddihy and Tomson, 2013; Mainsbridge et al., 2014; Pedersen, Cooley and Mainsbridge, 2014; Van Berkel et al., 2014 a; Maher and Conroy, 2015; Laska et al., 2016; De Cocker et al., 2016) incomplete outcome data (Carr et al., 2013; Schuna et al., 2014; Ashe et al., 2015; Biddle et al., 2015; Donath et al., 2015; De Cocker et al., 2016). Three studies were deemed to be at an unclear risk of bias due to incomplete outcome data (Danquah et al., 2016; Urda et al., 2016) and allocation concealment (Júdice et al., 2015; Urda et al., 2016). One study was judged to be at a low risk of bias (Evans et al., 2012). Due to only one study being at low risk of bias, it was not possible to conduct a sensitivity analysis. Refer to Figures 2-2 and 2-3 for a graph and summary of judgements about each risk of bias item for each included study.

2.3.3 Behaviour Change Techniques

A total of 104 BCTs were coded in the 17 included studies (Table 2-2) 20/93 unique BCTs were coded representing 21.5% of the taxonomy. The range of BCTs coded per study was one to 15. The most frequently coded BCT was "instruction on how to perform a behaviour" which was coded 15 times, "social support (unspecified)" (12 times), "prompts and cues" (11 times) and "adding objects to the environment" (11 times).

A total of 46 BCTs were coded in the 17 studies for the computer, mobile and wearable components of the interventions only. In these interventions, there were 14 unique BCTs coded, ranging from one to ten per study. The most frequently coded BCTs were "prompts and cues" (10 times), "self-monitoring of behaviour" (7 times), "social support (unspecified)" (7 times) and "goal setting (behaviour)" (5 times).

Table 2-2 BCT Coding and Frequency

BCT LABEL	Ashe 2015	Barwais 2013	Biddle 2015	Carr 2013	Danquah 2016	DeCocker 2016	Donath 2015	Dutta 2014	Evans 2012	Júdice 2015	Laska 2016	Maher 2015	Mainsbridge 2014	Pedersen 2014	Schuna 2014	Urda 2016	Van Berkel 2014 a	Total coded (whole intervention)	Total coded (technology)
1. Goals and planning																		25	10
1.1. Goal setting (behaviour)		x	x		x	x					x	x					x	7	5
1.2. Problem solving	xx		xx		x					x	x				x		x	9	2
1.4. Action planning	x		x			x						x						4	2
1.5. Review behaviour goal(s)	x		xx														x	4	1
1.7. Review outcome goal(s)					x													1	0
2. Feedback and monitoring																		10	8
2.2. Feedback on behaviour			x			x												2	1
2.3. Self-monitoring of behaviour		x	x	x						x	x	x	x	x				8	7
3. Social support																		13	8

3.1. Social support (unspecified)	x	x	xxx	x	x					x	xx						xx	12	7
3.2. Social support (practical)															x			1	1
4. Shaping knowledge																		15	4
4.1. Instruction on how to perform the behaviour	xx		x	x	x	x			xx	xx	xx		x	x		x		15	4
5. Natural consequences																		9	1
5.1. Information about health consequences			x		xx	x			xx				x	x		x		9	1
6. Comparison of behaviour																		2	1
6.1. Demonstration of the behaviour														x				1	0
6.2. Social comparison											x							1	1
7. Associations																		11	10
7.1. Prompts/cues			x	x	x		x	x	x	x			x	x	x	x		11	10

8. Repetition and substitution																		6	0
8.2. Behaviour substitution	x				x						x							3	0
8.7. Graded tasks	x				x			x										3	0
9. Comparison of outcomes																		1	1
9.1. Credible source											x							1	1
10. Reward and threat																		0	0
11. Regulation																		0	0
12. Antecedents																		12	3
12.3. Avoidance/reducing exposure to cues for the behaviour											x							1	0
12.5. Adding objects to the environment	xx	x	x	xx	x		x	x		x					x			11	3
13. Identity																		0	0
14. Scheduled consequences																		0	0

15. Self-belief																		1	0
15.1. Verbal persuasion about capability					x													1	0
16. Covert learning																		0	0

Shaded columns indicate interventions targeting workplace sitting, x=coded as part of the technology aspect, x=coded as part of intervention (non-technology aspects)

2.3.4 Effects of Intervention

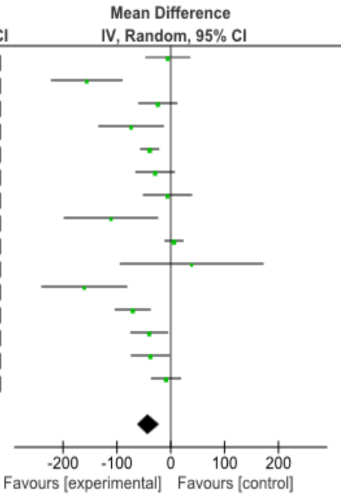
Results of the main meta-analysis (n=15; Figure 2-4) suggest that SB reducing interventions incorporating computer, mobile and/or wearable technology tools resulted in a mean reduction of -41.28 min/day (95% CI -60.99, -21.58, I^2=77%, n=1402), in the intervention group at endpoint follow-up.

Figure 2-4 Effects of intervention versus control on SB

Endpoint follow-up

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Ashe 2015	517.37	54.77	12	522.81	35.77	7	7.1%	-5.44 [-46.21, 35.33]
Barwais 2013	516	102	18	672	90	15	4.8%	-156.00 [-221.53, -90.47]
Biddle 2015	637.46	100.62	45	661.37	71.83	51	7.7%	-23.91 [-59.31, 11.49]
Carr 2013	526.1	77.3	23	599.7	106.6	17	5.3%	-73.60 [-133.31, -13.89]
Danquah 2016	310	71.03	173	349	79.2	144	9.6%	-39.00 [-55.71, -22.29]
De Cocker 2015	259	88	33	288	48	24	7.7%	-29.00 [-64.64, 6.64]
Evans 2012	336	66	14	342	54	14	6.7%	-6.00 [-50.67, 38.67]
Judice 2015	573	108	10	684	88.8	10	3.4%	-111.00 [-197.66, -24.34]
Laska 2016	78	80.27	179	72	78.92	173	9.6%	6.00 [-10.63, 22.63]
Maher 2015	474.58	314.71	36	435.68	283.18	44	1.8%	38.90 [-93.65, 171.45]
Mainsbridge 2014	211.91	130.45	11	372.44	34.67	18	3.9%	-160.53 [-239.27, -81.79]
Pedersen 2014	291.24	57.17	17	361.71	36.71	17	8.1%	-70.47 [-102.77, -38.17]
Schuna 2014	316.4	48.45	15	356.28	48.44	16	7.9%	-39.88 [-74.01, -5.75]
Urda 2016	325.2	71.4	22	363	44.4	22	7.7%	-37.80 [-72.93, -2.67]
Van Berkel 2014	301.03	97.84	112	309.77	105.44	110	8.6%	-8.74 [-35.51, 18.03]
Total (95% CI)			**720**			**682**	**100.0%**	**-41.28 [-60.99, -21.58]**

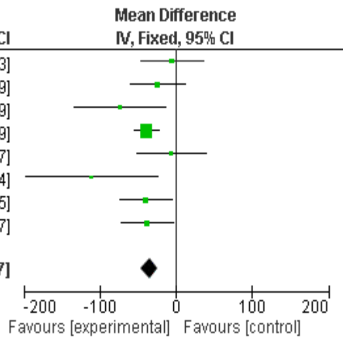
Heterogeneity: Tau² = 982.95; Chi² = 61.54, df = 14 (P < 0.00001); I² = 77%
Test for overall effect: Z = 4.11 (P < 0.0001)



Objective measures: endpoint

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Fixed, 95% CI
Ashe 2015	517.37	54.77	12	522.81	35.77	7	8.0%	-5.44 [-46.21, 35.33]
Biddle 2015	637.46	100.62	45	661.37	71.83	51	10.6%	-23.91 [-59.31, 11.49]
Carr 2013	526.1	77.3	23	599.7	106.6	17	3.7%	-73.60 [-133.31, -13.89]
Danquah 2016	310	71.03	173	349	79.2	144	47.3%	-39.00 [-55.71, -22.29]
Evans 2012	336	66	14	342	54	14	6.6%	-6.00 [-50.67, 38.67]
Judice 2015	573	108	10	684	88.8	10	1.8%	-111.00 [-197.66, -24.34]
Schuna 2014	316.4	48.45	15	356.28	48.44	16	11.4%	-39.88 [-74.01, -5.75]
Urda 2016	325.2	71.4	22	363	44.4	22	10.7%	-37.80 [-72.93, -2.67]
Total (95% CI)			**314**			**281**	**100.0%**	**-35.07 [-46.57, -23.57]**

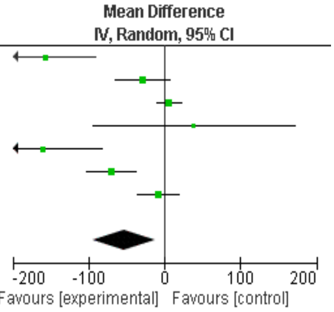
Heterogeneity: Chi² = 8.90, df = 7 (P = 0.26); I² = 21%
Test for overall effect: Z = 5.98 (P < 0.00001)



Subjective measures: endpoint

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Barwais 2013	516	102	18	672	90	15	12.8%	-156.00 [-221.53, -90.47]
De Cocker 2015	259	88	33	288	48	24	16.6%	-29.00 [-64.64, 6.64]
Laska 2016	78	80.27	179	72	78.92	173	18.4%	6.00 [-10.63, 22.63]
Maher 2015	474.58	314.71	36	435.68	283.18	44	6.4%	38.90 [-93.65, 171.45]
Mainsbridge 2014	211.91	130.45	11	372.44	34.67	18	11.2%	-160.53 [-239.27, -81.79]
Pedersen 2014	291.24	57.17	17	361.71	36.71	17	17.0%	-70.47 [-102.77, -38.17]
Van Berkel 2014	301.03	97.84	112	309.77	105.44	110	17.6%	-8.74 [-35.51, 18.03]
Total (95% CI)			**406**			**401**	**100.0%**	**-52.66 [-93.63, -11.69]**

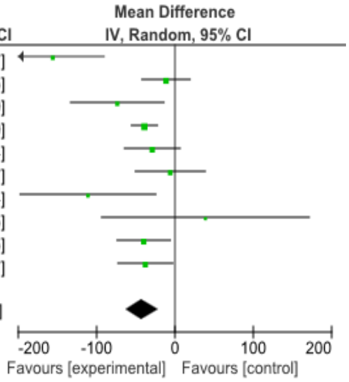
Heterogeneity: Tau² = 2296.90; Chi² = 49.23, df = 6 (P < 0.00001); I² = 88%
Test for overall effect: Z = 2.52 (P = 0.01)



Short term follow-up

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Barwais 2013	516	102	18	672	90	15	6.6%	-156.00 [-221.53, -90.47]
Biddle 2015	652.82	86.31	53	664.23	78.23	57	13.7%	-11.41 [-42.27, 19.45]
Carr 2013	526.1	77.3	23	599.7	106.6	17	7.5%	-73.60 [-133.31, -13.89]
Danquah 2016	310	71.03	173	349	79.2	144	17.4%	-39.00 [-55.71, -22.29]
De Cocker 2015	259	88	33	288	48	24	12.4%	-29.00 [-64.64, 6.64]
Evans 2012	336	66	14	342	54	14	10.3%	-6.00 [-50.67, 38.67]
Judice 2015	573	108	10	684	88.8	10	4.4%	-111.00 [-197.66, -24.34]
Maher 2015	474.58	314.71	36	435.68	283.18	44	2.2%	38.90 [-93.65, 171.45]
Schuna 2014	316.4	48.45	15	356.28	48.44	16	12.8%	-39.88 [-74.01, -5.75]
Urda 2016	325.2	71.4	22	363	44.4	22	12.6%	-37.80 [-72.93, -2.67]
Total (95% CI)			**397**			**363**	**100.0%**	**-42.42 [-63.21, -21.63]**

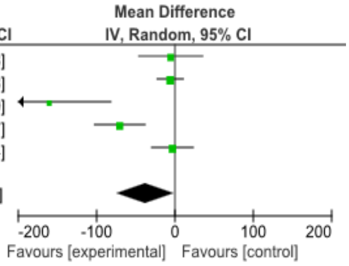
Heterogeneity: Tau² = 573.68; Chi² = 22.93, df = 9 (P = 0.006); I² = 61%
Test for overall effect: Z = 4.00 (P < 0.0001)



Medium term follow-up

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Ashe 2015	517.37	54.77	12	522.81	35.77	7	19.5%	-5.44 [-46.21, 35.33]
Laska 2016	84	83.57	194	90	83.57	194	24.5%	-6.00 [-22.63, 10.63]
Mainsbridge 2014	211.91	130.45	11	372.44	34.67	18	11.7%	-160.53 [-239.27, -81.79]
Pedersen 2014	291.24	57.17	17	361.71	36.71	17	21.5%	-70.47 [-102.77, -38.17]
Van Berkel 2014	296.96	97.76	112	300.17	103.45	109	22.7%	-3.21 [-29.76, 23.34]
Total (95% CI)			**346**			**345**	**100.0%**	**-37.23 [-73.70, -0.75]**

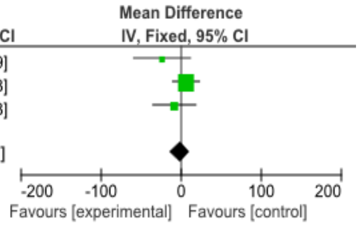
Heterogeneity: Tau² = 1339.86; Chi² = 26.28, df = 4 (P < 0.0001); I² = 85%
Test for overall effect: Z = 2.00 (P = 0.05)



Long term follow-up

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Fixed, 95% CI
Biddle 2015	637.46	100.62	45	661.37	71.83	51	13.7%	-23.91 [-59.31, 11.49]
Laska 2016	78	80.27	179	72	78.92	173	62.2%	6.00 [-10.63, 22.63]
Van Berkel 2014	301.03	97.84	112	309.77	105.44	110	24.0%	-8.74 [-35.51, 18.03]
Total (95% CI)			**336**			**334**	**100.0%**	**-1.65 [-14.77, 11.47]**

Heterogeneity: Chi² = 2.60, df = 2 (P = 0.27); I² = 23%
Test for overall effect: Z = 0.25 (P = 0.81)



In the eight studies which reported objective measures of SB (Evans et al., 2012; Carr et al., 2013; Schuna et al., 2014; Ashe et al., 2015; Biddle et al., 2015; Júdice et al., 2015; Danquah et al., 2016 Urda; Gorman and Larouere, 2016), the pooled analysis resulted in a mean reduction of -35.07 min/day (95% CI -46.57, -23.57, I^2 = 21%, n=595) in favour of the intervention group. The seven studies which reported subjective measures of SB (Barwais, Cuddihy and Tomson, 2013; Mainsbridge et al., 2014; Pedersen, Cooley and Mainsbridge, 2014; Van Berkel et al., 2014 a; Maher and Conroy, 2015; De Cocker et al., 2016; Laska et al., 2016) showed a mean reduction of -52.66min/day (95% CI, -93.63, -11.69, I^2 = 88%, n=807).

Ten of the 15 studies included in the meta-analysis reported short-term measures ($\leq$3 months) (Evans et al., 2012; Barwais, Cuddihy and Tomson, 2013; Carr et al., 2013; Schuna et al., 2014; Biddle et al., 2015; Júdice et al., 2015; Maher and Conroy, 2015; Danquah et al., 2016; De Cocker et al., 2016; Urda et al., 2016). The pooled analysis showed a mean reduction of -42.42 min/day (95% CI -63.21, -21.63, I^2=61%, n=760) in favour of the intervention group. Five interventions reported medium-term (>3 to 6 months) measures. The pooled effect showed a mean reduction of -37.23 min/day (95% CI -73.70, -0.75, I^2=85%, n=691). Three studies reported long-term measures of SB (>6 months). The pooled analysis showed a mean reduction of -1.65 min/day (95% CI -14.77, 11.47, I^2=23%, n=670).

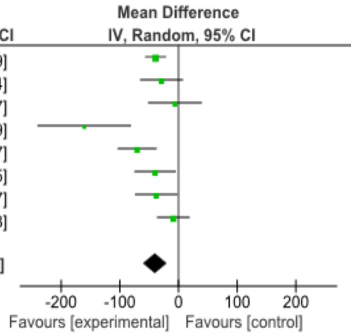
Eight interventions included in the meta-analysis focused on reducing workplace SB (Evans et al., 2012; Mainsbridge et al., 2014; Pedersen, Cooley and Mainsbridge, 2014; Schuna et al., 2014; Van Berkel et al., 2014 a; Danquah et al., 2016; De Cocker et al., 2016; Urda et al., 2016) (Figure 2-5). The pooled effect showed a mean reduction of -39.88 min/workday (time spent at work) (95% CI -59.58, -20.18, I^2=65%, n=762) in favour of the intervention group at endpoint follow-up.

Figure 2-5 Effects of workplace intervention versus control on workplace SB

Endpoint follow-up

	Experimental			Control				Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Danquah 2016	310	71.03	173	349	79.2	144	18.3%	-39.00 [-55.71, -22.29]
De Cocker 2015	259	88	33	288	48	24	12.5%	-29.00 [-64.64, 6.64]
Evans 2012	336	66	14	342	54	14	10.1%	-6.00 [-50.67, 38.67]
Mainsbridge 2014	211.91	130.45	11	372.44	34.67	18	4.8%	-160.53 [-239.27, -81.79]
Pedersen 2014	291.24	57.17	17	361.71	36.71	17	13.5%	-70.47 [-102.77, -38.17]
Schuna 2014	316.4	48.45	15	356.28	48.44	16	12.9%	-39.88 [-74.01, -5.75]
Urda 2016	325.2	71.4	22	363	44.4	22	12.6%	-37.80 [-72.93, -2.67]
Van Berkel 2014	301.03	97.84	112	309.77	105.44	110	15.2%	-8.74 [-35.51, 18.03]
Total (95% CI)			**397**			**365**	**100.0%**	**-39.88 [-59.58, -20.18]**

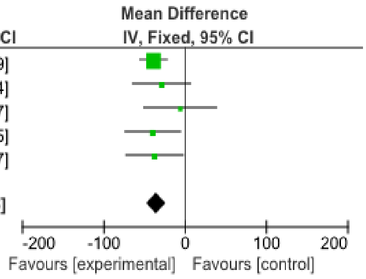
Heterogeneity: Tau² = 478.49; Chi² = 19.99, df = 7 (P = 0.006); I² = 65%
Test for overall effect: Z = 3.97 (P < 0.0001)



Short term follow-up

	Experimental			Control				Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Danquah 2016	310	71.03	173	349	79.2	144	54.8%	-39.00 [-55.71, -22.29]
De Cocker 2015	259	88	33	288	48	24	12.0%	-29.00 [-64.64, 6.64]
Evans 2012	336	66	14	342	54	14	7.7%	-6.00 [-50.67, 38.67]
Schuna 2014	316.4	48.45	15	356.28	48.44	16	13.1%	-39.88 [-74.01, -5.75]
Urda 2016	325.2	71.4	22	363	44.4	22	12.4%	-37.80 [-72.93, -2.67]
Total (95% CI)			**257**			**220**	**100.0%**	**-35.23 [-47.60, -22.86]**

Heterogeneity: Chi² = 2.05, df = 4 (P = 0.73); I² = 0%
Test for overall effect: Z = 5.58 (P < 0.00001)



Medium term follow-up

	Experimental			Control				Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Mainsbridge 2014	211.91	130.45	11	372.44	34.67	18	26.5%	-160.53 [-239.27, -81.79]
Pedersen 2014	291.24	57.17	17	361.71	36.71	17	36.3%	-70.47 [-102.77, -38.17]
Van Berkel 2014	296.96	97.76	112	300.17	103.45	109	37.2%	-3.21 [-29.76, 23.34]
Total (95% CI)			**140**			**144**	**100.0%**	**-69.34 [-140.58, 1.91]**

Heterogeneity: Tau² = 3369.29; Chi² = 19.78, df = 2 (P < 0.0001); I² = 90%
Test for overall effect: Z = 1.91 (P = 0.06)

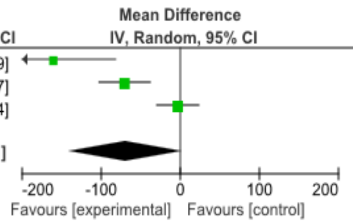
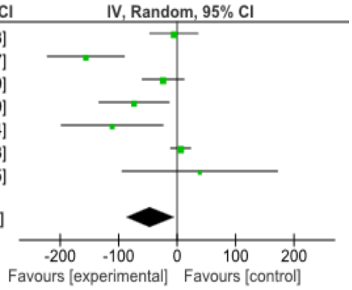


Figure 2-6 Effects of overall daily SB interventions versus control on daily SB

Endpoint follow-up

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Ashe 2015	517.37	54.77	12	522.81	35.77	7	17.1%	-5.44 [-46.21, 35.33]
Barwais 2013	516	102	18	672	90	15	13.5%	-156.00 [-221.53, -90.47]
Biddle 2015	637.46	100.62	45	661.37	71.83	51	17.8%	-23.91 [-59.31, 11.49]
Carr 2013	526.1	77.3	23	599.7	106.6	17	14.4%	-73.60 [-133.31, -13.89]
Judice 2015	573	108	10	684	88.8	10	10.8%	-111.00 [-197.66, -24.34]
Laska 2016	78	80.27	179	72	78.92	173	19.8%	6.00 [-10.63, 22.63]
Maher 2015	474.58	314.71	36	435.68	283.18	44	6.6%	38.90 [-93.65, 171.45]
Total (95% CI)			**323**			**317**	**100.0%**	**-45.11 [-86.63, -3.60]**

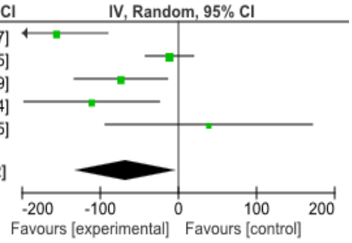
Heterogeneity: Tau² = 2195.27; Chi² = 33.25, df = 6 (P < 0.00001); I² = 82%
Test for overall effect: Z = 2.13 (P = 0.03)



Short term follow-up

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Barwais 2013	516	102	18	672	90	15	21.3%	-156.00 [-221.53, -90.47]
Biddle 2015	652.82	86.31	53	664.23	78.23	57	25.6%	-11.41 [-42.27, 19.45]
Carr 2013	526.1	77.3	23	599.7	106.6	17	22.1%	-73.60 [-133.31, -13.89]
Judice 2015	573	108	10	684	88.8	10	18.3%	-111.00 [-197.66, -24.34]
Maher 2015	474.58	314.71	36	435.68	283.18	44	12.8%	38.90 [-93.65, 171.45]
Total (95% CI)			**140**			**143**	**100.0%**	**-67.72 [-132.82, -2.62]**

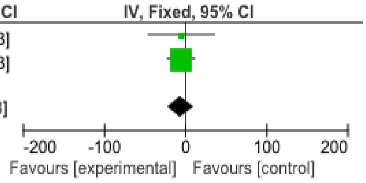
Heterogeneity: Tau² = 4068.62; Chi² = 20.21, df = 4 (P = 0.0005); I² = 80%
Test for overall effect: Z = 2.04 (P = 0.04)



Medium term follow-up

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Fixed, 95% CI
Ashe 2015	517.37	54.77	12	522.81	35.77	7	14.3%	-5.44 [-46.21, 35.33]
Laska 2016	84	83.57	194	90	83.57	194	85.7%	-6.00 [-22.63, 10.63]
Total (95% CI)			**206**			**201**	**100.0%**	**-5.92 [-21.32, 9.48]**

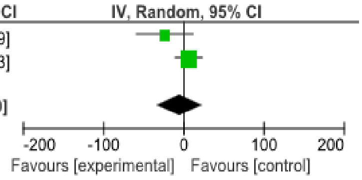
Heterogeneity: Chi² = 0.00, df = 1 (P = 0.98); I² = 0%
Test for overall effect: Z = 0.75 (P = 0.45)



Long term follow-up

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Biddle 2015	637.46	100.62	45	661.37	71.83	51	35.8%	-23.91 [-59.31, 11.49]
Laska 2016	78	80.27	179	72	78.92	173	64.2%	6.00 [-10.63, 22.63]
Total (95% CI)			**224**			**224**	**100.0%**	**-4.71 [-32.81, 23.40]**

Heterogeneity: Tau² = 248.23; Chi² = 2.25, df = 1 (P = 0.13); I² = 55%
Test for overall effect: Z = 0.33 (P = 0.74)



Five of these studies reported short-term measures (Barwais, Cuddihy and Tomson, 2013; Carr et al., 2013; Biddle et al., 2015; Júdice et al., 2015; Maher and Conroy, 2015) showing a mean reduction of -67.72 min/day (95% CI -132.82, -2.62, I^2=80 %, n=283) in favour of the intervention group. Two studies (Ashe et al., 2015; Laska et al., 2016) reported medium-term measures showing a mean reduction of -5.92 min/day (95% CI -21.32, 9.48, I^2=0%, n=413). Two studies (Biddle et al., 2015; Laska et al., 2016) reported long-term measures showing a mean reduction of -4.71 min/day (95% CI -32.81, 23.40, I^2 = 55%, n=448), with substantial heterogeneity in the observed effects studies.

2.4 Discussion

This systematic review and meta-analysis found that SB reduction interventions using computer, mobile and wearable technology resulted in a mean reduction of 41 min/day in the intervention group at endpoint follow-up. Interventions focusing on workplace SB showed a mean reduction of 40 min/workday in the intervention group at endpoint follow-up. Interventions focusing on overall daily SB showed a mean reduction of 45 min/day in the intervention group at endpoint follow-up. Due to risk of bias issues, caution should be taken whilst interpreting these results. Nevertheless, these reductions are encouraging as it has previously been reported that every 30 minutes of SB reallocated to light PA results in a 2–4% improvement in triglycerides, insulin, beta-cell function biomarkers (Buman et al., 2013), suggesting clinically meaningful health outcomes.

The magnitude of the mean reduction in sedentary time in this review (41 min/day) is in line with a previous meta-analysis reporting a 42 min/day reduction (Martin et al., 2015), however, is well below the 91 min/day reduction reported by Prince et al. (2014). This inconsistency may be explained as Prince et al. (2014) included non-randomised trials and focused on any intervention that targeted PA and/or SB

The reduction of approximately 40 min/workday in intervention group in this review echoes results from a similar meta-analysis which also showed a reduction of 40 min/workday in favour of the intervention group (Chu et al., 2016). Other systematic reviews have shown slightly higher reductions in SB among intervention participants. For example, activity permissive workstation interventions have been reported to contribute to a reduction of 77 min/workday in favour of the intervention group (Neuhaus et al., 2014 a). It is likely that this larger reduction is due to intervention type investigated. These interventions allow participants to stand but also continue working. Although this represents a higher reduction than seen in our review, these work stations are costly to provide and their widespread deployment may not be feasible. From a public health perspective computer, mobile and wearable technology may hold promise for large-scale, cost-effective interventions (Lyons et al., 2017, Thomas and Bond, 2014; Direito et al., 2016).

The inconsistencies in the above comparisons may be explained by differences in inclusion criteria, as most of these reviews included studies that aimed to increase PA, and/or reduce SB or addressed interventions that reported on SB outcomes, however, did not necessarily target SB in the intervention (Chau et al., 2010; Prince et al., 2014; Gardner et al., 2015; Martin et al., 2015; Shrestha et al., 2016; Chu et al., 2016; Direito et al., 2016; Schoeppe et al., 2016). This may be relevant as intervention components that successfully increase PA, may not effectively reduce SB, and vice versa (Gardner et al., 2015). Furthermore, many of the studies in these other reviews were composed of small sample sizes, used different study designs and intervention durations, used a range of SB measurement tools and varying comparator groups.

Results from the meta-analysis suggest that SB interventions have the greatest effect on sitting in the short-term ($\leq$ 3 months), with results lessening over time. Interventions targeting overall daily sitting time also follow this trend. The attenuation of the effects on sitting reported by Martin et al. (2015), is similar to that reported in our results, with the greatest impact on SB reduction (42 min/day) in the short-term ($\leq$ 3 months) follow-up declining to 3 min/day at long-term follow-up (>12 months). These results suggest that maintaining long-term behaviour change is challenging, possibly due to the wearing off of the initial "novelty" of technology mediated behaviour change interventions (Eysenbach, 2005; Yardley et al., 2016).It must be noted that only three studies reported long-term follow-up measures of SB highlighting a lack of evidence for long-term SB reductions. It was also not possible to analyse interventions targeting workplace sitting at long-term follow-up points as there was insufficient data to conduct a meta-analysis. This lack of long-term evidence is seen in other reviews exploring interventions to reduce SB (Chau et al., 2010; Commissaris et al., 2015; Chu et al., 2016); where they also did not or could not evaluate long-term effectiveness. Given the importance of sustained behaviour change for health effects, this lack of data highlights the need for studies to examine the effects of longer term SB interventions and over longer follow-up periods.

Greater reductions in SB were found in studies where self-report/proxy measures (53 min/day) of SB were used compared to objective measures (35 min/day). This was also seen in a similar meta-analysis on interventions to reduce SB (Martin et al., 2015). This may be due to the subjective assessment of SB being limited by the ubiquitous nature of the behaviours, which may be unremarkable, intermittent and incidental and therefore difficult to accurately recall (Shephard and Tudor-Locke, 2016). Objective measures are also not without limitations. It was not possible to compare cut points and wear time algorithms used in studies, it should be noted that these differences may introduce differences in the scale observed. The development and refinement of valid and reliable objective measures of SB which can incorporate the type and contextual factors, as well as clear guidelines on wear time and cut points are required (Atkin et al., 2012).

This is the first review to collate BCTs used in SB change interventions using computer, mobile or wearable technology in adults. The aim was not to provide definitive conclusions regarding the most effective behaviour change intervention components, but code to identify which techniques have been used to reduce SB. It is, however, difficult to conceptually separate PA promotion and SB reduction components within an intervention (Gardner et al., 2015). In typical applications of

BCT taxonomies in other literatures, a single behaviour is defined and targeted by the intervention, and the link to BCTs can be assumed to be explicitly related to changing that single behaviour (Presseau et al., 2015). The reality of the design and reporting of many interventions within this review is that they target multiple behaviours and outcomes. Thus, making it more difficult to link BCTs to specific behaviours. Moreover, there was a lack of clear and consistent reporting of which BCTs were undertaken within each intervention making classification of BCTs difficult, this issue has been noted in another study analysing BCTs in health behaviour change interventions (Soltani et al., 2016). Research is warranted to identify the 'active ingredients' of successful interventions to refine the design of optimal BCT use and produce an evidence base upon which SB interventions can be developed. In order to assess the impact of BCTs, the reporting of intervention content must be improved. Researchers should "clearly define and provide a rationale for all BCTs that have been included" with full intervention manuals being provided as supplementary electronic files (National Institute for Health and Care Excellence (NICE), 2014). In complex interventions, clearer delineation of strategies used to change PA and SB, respectively, in intervention reports is required.

The most frequently coded BCTs to reduce SB across the interventions as a whole were "instruction on how to perform a behaviour" "social support (unspecified)", "prompts and cues" and "adding objects to the environment". Whereas, the most frequently coded BCTs for computer, mobile and wearable components of the interventions were "prompts and cues", "self-monitoring of behaviour", "social support (unspecified)" and "goal setting". These differences suggest some BCTs may lend themselves well to certain modes of delivery and that the BCTs identified in the technology components might fruitfully be incorporated into future technology based interventions to reduce SB.

When comparing the computer, mobile and wearable components in workplace interventions and overall daily interventions, "prompts and cues" was more frequently coded in workplace interventions and "social support (unspecified)" was more frequently coded in overall daily interventions. This reflects the results in Gardner et al. (2015) where it is suggested that workplace SB may be more receptive to planning and routinisation than non-workplace SB, which occurs in less predictable and structured contexts. This highlights the need for interventions to be chosen on the basis of what is most appropriate and feasible in the specific setting (Michie, Atkins and West, 2014). The high usage of the BCT 'prompts/cues' identified in this review and that of Direito et al. (2016) illustrates that technology may be harnessed to facilitate intervention delivery, however, also to conduct intervention "top-ups" beyond the intervention core duration. This may be a vital component for interventions to prevent relapse.

This study has a number of strengths, including a comprehensive search strategy in multiple databases and the adherence to methodological criteria for high quality-systematic reviews and meta-analysis. In addition, the systematic detailing of BCT coding procedures using the most recent BCT taxonomy (v1), allows future researchers to replicate and review methods used in detail. However, non-English publications were excluded from review and the search was limited to peer reviewed publications. There was considerable heterogeneity of included studies with regard to intervention type, sample size, follow-up duration, type and outcome estimates and no meta-regression was performed. Baseline sitting levels varied across the studies, the scope for change post intervention may be influenced by how long participants sat pre intervention. It must also be noted that how central technology was to each intervention varied greatly. 13/17 included studies were of high risk of bias, with particular concerns in the areas of detection and attrition bias. Six studies were at high risk of attrition bias due to high dropout levels. SB measures used to determine intervention effects in this analysis were measured through subjective measures in seven studies and thus were at high risk for detection bias. These identified methodological flaws present a problem when trying to draw conclusions and evidence presented in the current review should be interpreted with caution. This review also included ‘active’ comparator groups which may contribute to smaller intervention effects. It was not possible to statistically analyse the individual effectiveness of BCTs or to assess the effectiveness of different combinations of behaviour techniques due to the number of different combinations of BCTs present within studies. In order to address this, future study designs could consider using adaptive interventions such as sequential multiple assignment trials (SMART) (Murphy et al., 2005) or multiphase optimisation strategy (MOST) designs (Collins et al., 2005). Finally, technology development often out-paces academic research

(Agarwal et al., 2016) and this review includes two studies using the Gruve activity monitor which is no longer commercially available.

This systematic review provides a useful overview of the effectiveness of computer, mobile and wearable technology interventions in reducing SB and has exposed important gaps in the current evidence base which warrant further attention. Future research should focus on attrition rates to reduce drop out and improve engagement. Such studies may consider using technology to refresh the intervention, varying the approach or introduce a new intervention as time passes to encourage long-term maintenance of SB reductions. Furthermore, research should aim to improve detection bias by using objective measurement tools of SB e.g. accelerometer/inclinometer, in order to better detect intervention effects. The lack of long-term follow-up highlights the need for extended follow-up in future studies to examine potential long-term impacts of SB interventions. We also recommend including outcome measures that will be of interest to workplaces and policy makers to determine efficient use of resources such as the cost-effectiveness of technology supported strategies to reduce SB.

2.5 Conclusion

This review provides new knowledge regarding technology interventions incorporating BCTs for reducing SB. Our findings suggest that computer based, mobile and wearable technologies appear to be promising approaches to reduce SB. However, due to risk of bias issues, caution should be taken whilst interpreting these results. The reduction in sitting time appeared to be most prominent at short-term follow-up and attenuated over time, with the exclusion of interventions targeting work place sitting, where results were most prominent at medium-term follow-up. A range of BCTs were implemented in these interventions. Future studies need to improve reporting of BCTs within interventions and address the methodological flaws identified within the review through the use of more rigorously controlled study designs with longer-term follow-ups, objective measures of SB and the incorporation of strategies to reduce attrition.

Note: The searches from this study were carried out in June 2016. This systematic review and meta -analysis was published in IJBNPA in August 2017 (Appendix A) . In order to keep abreast of the current literature in this area, the same search terms were used to explore PubMed for recent eligible studies in August 2018. These findings are discussed in the concluding chapter (Chapter 6).

Chapter 3 - Understanding the barriers, facilitators and potential technology supported strategies to reduce sitting at work: Exploring the views of desk-based office workers and their employers.

3.1 Introduction

As previously outlined in Chapter 1, prolonged occupational sitting has been linked to several negative health concerns. To reduce the risk of desk-based employees developing health problems there is a pressing need for future workplace health interventions to reduce occupational SB (Kazi et al., 2014; De Cocker et al., 2015). In order to develop effective workplace SB reduction interventions in the occupational setting, it is important to identify the barriers and facilitators beforehand so they can be anticipated, facilitating implementation (Wierenga et al., 2013).

Changing a behaviour requires an understanding of the influences on the behaviour in the context in which they occur (Atkins et al., 2017). Focus-group interviews are increasingly popular in health research for exploring what individuals believe or feel about certain issues, as well as why they behave in the way they do (Rabiee, 2004). Focus groups explore specific topics and individuals' views and experiences, through synergistic interaction (Litosseliti, 2003). They allow researchers to consult with members of the target population to determine intervention needs and design from their perspective (Rennekamp and Nall, 2006). Taking their views on perceived barriers and facilitators and strategies may make an intervention more likely to succeed long term (Wierenga et al., 2013; Deliens et al., 2015). It is also essential to ensure all key stakeholders are given a voice in developing health promotion interventions (Van Berkel et al., 2014 b). As such, in the workplace setting there is a need to take into account the beliefs of employers and company board members alongside those of the employees (De Cocker et al., 2015). Buy-in from top-level management appears to be imperative for the success of workplace health initiatives (Waters et al., 2016), which reflects their role as financial gatekeepers and decision makers, dictating what initiatives are rolled out within the companies.

There are only a small number of focus group and interview studies which have identified barriers and facilitators to reducing SB at work, from the perspective of both the employees and their managers, with none of these consulting managers at a board level (Cole, Tully and Cupples, 2015; Hadgraft et al., 2016 b; Waters et al., 2016). Identified barriers were the nature of computer-based work, business and social norms, seated workstations and the office environment, while facilitators included; managerial and peer support, having a reason to leave desk and relief of musculoskeletal symptoms associated with prolonged sitting. Strategies suggested from these studies included SSWD, active or standing meetings, centralised facilities, education and managerial role modelling.

Although activity trackers, mobile phone apps and digital prompts were also briefly mentioned as potentially feasible strategies (Hadgraft et al., 2016 b; Waters et al., 2016), they were not the focus of the discussions. There is very little evidence exploring employee perceptions of how these types of digital tools would be received as an intervention to reduce occupational SB. Furthermore, even less research has been conducted on how other key stakeholders such as managers and board members perceive technology as a workplace intervention strategy, particularly in preparation for a SB reduction intervention.

The current study sought to address these gaps in the evidence by exploring the perceptions of employees, employers and company board members on the barriers and facilitators to reducing sitting at work and ascertain their beliefs regarding implementable strategies with an emphasis on technology supported approaches.

3.2 Methods

Invites and information sheets were sent to three private companies and two public organisations in NI. These were identified based on the researchers' networks. In each organisation a contact person assisted with identifying and inviting potential participants from within the business. Those interested were provided with participant information sheets detailing all aspects of the study and were given at least 48 hours to reflect on the information and ask any questions (Appendix D).

Employees were recruited if they met the following inclusion criteria; desk-based office workers aged 18-65 years, working at least three days per week and fluent in English. Employees were excluded if they were non-ambulatory or pregnant. For employers to be eligible they had to be aged 18- 65 years, business owners, line managers or responsible for organisational occupational health and safety, and fluent in English. Board members had to be aged 18-65 years, fluent in English and a member of the board of directors from the company/organisation.

It was planned to conduct three to six focus groups per category (employee and employer), with five to eight participants per group. This was based on previous evidence that as few as three to six focus groups are likely to identify 90% of themes within a discussion (Guest, Namey and McKenna, 2016). The target number per group was five to eight, based upon recommendations for non-commercial research by Krueger and Casey (2015). Focus groups were deemed most appropriate for the employee and employer groups. This was not possible for board members due to a smaller pool from which to recruit and scheduling conflicts, therefore individual interviews were used instead to gather data.

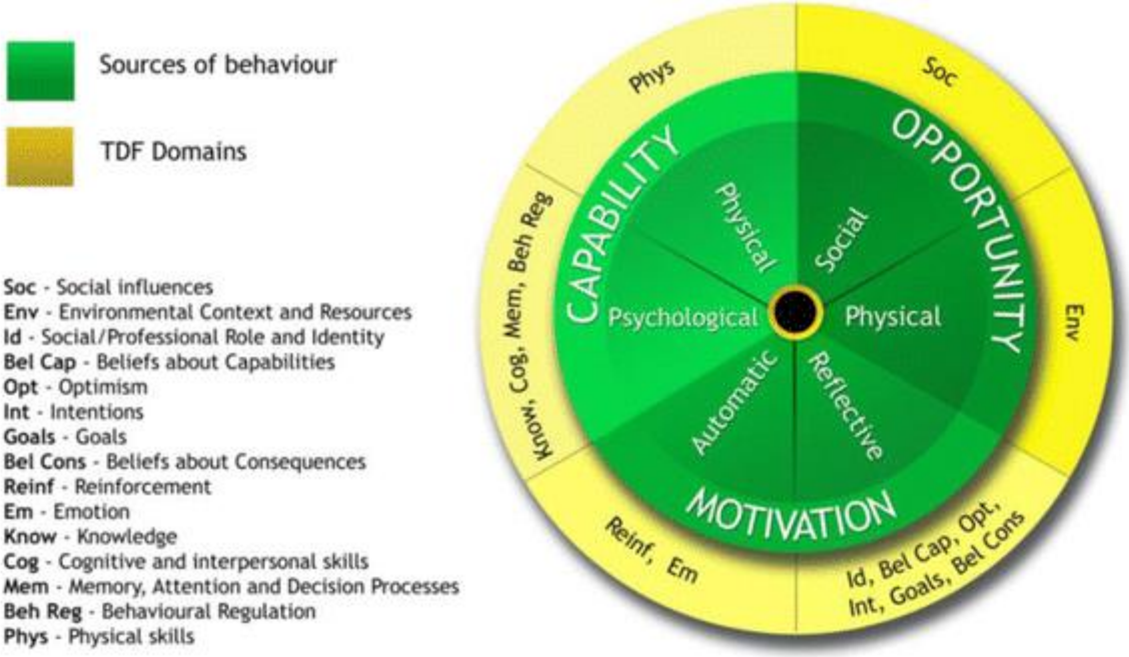
Participants were assigned to a focus group/interview at their place of work. Employee, employer and board manager discussions were conducted separately to avoid group hierarchies. Prior to the focus group, written informed consent (Appendix E) was obtained and participants completed a demographic questionnaire with questions regarding their age, sex and self-reported sitting at work (Appendices F and G). Ethical approval was granted by Ulster University's School of Sport ethics filter committee (Appendix H).

The questioning routes were similar for all groups, centering on attitudes toward workplace SB, perceived effects on productivity, difficulties in reducing SB and strategies to reduce SB. Appendices I, J and K show the topic guides used during the discussions. Development and content of the topic guide was shaped by the academic experience of the research team and the components of the Theoretical Domains Framework (TDF) (Cane, O'Connor and Michie, 2012).

The TDF simplifies and integrates a plethora of behaviour change theories and make theory more accessible to and usable by other disciplines (Cane, O'Connor and Michie, 2012). It originally consisted of 12 domains (Michie et al., 2005) and the more recently refined framework contains 14 domains (Cane, O'Connor and Michie, 2012). These domains are: 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; Emotion; and Behavioural Regulation. Domain definitions and constructs are available in Appendix L (Atkins et al., 2017). The TDF fits well with the BCW and COM-B system (Michie, van Stralen and West, 2011), discussed in Chapter 1. The domains from the refined framework have been independently mapped onto the COM-B segments by experts in behaviour change, with 100% agreement (Cane, O'Connor and Michie, 2012). The TDF provides a more granular level of understanding and consists of domains that can be condensed to fit the three components of the COM-B model (see Figure 3-1). Using the TDF can explain implementation problems and inform implementation interventions (Cane, O'Connor and Michie, 2012).

This framework provided a theory-informed approach to identify determinants of sitting behaviour (Atkins et al., 2017). It covers a broad spectrum of individual and organisational theories, thereby limiting the risk of omitting important areas (Bussières et al., 2012). Questions were designed to generate discussion and probe for barriers and facilitators to reducing SB within the domains, however the "Skills" domain was not deemed relevant for discussion. Therefore, the questions related to 13 of the 14 TDF domains. As the target behaviour was to reduce SB in employees, the employee topic guide was structured around the TDF. Although an adapted version of these questions was used to guide the employer and board manager questions, these participant groups were also asked about their views on employee sitting and implementation barriers to reducing SB. As this resulted in multiple target behaviours, these were not mapped to the TDF.

Figure 3-1 TDF Domains linked to COM-B components



Source: Atkins et al., 2017

The topic guide was piloted with a group of desk-based office workers (n=8) to optimise comprehension and was amended as required. Changes included; more open questioning, adaptation of wording to ensure simple non-scientific language was used and no leading questions were asked. Data from these pilot interviews were not included in the data analysis.

All discussions were led by a moderator (AS) in order to direct the discussion and keep the flow (Krueger and Casey, 2015). The moderator started each session with an introduction on the concept of SB and the known health consequences of SB. Participants were shown an infographic regarding the potential negative health consequences of SB to assist with this (Appendix M). The guidelines and ground rules of the discussion were also set before commencing. Questions largely followed the same format for all three groups, relating to barriers, facilitators and strategies to reducing sitting in the workplace. The questioning was semi structured, broad and open ended in nature to encourage discussion of key topics whilst allowing for flexibility and to speak freely around the issues raised. Probes were used to solicit additional information when required (Litosseliti, 2003). Participants were assured there were no right or wrong responses and the researcher strived to be neutral and non-judgemental in approach. All focus groups and interviews were audio recorded. The focus groups and interviews were conducted between March and June 2017 in a private room at their place of work, where a light lunch was provided.

3.2.1 Data Analysis

Descriptive analysis of the demographic questionnaire data was conducted using the Statistical Package for the Social Sciences (SPSS) (IBM SPSS, Statistics for Windows, Version 23.0) to summarise participant characteristics.

The audiotaped focus groups/interviews were transcribed verbatim by AS. Anonymity was assured by removing participant information and any references made that could lead to identification (e.g. the names of any workplaces or colleagues) from the transcripts. Thematic analysis was used to systematically identify, organise, and offer insights into patterns of meaning i.e. themes (Braun and Clarke, 2006).

To undergo a process of familiarisation, each transcript was read independently several times by two members of the research team (AS and JM), searching for meanings and patterns in the data. Line-by-line coding was then undertaken by JM and AS independently, to assign conceptual labels to relevant excerpts. After both researchers had separately identified initial codes and applied these to the dataset, they met to discuss doubts or disagreements until consensus was reached. This consensus stage was assisted by IW, an expert in qualitative methods. The codes were then sorted into potential themes under the guidance of IW. This led to the development of a thematic framework which was iteratively refined to reflect emerging views, with constant moving back and forward between the entire data set, the coded extracts and the themes being produced (Braun and Clarke, 2006). Themes were refined by expanding and collapsing them as required. Consensus was then reached on the finalised themes by three members of the team (AS, JM, IW). Pertinent quotes were selected to characterise each theme.

3.3 Results

Baseline demographics are presented in Table 3-1. Five focus groups were conducted with employees (n=27 participants, 37% female, 4-8 participants per focus group, mean age 33 years). Four focus groups were conducted with employers (n=19 participants, 42% female, 4-6 participants per focus group, mean age 44.16 years,) and two interviews of board members (n=2, 50% female) were conducted. A range of different job roles were represented including architects, engineers, clerical officers, receptionists, human resources and software developers. There was a wide range in the amount of formal education received by participants and length of time in the company. The companies involved, consisted of an architectural firm (45 staff members), developers of medical postural equipment (189 staff), a technology company (17 staff), district council (255 staff) and a regional governmental department (83 staff). None of these companies had implemented any formalised approaches to reducing SB. Employees self-reported sitting for 6.7 hours ± 0.9 at work each day. The discussions ranged in length from 23 to 56 minutes with an average duration of 43 minutes. All participants took part in the discussions.

Table 3-1 Demographic Characteristics

	Age (years ± SD)	Gender (% female)	Career level	Years in company	Educational level	Self-reported daily occupational sitting time (hours ± SD)
Employees n=27	32.96 ± 12.3	37%	Entry= 3.70% Junior= 14.81% Intermediate= 55.56% Senior= 25.93% Lead= 0%	0-1 years= 22.22% 1-2 years=18.52% 2-5 years=29.63% 5-10 years =7.41% 10+ years= 22.22%	(n=26) Level 8 = 0% Level 7 =42.31% Level 6 =34.62% Level 5= 7.69% Level 4= 3.85% Level 3 =7.69% Level 2 =3.85%	6.70 ± 0.90
Employers n=19	44.16 ± 8.57	42%	Entry= 0% Junior= 0% Intermediate = 47.37 % Senior= 36.84% Lead = 15.79%	0-1 years= 0% 1-2 years=5.26% 2-5 years=5.26% 5-10 years =21.05% 10+ years=68.42%	Level 8= 5.26% Level 7= 57.90% Level 6= 10.53% Level5 =5.26% Level 4= 10.53% Level 3= 5.26% Level 2= 5.26%	Not collected
Board Member n=2	(n=1) 49	50%	Lead= 100%	10+ years= 100%	Level 7= 100%	Not collected

± standard deviation, Educational Level: Level 8 (PhD, Doctorate, Higher Doctorate), Level 7 (Master's Degree, PGCE, PGDip PGCert, Level 6 (Bachelor's Degree, Graduate Certificate/ Diploma, Professional Certificate in Education), Level 5 (e.g. Foundation degree, HND, DipHE), Level 4 (Diploma, CertHE), Level 3 (A level, AS level, NVQ), Level 2 (GCSE, NVQ), Level 1 (Other)

3.3.1 Themes

3.3.1.1 Overarching theme

The themes are presented below and in Table 3-2. The overarching theme to emerge from the data was the primacy of work. The employees, employers and board members felt that while at work, an employee's main priority was to complete job tasks and meet the required business objectives.

"*When you're in work you're, you're there to do your job which is to be productive and get your work done*…" Focus Group 2, private employee

Table 3-2 Themes associated with reducing workplace SB

Overarching theme: Primacy of Work			
Themes	**Barriers**	**Facilitators**	**Barrier & facilitator**
Environment	IT reliance		Office design
Productivity	Workplace priorities		Break of flow Nature of the job
Judgemental Culture	Perception of work avoidance		Acceptable to move
Knowledge	Why and how to change	Evidence based change	Health

Four further themes were identified from the analysis which captured the barriers and facilitators to reducing employee sitting. These themes were: 1. Environment (Office design, Information Technology (IT) reliance), 2. Judgemental Culture (Perception of work avoidance, Acceptable to move), 3. Productivity (Nature of Job, Workplace priorities, Break of Flow), 4. Knowledge (Health, Why and how to change, and Evidence based change). The major themes for barriers and facilitators were similar across employees, employers and board managers. Within the four themes, four barriers, one facilitator and five that were deemed both barriers and facilitators were observed. The perceived barriers and facilitators were often two sides of the same coin (e.g., lack of facilities to allow standing at work, and the need for standing equipment as a facilitator).

3.3.1.2 Environment

In general, participants reported that the office design (desk space, canteen, meeting rooms) was centred around sitting. All staff involved in this study used a seated workstation and did not have access to a SSWD. This inadaptable seated environment was seen as a major barrier to reducing SB.

"It's the office environment, you know the furniture, so it's naturally geared towards sitting and so are the meeting rooms." Focus Group 4, public employee

Most participants agreed that having access to height adjustable furniture would encourage them to reduce their SB. It was noted that these are costly and may not be used in the long term.

Participants recognised that they felt "at home" while at their desks. This was seen as a barrier to reducing SB as it reduced incidental opportunities to get up and move around as they have all their requirements for the job (e.g. computer, printer, paper files, and bins) to hand.

"You have your computer screen, your information around you, your information on the server, telephone, email, everything so therefore there's no need to move necessarily." Focus Group 4, public employee

In contrast to this, others saw their office design as a facilitator to reduce sitting time. They pointed out that a centralised canteen, coffee machine location, toilet location, having colleagues in other offices in the building encouraged movement and facilitated the reduction of SB.

"The kitchen and meeting rooms are on this level, toilets are on the level below, so you know, even to use bathroom breaks they have to physically walk down the stairs to get to them." Interview 2, private board member

The reliance on computers and landline telephones to complete work was identified as a barrier to reducing SB.

"You can't get up and walk around when you're having to work on a computer." Focus Group 2, private employee

Participants believed they would find it very difficult to complete computer-based work in a standing position without the use of a SSWD. The requirement of an electronic paper trail was seen as a barrier to having meetings away from the desk or face to face communication.

3.3.1.3 Productivity

Workplace priorities were deemed to be a barrier to reducing SB at work. Participants agreed that a reduction in sitting was seen as peripheral to core business, and work demands took precedence.

"I'd prefer not to compromise in standing to do the job if it's not as efficient as me sitting down…" Focus Group 1, private employee

The employees, employers and managers agreed reducing sitting was not a personal or organisational priority and that they did not want staff to engage in anything that may compromise productivity.

"And being old school it has to go with efficiency as well. Can't have all the standing up and walking about and not working, productivity has to be maintained." Focus Group 7, private employer

"Honestly, if I sat less I probably would be getting less done." Focus Group 5, private employee

Being immersed in work was reported as a barrier to reducing SB at work. Some participants found that they needed long periods of time uninterrupted to "get in the zone". Reducing SB by taking a break was seen to be detrimental to the task.

"When you're starting work on something, it takes, as everything, it takes a while to get in to the work and once you're focused on the work you, you don't want to be disrupted doing your work…" Focus Group 7, private employer

However, others acknowledged that breaking up sitting throughout the day allowed employees the opportunity for a "brain break", a chance to refresh and refocus, ultimately leading to better productivity.

"But there's something to be said for productivity and getting your head cleared so, like, that sort of space to come back to be more productive." Focus Group 5, private employee

Some participants believed that sitting comes with a desk job, where the very nature of their job requires them to sit. Their work routines, lack of time and heavy workloads can be seen as a barrier to reduce sitting.

"The nature I think of an office job is that you do come in, you sit down, you do work, primarily on a computer." Focus Group 1, private employee

There was also the perception that the amount of sitting done in the workplace and the scope for reducing these levels is dependent on professional roles and tasks. Some participants reported having tasks integral to their job description gave opportunity to perform tasks away from their desk, such as site visits, reducing the amount of time they spent sitting.

“I mean, when I say that there's work reasons for them to move about, so the time that they sit is limited but it’s probably over and above what would be ideal.” Interview 1, public board member

3.3.1.4 Judgemental culture

The feeling of being judged by colleagues and managers as trying to avoid work acted as a barrier to reducing SB. Staff did not want to be seen to be engaging in anything that may not be an acceptable social or professional norm.

“I suppose in some type of cases, if you’re, you’re perceived to be walking about the building then you might be not actually doing your job, so there's a balance to be had between getting up and going for a walk and kind of getting away from sitting.” Focus group 8, public employer

Most participants wanted to fit in with their peers and engage in acceptable workplace norms. There were concerns that reducing SB may distract their colleagues or draw unwanted attention to them so that they “stand out” from the crowd. There was also the belief that standing may be seen as unprofessional in certain situations e.g. a meeting where others are seated.

“I think if I was to stand at a meeting while everybody else was sitting, you might, I would certainly would feel it, that it might make everyone else feel uncomfortable, it’s not really the done thing, is it?” Focus group 4, public employee

In order to make it acceptable, participants reported the need for a valid reason to be away from your desk. Participants commented that knowing they had their employers backing would facilitate reducing SB.

“I suppose employees don’t want to be doing something that they see isn’t supported by their, by their managers so from that point of view and I suppose the other thing as well is employees don’t want to be seen to doing something or taking part in something where there work is going to be affected?” Focus group 4, public employee

3.3.1.5 Knowledge

Participants associated prolonged sitting with musculoskeletal pain from postural issues. It was this belief that acted as a facilitator to reducing SB, not because it may improve their health status.

"It's not good for like back problems and stuff, you people who already have sort of problems with their back or whatever, prolonged sitting can affect it you know sitting all day." Focus Group 2, private employee

They acknowledged a vague awareness of other negative health consequences linked to prolonged sitting e.g. weight gain, poor circulation, but that they lack good insight.

"I just feel like I'm not aware of like any kind of research that says you should not be sitting for seven hours, I don't know, I think there's a feeling its maybe healthier if you can get up and about and be more mobile but that's just a perception…" Focus Group 3, public employee

Participants generally reported high levels of occupational sitting amongst employees. This was seen as a norm, not only at work, but they felt conditioned to sit across all parts of their day. However, many believed that office sitting was regularly interrupted to get coffee, go to the printer, visit the bathroom etc. Many participants did not perceive occupational sitting as problematic. A potential lack of knowledge was identified concerning the current evidence on SB reduction, the parameters of "prolonged sitting", how to reduce SB and why this would be beneficial to employees.

"*We don't quite know how [to reduce SB], nor how much, but nor do we really have a clear idea how we can achieve that without causing extreme disruption to the productivity and to the environment so we don't."* Focus Group 2, private employee

There were also concerns regarding standing as a replacement activity. Many participants expressed concern that standing may cause discomfort and held doubts regarding the benefits of replacing sitting with standing, as opposed to engaging in light PA. There was a general consensus that more understanding by all stakeholders may help to reduce SB, but also a need for compelling evidence to justify changes was noted. An evidence based business case covering employee health, productivity and absenteeism was believed to be required to obtain buy in.

"*I don't know if there is any, you know concrete research that links those medical benefits [from reducing SB] directly to productivity of a company and if you're able to show that at a board level, I think they would be very much more engaging…"* Focus Group 6, private employer

3.3.2 Suggested Strategies

Table 3-3 lists the suggested strategies and considerations for intervention designers that could be implemented in the workplace to reduce SB. These strategies were broken into five approaches; 1. Environmental, 2. Workday, 3. Organisational, 4. Educational, 5. Team. The final section deals specifically with technology supported strategies.

Table 3-3 Strategies

Strategies	Examples	Considerations
Environmental Approach	• Height adjustable furniture • Centralised facilities e.g. printers, coffee machines • Open plan office • Portable IT equipment • Active sitting furniture e.g. desk pedal exerciser	• New equipment may not be used after initial novelty period • Space issues • Cabling • Cost • Working at standing height may be visual invasion/distraction to others
Workday Approach	• Standing/walking meetings • Use breaks effectively • Drink more water • Incorporate standing/moving into work tasks e.g. while on phone, visit colleague instead of email	• Breaks should be purposive where possible so as not to affect productivity • Use opportunities for incidental movement
Organisational Approach	• Managerial role model • Flexi hours policy	• Better uptake with board buy in
Educational Approach	• Distribute information and awareness regarding the issues of SB at work • Educational posters • Tip of the week • Health checks • Suggest alternatives to sitting	• Shock tactics with health risks linked to SB
Team Approach	• Office competitions	• Adds social element • Competition may draw unwanted attention to those at top and bottom of table

Environment: These strategies generally focused on the addition of standing friendly furniture, that would allow them reduce their sitting without impacting on their work performance. These suggestions were met with concerns regarding cost, low usage and space constraints.

Workday: Participants recognised opportunities in the work day to reduce SB e.g. walking meetings and active lunch breaks, so as not to interfere with productivity.

Organisational: The introduction of strategies such as “Sit-Less” role models (preferably a manager) and a flexi working policy whereby employees knew it was acceptable to break sitting were popular.

Educational: Approaches to educate staff about the potential negative health consequences and impacts on productivity were acknowledged as potential strategies.

Team: A team based “Sit-less” competition approach was suggested to introduce a fun element and foster social connections.

Although these strategies were seen as possible feasible options, it was acknowledged that there was no ideal “one size fits all” approach. Strategies must consider the type of worker, the tasks involved and their personal preferences. There were differing views on whether strategies should be obligatory or have an element of choice.

The technology strategies that were suggested by participants were categorised into two approaches: 1. Digital reminders and prompts and 2. Activity/SB monitoring. These are detailed in Table 3-4.

Table 3-4 Technology Strategies

Technology Strategies	Examples	Considerations
Digital reminders and Prompts • To draw attention to the behaviour	• Alarms • Apps • Vibrations • Emails • Computer alerts • PC "lock outs"	• May be ignored • May be used sporadically or not used after novelty wears off • Prompts may become distractions/annoyance/ stressful • Frequency and timing of prompts • Unprofessional
SB/PA monitoring • To allow users self-monitor their sitting/activity • To set goals to reduce SB • To allow them receive personalised feedback on their sitting/activity • To allow competition	• Wearable devices e.g. Fitbit/Apple watch • Pedometers • Apps • Stairs counters	• May be used sporadically or not used after novelty wears off • Wearables currently "trendy" • Wearables can be costly • Devices need to be quick and easy to use • Require minimal interaction • Can become demotivating if not meeting-guilt onset • Feedback can come across as patronising • People can become obsessed with tracking behaviours • Accuracy of data • Unprofessional • Don't want to wear or carry device

Digital reminders and prompts

A digital prompt or reminder was a suggested mechanism to draw attention to long periods of sitting and encourage a break. Suggested ways to do this were via mobile apps, computer software, wearable devices and emails. Some perceived that these reminders may become irritating, distracting or cause unnecessary stress, while others agreed that these prompts may come as a welcome opportunity to break sitting in a structured fashion.

Activity/SB monitoring

It was suggested that using apps, wearables and pedometers to self-monitor SB/PA may allow users to become more aware of SB, receive tailored feedback and track progress. The feasibility of these strategies was met with concerns that the devices were costly and would not be used long-term.

Overall technology was highlighted as a valuable tool, but participants were concerned about long-term engagement and whether using technology at work would appear unprofessional. Participants preferred interventions with low user burden, delivered in a personalised, accurate and non-patronising fashion. In response to being asked about issues with their employer collecting employee activity data, participants were generally not concerned, as long as it was used to improve health, but were not supportive if this data could be used punitively.

3.4 Discussion

Qualitative analysis from focus groups and interviews with employees, employers and board members revealed barriers, facilitators and potential strategies to reducing occupational sitting. The primary observation was that while at work, it was perceived that work is the primary priority. Therefore, initiatives to reduce SB may come secondary to work tasks and should be considered in SB reduction interventions. Other barriers included the office design centred around sitting, reliance on IT to complete work tasks, work tasks taking priority, feelings of being judged as avoiding work and a lack of knowledge on how and why to reduce SB. Facilitators included an open plan office with centralised facilities and standing friendly furniture, "brain breaks" to refresh mind-set, using opportunities within the work day to build in PA, supportive colleagues and managers, relief of musculoskeletal pain and a solid evidence-based business case with buy in from management to reduce SB. Potential strategies such as SSWD, education on the negative health consequence associated with SB and ways to reduce SB, workplace health policies and active breaks were suggested. Technology was generally seen to be a useful tool, with some concerned about long-term user engagement and that using technology at work may appear unprofessional. Participants preferred interventions with low user burden, caused little disturbance, delivered in a personalised, accurate and non-patronising fashion. In particular, its use was thought to be most valuable in providing prompts and as a platform to allow behavioural self-monitoring via smartphone apps.

The emergence of “Primacy of work” as the overarching theme is an important consideration when developing and implementing interventions. Participants believed that the main focus when at work should be on completing the tasks they are being paid to do. Concerns have been noted elsewhere that workplace health interventions may distract workers from their day-to-day duties, negatively impacting productivity (Goetzel and Ozminkowski, 2008; Gilson et al., 2011; Gilson et al., 2012, Hadgraft et al., 2016 b). In the current study, there were varying views on how breaking sitting may affect productivity, with some believing breaks were detrimental and others noting a positive impact. There is a lack of strong evidence available on the direct influence of workplace sitting on productivity (Healy et al., 2012) and this may be a reason for the conflicting views. This highlights the need for future work to explore links between SB breaks and productivity and to use productivity as an outcome measure when assessing intervention efficacy.

Participants in the current study identified aspects of the workplace environment as being both barriers and facilitators to sitting. A systematic review by Gardner et al. (2015) which investigates behaviour change strategies for all types of SB, suggested that SB reduction interventions based on environmental restructuring were amongst the most promising interventions. This reiterates the views of Healy et al. (2012) where it is noted that the built environment plays an important part in reducing occupational SB and is a key consideration in developing occupational “sit-less” programmes. Participants in this study felt that standing friendly furniture e.g. SSWDs were particularly promising strategies as they allowed a reduction in SB without impacting on productivity. Building on strategies to reduce SB throughout the work day e.g. walking meetings was also seen to be feasible. This finding is in line with those of Hadgraft et al. (2016 b) where identifying practices that have dual benefits may encourage greater buy-in.

The effects of social support and social networks on health status are widely recognised as having a powerful protective effect on health and may also encourage healthier behaviour patterns (Donev, Pavlekovic and Zaletel-Kragelj, 2007). Results from the current study also suggest that support from colleagues and managers to reduce SB was seen as an enabling factor, as staff did not want to be seen to be engaging in anything that may not be an acceptable social or professional norm. Similar qualitative findings were reported by Cole, Tully and Cupples (2015), suggesting supportive peers and employers play a key part in the success or failure of an SB reduction programme at work.

Another major barrier to reducing SB was that there was little understanding of its negative health consequences. This lack of understanding is well noted in the literature. Duncan, Gilson and Vandelanotte (2014) suggest that two thirds of the adult population is unaware of the risks associated with prolonged sitting. Participants in the current study did not see SB as an issue and therefore felt no pressing need to change the behaviour. In terms of health, most participants associated SB with musculoskeletal issues and had experienced it themselves. The cardio-metabolic impacts of prolonged sitting were not widely recognised or experienced, which may be due to the relatively young age range of participants. Together, these findings suggest that participants were reactive, rather than proactive, in their approach to SB and health. Participants noted that if they were better informed about the negative health concerns they may face in the future due to prolonged sitting they may be more motivated to change. This fits with results from Tasdemir-Ozdes and colleagues (2016) who found that those who saw future health-related events as important were more likely to make healthy lifestyle choices. Education may work as a strategy by highlighting the potential future negative health consequence associated with a sedentary desk job thereby motivating participants.

A variety of strategies were provided by participants, with varying views on their acceptability. According to participants in this study, there is potential value in using technology as a platform to self-monitor SB in an effort to reduce occupational sitting. This is an encouraging finding as self-regulatory techniques, such as self-monitoring, have been shown to be common features in promising SB reduction interventions (Gardner et al., 2015). Another potentially useful strategy to reduce SB using technology that emerged was prompting users to break prolonged sitting bouts. Technology cues to interrupt sitting at work may be particularly useful for office workers as they noted they are often “lost in their work” at a desk which is designed for sitting. The non-conscious nature of sitting likely limits awareness of true sitting time (Gardner et al., 2017), and this prompt may act as a timely reminder to break their sitting when their focus is elsewhere.

Since this study was conducted three additional focus group or questionnaire based studies exploring the beliefs of employees and/or their managers regarding barriers, facilitators and strategies to reduce occupational SB have been published (McGuckin et al., 2017; Nooijen et al., 2018; Munir et al., 2018). Technology was only mentioned as a strategy to reduce SB in one of these studies (McGuckin et al., 2017). In agreement with the current study, the findings from McGuckin and colleagues (2017) suggested that digital prompts to break SB may be a potentially feasible option. However, exploring participants' perceptions on technology was not the focus of any of these discussions.

Within the identified strategies (both technology and non-technology based) of the current study, there was a desire for choice and individual preference. This view has also been noted in other workplace health promotion studies (including SB reduction) (Gilson et al., 2011; Tsiga, Panagopoulou and Niakas, 2015) due to different office-based roles, as well as individual preferences. This suggests that a "one size fits all" approach may not be effective. Technology offers the ideal platform to overcome this hurdle as it provides opportunity to tailor and personalise the content of the intervention to each participant or group of participants (West and Michie, 2016).

The participants in this study also raised some considerations regarding the use of technology as an intervention strategy. Participants were concerned that prompts may become annoying and disturbing. This concern has also been recognised by

Dennison and colleagues (2013) who suggested reminders and prompts may be considered a nuisance without genuine motivation of the user. Participants in the current study also highlighted the potential for activity monitoring to trigger negative emotional reactions such as guilt by potentially highlighting high levels of SB or low levels of PA. Self-monitoring technology has previously been linked to evoking feelings of guilt in users (Sjjklint, Constantiou and Trier, 2015) however; this feeling of guilt may be an enabler of motivation and willpower (Hoch and Loewenstein, 1991).

The participants in the current study also cited a potential distrust of digitally gathered PA/SB information if not accurate. Sanders and colleagues (2016) suggest that accurate and trustworthy data are required for more potent behaviour change otherwise users of self-monitoring technologies may become disenfranchised. Results from the current study heavily stressed that a successful technology enhanced intervention must have low user burden, should not negatively impact upon their work and should provide accurate data. There were fears that if the intervention did not minimise these issues, it could ultimately lead to disengagement. These challenges are widely noted throughout the digital behaviour change intervention literature (Eysenbach, 2005; Dennison et al., 2013).

Participants in the current study generally did not express concern regarding their employer collecting and having access to their activity data. This is a promising finding as it has been noted elsewhere that technology users may be concerned about the privacy and ownership of their health data (Sanders et al., 2016).

Another consideration for intervention developers in this area is that of using technology to enhance interventions. The combined use of technology to enhance interventions to reduce SB was not a focus of this study; however, most of the non-technology based strategies identified to reduce SB (environmental, workday, educational, and team based approaches) may be enhanced with the assistance of technology. Technology delivered prompts to remind people to use environmental strategies e.g. SSWD or to prompt a standing telephone call or walking meeting may maximise the effectiveness of these intervention approaches. Leveraging technology also allows for educational elements to be disseminated digitally and social support systems to be incorporated into an intervention via group challenges and leader boards. Further exploration of the combined effects of these interventions is warranted.

3.4.1 Strengths and Limitations of the Study.

The strength of this study is that it provides insights into the perspectives of employees, employers and board-level managers regarding occupational SB and technology enhanced strategies to reduce SB. Their voices have been deemed critical in developing worksite health promotion interventions (Van Berkel et al., 2014 b). The study also recruited a heterogeneous sample of office workers of varying professional backgrounds, career levels, ages and sexes deemed to be fairly representativeness of a typical office-based workforce. However, this was a convenience-based sample from two cities in NI, which may compromise generalisability to other locations and transferability to other office-based workplaces. It could be argued that, by taking part in the study, the participants were more aware of the negative health consequences of sitting. However, the sample provided us with differing views on the topic, covering a range of perspectives. The barriers, facilitators and strategies that were generated were, at times, based on hypothetical cases rather than lived experience; however, these perceptions should be taken into account when designing interventions. The presentation given at the beginning of the focus group regarding the definition of SB and potential negative health concerns may have influenced the group discussion. It was decided that this was a necessary part of the study as the pilot session revealed a lack of knowledge on the topic, in particular, a misunderstanding between SB and physical inactivity, which limited discussion. Using the TDF to structure the topic guide ensured a robust theoretical basis to the questioning that covered a wide range of behavioural influences (Atkins, 2017), however it was not used as an explicit framework to guide the analysis of the data. Thematic analysis was selected to allow analysis to be more freely guided by the data rather than the restricted TDF domains. This analytical approach has been used successfully in a previous theory-based, qualitative interview study exploring changes in PA during the retirement transition (McDonald et al., 2015). To ensure reliability of coding and initial data interpretation, analyses were carried out independently by two researchers. Although we reached our target number of focus groups for employees and employers, we did not reach the target of having at least five participants per group. There was one employee and two employer focus groups with only four participants. This may have limited the total range of experiences, however smaller focus groups are gaining popularity as they are easier to host and recruit; and may be more comfortable for participants (Krueger and Casey, 2015). In a workplace setting, due to staff time commitments and busy schedules, smaller focus groups may be more realistic and feasible to conduct.

To our knowledge, this study was the first qualitative study to investigate perceptions of employees, employers and board members regarding the use of technology as a potential strategy to reduce workplace SB, in order to inform development of such an intervention. These findings will assist researchers with future development of such interventions. The findings provide qualitative insights into the barriers, facilitators, potential interventions strategies and considerations that must be given attention when designing interventions to tackle occupational sitting. It was identified that above all, interventions should not impact on the primacy of work. Intervention designers need to consider individual preferences, as well as the environmental factors, the judgemental culture, productivity concerns and the knowledge levels of employees and employers. The diverse nature of the barriers, facilitators and strategies elicited from these results would suggest that interventions should be multifaceted in nature, incorporating a variety of behaviour change strategies.

Chapter 4 - Development of the Digital Intervention

4.1 Introduction

The use of digital technology to monitor and modify health is growing in popularity, with the number of users increasing each year. Accenture conducted a consumer survey on digital health with 7905 adults across seven countries; Australia, England, Finland, Norway, Singapore, Spain and the US. The results showed that 75% of US consumers said technology is important in managing their health (Accenture, 2018 b). Compared to 2016, consumers surveyed in England in 2018 reported that several technologies have become more important to managing their health, including mobile device usage (up from 37 to 48%), and wearable usage (up from 22 to 31%) (Accenture, 2018 a). These figures are similar to the combined figures across the seven countries where the use of mobile devices has risen (up from 33 to 48 percent) and wearable usage also rose (up from 21 to 33%) (Accenture, 2018 b).

Evidence to support digital technologies as intervention tools to improve health behaviours (McIntosh et al., 2017; Oosterveen et al., 2017) and reduce SB is encouraging (Direito et al., 2016; Stephenson et al., 2017) however research relating to how these digital tools can be harnessed to reduce SB is still in its infancy. The systematic review and meta-analysis presented in Chapter 2, suggest that SB reduction interventions using computer, mobile and wearable technology have potential to reduce SB over the whole day and during working hours (Stephenson et al., 2017). Moreover, the qualitative results from focus groups and interviews with office employees and employers presented in Chapter 3, suggest that technology is a potentially suitable platform to deliver occupational SB reduction interventions. There are many features of digital behaviour change interventions that make them potentially effective (West and Michie, 2016). They can broaden the reach and scale of behaviour change interventions, be highly personalised and deliver information in a way that is engaging and rewarding (Lathia et al., 2013; West and Michie, 2016). Research also suggests that technology based interventions can be cost effective and less labour intensive than face to face interventions (Cucciare and Weingardt, 2010; Kruskowski et al., 2011; West and Michie, 2016; Iribarren et al., 2017).

Recent recommendations on the prevention and management of NCDs highlight the need for research focused on behaviour change as the core component (Matheson et al., 2013). The importance of behaviour change theories in digital technologies has also been stressed (West and Michie, 2016). Research suggests that internet based interventions developed with more extensive use of theory are associated with larger effect sizes than those without (Webb et al., 2010). Despite the clear recommendations for use of theory, it appears that many digital interventions lack a theoretical basis to change health behaviour (Bastawrous and Armstrong, 2013; Pagoto et al., 2013; Middelweerd et al., 2014; Watkins and Xie, 2014).

There is a need for the rigorous development and evaluation of new, theory-supported, technology-based interventions to reduce occupational SB. However, reporting on the development steps used in creating health-related digital technology is limited (Kirwan et al., 2010). The process of developing effective digital interventions requires numerous decisions that integrate behavioural theory, user testing, and technical and practical feasibility considerations (Mummah et al., 2016 a; Simons et al., 2018). The BCW as discussed in detail in Chapter 1, provides a structured, theoretical framework for designing behaviour change interventions and strategies (Atkins and Michie, 2015). The model has been successfully applied as a framework to develop digital health behaviour change interventions (Fulton et al., 2016; Tombor et al., 2016).

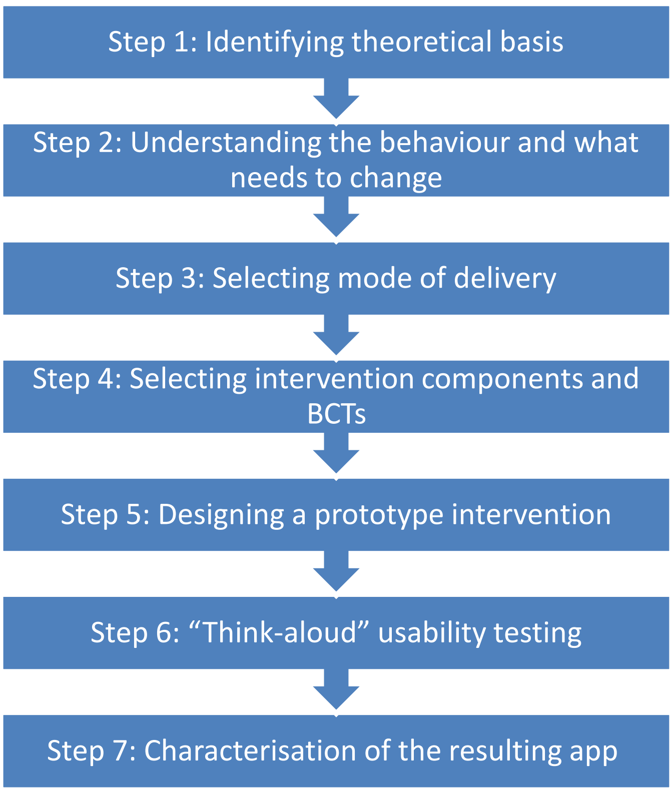
High dropout rates are a typical feature of digital intervention trials to change behaviour, perhaps due to the lack of supervision and direct face to face contact with the researchers (Eysenbach, 2005.). A digital tool is likely to be rejected if it is not perceived as creating any user benefit or if it has usability problems (Eysenbach, 2005). To promote engagement with digital interventions, a “user-centred” approach is essential (Michie et al., 2017). User-centred design (UCD) is an iterative design process in which designers involving users throughout the design process (The Interaction Design Foundation, 2018). This ensures that interventions are responsive to users’ needs and preferences, and are designed “from the ground-up” rather than based on developers’ preconceptions or rigid procurement briefs (Pagliari, 2007; Michie et al., 2017).

The aim of this chapter is to describe the design, development and usability evaluation of a digital intervention to reduce occupational SB. For the purposes of this chapter the word “intervention” refers to the digital element developed in this chapter and not the full multicomponent intervention which is described in Chapter 5.

4.2 Methods

The development process reported in this paper involved the steps presented in Figure 4-1 and were carried out between June and August 2017.

Figure 4-1 Steps involved in the development process



The process was managed by a collaborative planning and design team including; behaviour change researchers, SB/PA experts, computer scientists and target end users. These interdisciplinary collaborations are vital for achieving sustainable growth in the field of digital health (Becker et al., 2014). The process was iterative and involved regular development team meetings, repeated reviews and multiple discussions to resolve issues as they arose.

4.2.1 Step 1 Identifying the Theoretical Basis

The BCW and BCTs were used to guide the process and form a basis for selecting the intervention components. It was chosen to promote a systematic and comprehensive analysis of the available options using behaviour change theory and the available evidence (West and Michie, 2015). The key benefit of using this framework was to allow the designers to be comprehensive in considering all options, to intervene, and then to systematically select those that are most promising for the context (Atkins and Michie, 2015).

4.2.2. Step 2 Understand the Behaviour and What Needs to Change

This step involved defining the problem in behavioural terms, being specific about the population involved in the behaviour, clarifying the behaviour itself and identifying the needs of the target population in order to change the behaviour (Michie et al., 2014). Prolonged occupational SB was established as the problem to be addressed due to the negative health consequences associated with prolonged sitting (Van Uffelen et al., 2010; De Rezende et al., 2014). Reducing total time spent in SB at work was therefore established as the primary target behaviour of the intervention, achieved through reductions in time spent sitting, number of prolonged sitting bouts, increases in interruptions to sitting and transitions from sitting to standing. Individual desk-based office workers were identified as the target population.

The needs of the target population were identified in Chapter 3. Determinants important to employees, employers and company board members were noted. Practical barriers and facilitators to reducing SB at work were used to frame the intervention and guide the proposed approaches and content. Specifically, the development process focused on a personalised approach, minimising impact on work tasks, highlighting opportunities to break SB during the work day so as not to compromise productivity, educating employees regarding the negative health consequences associated with prolonged SB. Their preferences for digital interventions with low user burden, delivered in a personalised, accurate and non-patronising fashion were also considered.

4.2.3 Step 3 Selecting Mode of Delivery

Consensus workshops were held with the research team (AS,JM, CN, MGC, MM, SMcD) to amalgamate and discuss findings of Chapter 2 and Chapter 3, gain expert opinions and draw upon evidence from existing literature. The findings were subject to analysis using the COM-B model and progressed to the selection of intervention functions, as outlined by the BCW framework. Brainstorming sessions were held with members of the design team to define the requirements of the technology supported intervention. The APEASE criteria (Acceptability, Practicability, Effectiveness and cost-effectiveness, Affordability, Safety/side-effects, Equity) was used when making decisions about which technology strategy would be most appropriate (Michie et al., 2014).

During the qualitative work (Chapter 3), digital reminders/prompts and PA/SB monitoring were identified as possible intervention strategies. The research team considered available technologies that could be used to do this in the workplace. Websites and computer based prompts were not selected as they were not portable. Portability was deemed to be an important factor as a portable platform allowed users to interact with the intervention when they were away from their desk e.g. off site or in a meeting. It has been reported that the most promising interventions tend to target SB instead of PA (Gardner et al., 2015; Martin et al., 2015). PA monitors such as Fitbit wearable activity trackers (Fitbit Inc. US) were not used as the design team wanted to focus on SB and not PA or inactivity. These monitors usually contain an accelerometer which can measure PA and/or step counts but may not accurately capture SB and often use low activity counts per minute to imply SB (Tudor-Locke, Camhi and Troiano, 2012). A recent scoping review of devices for self-monitoring sedentary time highlighted there were only a small number of devices capable of providing SB feedback, none of which were originally designed to measure SB (Sanders et al., 2016). Research grade inclinometers are available which can record SB (ActivPAL™), however these are designed for research purposes, lack a user-friendly interface, and are not appropriate for everyday consumer use. This highlights a need for the development of tools to specifically measure and feedback on SB in real-time, as echoed by Sanders and colleagues (2016).

The research team concluded that a smartphone app that allows individuals to monitor their SB by self-report would overcome the device-based measurement issues mentioned above. Mobile phones are ubiquitous, portable, small and light (Boschen and Casey, 2008). In addition, mobile apps to reduce SB were deemed potentially acceptable from the qualitative work in Chapter 3. The research team also had expertise in app development; therefore a smartphone app was the chosen technology strategy.

The use of app interventions to reduce SB is in its infancy, but findings appear promising. Results of the systematic review (Chapter 2) showed that only one RCT used a mobile app as an optional part of a successful intervention to reduce SB. Additional literature searching identified a small number of studies (non RCT) that had delivered SB reduction interventions showing successful reductions in SB via apps (Bond et al., 2014; King et al., 2016). However, the main focus in both these studies was to encourage participants to engage in PA, rather than to specifically reduce their SB.

4.2.4 Step 4 Selecting Intervention Components and BCTs

Out of a possible nine intervention functions within the BCW, the team identified five which were suitable to be incorporated into app components to reduce SB. These were: Education, Persuasion, Enablement, Training and Environmental Restructuring (Table 4-1).

The selection of these intervention functions for inclusion in the app components was determined by:

1. The results from the systematic review (Chapter 2) and qualitative work (Chapter 3),
2. A review of existing apps to reduce SB and other behavioural domains available for download on the Apple app store,
3. An expert discussion and consensus-building exercise on “best bets” was conducted at the consensus workshops described in step 3. Decisions were informed by knowledge of the all the experts on the design team and current evidence,
4. Expert advice on function feasibility in terms of computer programming.

The culmination of these stages resulted in an app consisting of 4 key components:

1. Self-reporting and feedback
2. Prompts to break sitting
3. Goal Setting and monitoring
4. Educational Facts and Tips

Table 4-1 App components aligned to the BCW

Component	COM-B	Intervention Function	BCTs
Self-reporting and feedback	Psychological Capability Reflective Motivation Reflective Motivation Automatic Motivation Psychological Capability Reflective Motivation	Education Persuasion Enablement	2.2. Feedback on behaviour 2.3. Self-monitoring of behaviour 2.2. Feedback on behaviour 2.3. Self-monitoring of behaviour
Goal Setting	Reflective Motivation Automatic Motivation Reflective Motivation	Persuasion Enablement	1.1. Goal setting (behaviour)
Prompts to break sitting	Automatic Motivation Physical Opportunity Psychological Capability	Environmental restructuring Enablement	7.1. Prompts/cues 7.1. Prompts/cues
Educational facts and tips	Psychological Capability Reflective Motivation Physical Capability Psychological Capability Physical Opportunity Automatic Motivation	Education Training	5.1. Information about health consequences 4.1. Instruction on how to perform the behaviour

	Reflective Motivation Automatic Motivation Physical Opportunity Automatic Motivation Social Opportunity		
Providing the app	Automatic Motivation Physical Opportunity Social Opportunity	Environmental restructuring	12.5 Adding objects to the environment

1. Self-reporting and feedback

This was deemed to be the key component of the intervention. It was selected based on expert discussion of the published literature and results of the qualitative study (Chapter 3), that suggested monitoring SB using technology could be a potentially suitable strategy. As was shown in a similar community based "sit-less" intervention using a digital activity tracker, feedback on percentage time spent sedentary was the most important factor in supporting behaviour change (Martin et al., 2017). Furthermore, a recent systematic review exploring interventions with potential to reduce sedentary time in adults recommended that new interventions should be developed around technologies that allow people to monitor their SB (Martin et al., 2015).

The BCTs selected to be used within this app feature were "self-monitoring of behaviour" and "feedback on behaviour". Self-monitoring has been shown to be a particularly promising BCT in interventions to reduce SB (Gardner et al., 2015).

Personalised feedback has also been shown to be effective in digital weight loss interventions and has been suggested as an effective component within technology-based behaviour change interventions (Sherrington et al., 2016).

The concept of self-monitoring is comprised of two major attributes: (1) awareness of bodily symptoms, sensations, daily activities, and cognitive processes and (2) measurements, recordings, or observations that inform cognition and provide information action (Wilde and Garvin 2007). Self-monitoring can make the monitored activities more salient to the user (Klasnja, Consolvo and Pratt, 2011). Feedback allows the rate of progress toward a goal to be determined and augments the effects of self-monitoring (Crane, 2017).

Self-monitoring and feedback was also selected as a key feature because it allows the intervention to be tailored to the individual. Tailoring interventions is crucial as people tend to stop using technologies that do not correspond with their daily lives (Van Gemert-Pijnen et al., 2011). Hence, tailoring to the user's needs and preferences can improve engagement (Michie et al., 2017).

2. Prompts to break sitting

This was selected as an app feature as periodic prompts have been shown to yield positive results in health behaviour interventions to encourage and maintain behaviour change (De Leon, Fuentes and Cohen, 2014).

The specific BCT included in this section was “prompts and cues”. This BCT was selected as it was identified in an intervention description where digital prompts to break sitting were shown to be superior to education alone in reducing occupational SB (Evans et al., 2012).

3. Goal setting and monitoring

Goal setting was added to the intervention components based on the recommendation of its use in behaviour change interventions by the National Institute for Health and Care Excellence (NICE, 2014). It was also selected due to its current evidence base in behaviour change interventions. Having a goal serves as a directive and energising function, and can positively affect persistence and action (Locke and Latham, 2002). Results from a recent meta-analysis (Harkin et al., 2016) also suggest that monitoring goals is an effective self-regulation strategy.

“Goal setting (behaviour)” was included as the main BCT for this intervention component. This was selected as it was identified as one of the most common BCTs in recent systematic reviews (Chapter 2 and Gardner et al. (2015)).

4. Educational facts and tips

The inclusion of educational facts and tips for this intervention component was mainly due to the qualitative results of Chapter 3, which identified a lack of knowledge amongst employees around the negative health issues related to prolonged SB. It cannot be assumed that all members of the general public are aware that sitting could be detrimental to their health, as it is still is an emerging area of research (O'Dolan et al., 2018). It was also identified in a systematic review by Gardner and colleagues (2015), that surprisingly few SB reduction interventions seek to motivate participants through information provision or education. The same review also reported that interventions based on environmental restructuring, persuasion, or education were most promising.

The facts and tips were designed upon the basis of two BCTs "instruction on how to perform the behaviour" and "information about health consequences" to give health advice and tips to encourage less SB at work. Both of these BCTs have been identified as promising in reducing SB (Gardner et al., 2015). Although content of some of the educational tips which were selected randomly from a cluster of 50 may contain other BCTs, it was not the main focus of this intervention component. For example, some tips suggest restructuring office layout to facilitate a reduction in SB. This could be coded as "Restructuring the physical environment" as advice is given to change the physical environment.

4.2.5 Step 5 Designing a Prototype Intervention

Once the intervention content and BCTs were identified, potential versions of an app were discussed amongst the team. A "white boarding" ideation session was held and from that, wireframes were drawn up. These sketches presented a schematic of the main content and a basic design structure. An intervention specification document detailing the design brief was drawn up by the team which was then used to create a high fidelity functional prototype. The app was constructed by MGC using the Xamarin cross platform development tool (Microsoft Corporation, CA, US).

Apps that make better use of app design and technology may improve retention (Zhao, Freeman and Li, 2016). Therefore, the design strategy focused around a simple interface, with easy navigation, comprehensible displays, user friendly language and low text content. The app was designed based on principles from Usability Heuristics for User Interface Design (Nielson, 1995), Eight Golden Rules of Interface Design (Shneiderman, 2014) and Human Interface Guidelines (Apple, 2018). Briefly these principles suggest that the app should:

- Use consistent and familiar terminology
- Offer informative feedback
- Keep displays simple and minimalistic
- Be visually appealing
- Provide clear engaging feedback

As the intervention relies heavily on self-reporting of SB, it was important that data entry was simple. A survey of health app use among US mobile phone owners showed that approximately half of app users stopped using the app, with high data entry burden mentioned as one of the primary reasons (Krebs and Duncan, 2015). Data entry was achieved by moving a fixed-width slider across the screen until the desired value was presented. We based the data entry methods on a previous study which implemented the same data entry mechanism with success (Hartin et al., 2016).

To further promote engagement, the prompts to break sitting were designed to be non-punitive or didactic as this can affect the user experience (Dennison et al., 2013). The use of push notifications was also used to increase user engagement. These were used to remind the user to engage with the app and once interacted with, provided a quick "shortcut" to the apps self-monitoring section, lessening user burden. Functional prototypes were tested iteratively "in house" during development for platform stability and bugs, and were amended as required.

4.2.6 Step 6. "Think-aloud" Usability Testing

Usability is one of the main barriers to the adoption of mobile health systems, (Zapata et al., 2015), particularly smartphones, whose small displays present particular usability challenges (Holzinger and Errath, 2007). Therefore, evaluating usability was an important phase of the development process. "Think-aloud" is a research method in which participants speak aloud any words in their mind as they complete a task, or recall thoughts immediately following completion of that task (Charters, 2003; Eccles and Arsal, 2017). It can be of high value in evaluating a system's design on usability flaws and is therefore frequently used to gather information about a system's usability with potential end users (Jaspers, 2009). It can reveal how intervention techniques are interpreted by the intended recipients, help to ensure the language used is understandable and give insight into what users think of the graphic design, navigation and functionality (Davies, 2016; Crane, 2017). It is an industry standard approach in software development (White et al., 2016), and has been used in similar studies to assess usability in the development of digital interventions (Davies, 2016; Bradbury et al., 2018).

In order to assess the usability of the app developed in this chapter, a "think-aloud" analysis was undertaken (Ericsson and Simon, 1980). Ethical approval was obtained from Ulster University School of Sport research ethics filter committee (Appendix N). A convenience sample of five desk-based office workers (100% Female) was selected. Participants were given participant information sheets and gave written informed consent before the study commenced (Appendix O and P). All sessions were one-on-one and conducted face-to-face by AS. These took place in a private space within Ulster University in September 2017, and each session lasted 20 to 26 minutes.

Participants were given a time compressed version of the functional app prototype, whereby one hour was compressed to two minutes. This was to represent a compressed 8-hour work day, as it was not feasible to test the app over the entire course of a workday. The participants were requested to continue with their work tasks and to interact with the app as prompted (at two minute intervals). Participants were requested to verbalise what they were thinking about, looking at, doing, and feeling throughout the process of engaging with the app. After the compressed work day ended, participants were asked to provide information on how they liked the app, difficulties encountered and suggestions for improvement. The exact questions are available in Appendix Q.

The interviews were audio recorded, transcribed verbatim and analysed with thematic analysis (Braun and Clarke, 2006). This method has been used previously to analyse usability studies of smartphone apps (Lyles et al., 2011; Dennison et al., 2013). The thematic analysis procedure used here was the same as the process used for analysing the focus group and interview data in Chapter 3, where it was discussed in detail. Briefly, the transcripts were read multiple times to familiarise content. Codes were applied to the data set. These codes were then used to devise an initial set of themes which were revised iteratively before producing a final thematic framework. Two major themes emerged from the data; (1) app design and (2) content. These were both considered important elements influencing usability.

Design: The app design theme reflected participants' need for simple data entry systems which did not distract the user from their work. Most participants deemed the slider mechanism as a simple and efficient method of data entry, although one participant mentioned slight trouble with the touch screen when attempting to use the slider. The design of the prompts, their delivery and the repeated need for data entry were flagged by participants as potentially disruptive when workload was high. Participants reported that the app was easy to operate, and they valued the quick and intuitive navigation afforded by the app. The visual feedback graphs and goal setting displays were welcomed by users, however, most participants had issues interpreting the information due to the units not being displayed on the graphs and an inadequate explanation of the goal setting display.

Content: The content of the app was generally seen as useful, educational and informative. One participant felt the app unsuitable for her at work as she preferred to sit whilst at work. The other participants found the content to be thought provoking and motivating. Participants generally liked how the app was not overly complicated and did not have an excessive amount of features. The low app content was praised by users as they felt too much content may be distracting and would overwhelm them with choice.

Overall, participants were very positive about the app. They generally felt that the app was well designed and that the content was relevant. Participants expressed positive interest in the app.

"It's a nice wee app to use, it's very easy, it's good". Participant 1

They used and understood the app without major issues; although some participants were unsure about exactly what they should do when they were prompted to reduce SB and how long they should reduce their SB for.

Participants had suggestions to improve the overall user experience. The visual display of feedback charts could be improved by adding units to the chart. They suggested a short description of how the goal setting feature worked and what the display represented would be beneficial. It was noted that the prompts to log sitting were very frequent which was “annoying”. This was later identified as a bug in the system; when users were entering the data another prompt to enter data was sent to the phone.

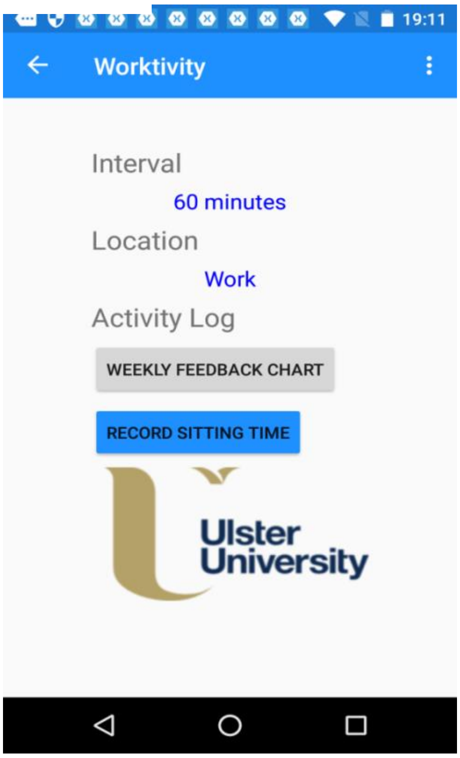
Based on these findings, the interface of the app was adapted and a number of modifications were made to correct errors. Units (minutes per day) were added to the feedback chart and a description of the goal setting feature was added. The new version of the app went through thorough “in house” testing by the research team before releasing a final version.

The issue noted by one user where the slider was difficult to slide across the screen was not fixed as the slider feature was generally well liked by the other participants. The issue whereby users were unsure how long to break sitting by and what exactly to do with their time was also not dealt with in app amendments. This was because the design team did not want to impose tight rules on how to change behaviour and instead wanted users to be free to make their own SB reduction choices.

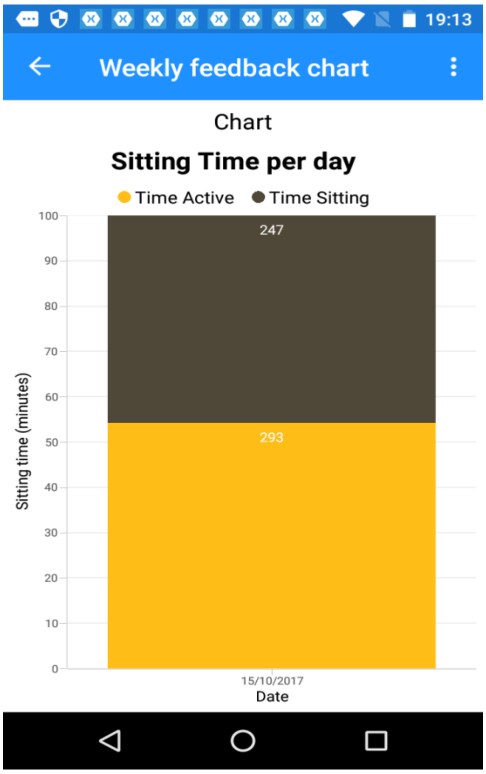
4.2.7 Step 7. Characterisation of the Resulting App.

The research team named the app “Worktivity”, a portmanteau of the words “work” and “activity”. The core component of the mobile app was self-monitoring and feedback of SB at work. This was complemented by additional features focusing on goal setting, prompts to break sitting and educational facts and tips. Screenshots of these features are available in Figure 4-2.

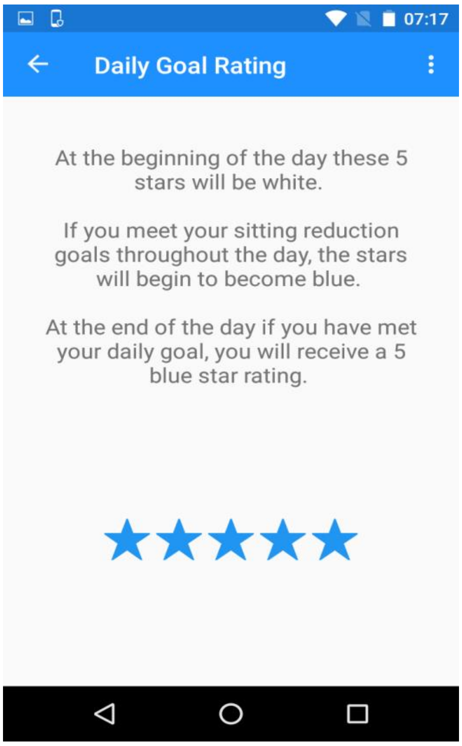
Figure 4-2 App Screenshots



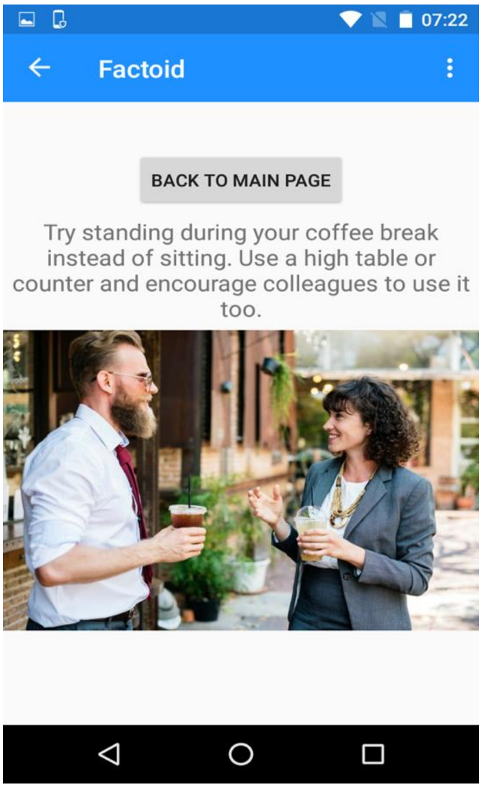
Home Screen



Feedback graph



Daily Goal Rating



Educational Fact/Tip

Description of how the app works

The app allows users to report their sitting each hour at work by responding to a prompt reminder every 60 minutes. The app prompts the user to self-monitor sitting time at work by asking "how much time have you spent sitting in the last hour?", each hour over the eight-hour work day. The first prompt to self-report appears after the first hour of work each day (e.g. 10.00am) and the last self-monitoring prompt occurs just as they are scheduled to leave work (e.g. 5.00pm). Data entry takes place in the form of a user-friendly horizontal "slider" and participants respond to the question by moving the slider to the number of minutes they reported to have spent sitting in the last hour. After five minutes, if no response is entered, a reminder is delivered. Based upon the results of the personalised goal set by the user (discussed below) and their self-monitoring input, if their sitting time is too high, a prompt appears on the screen with advice to break their sitting. This prompt is in the form of a visual screen prompt, vibration and an auditory alarm. Participants can set the phone to their preference of alert but were advised to keep the device's default auditory and vibratory prompts activated.

The app also provides a feedback progress report with graphical displays of time spent sitting and time spent in activity each day. These reports are based on the self-reported data entry. Users can access this feedback at any time and it is possible for users to view the data historically from each day the app was used in the past.

The apps goal setting feature allows users to set goals to reduce SB at work. The goal chosen reflects how much time each day the user wishes to reduce their SB by. The app then calculates how much time the user must spend not sitting each hour of the work day, in order to meet their goal. For example, if a participant sets a 2 hour (120 min reduction) per day “sit-less” goal, the app calculated how much time they need to reduce their sitting by each hour over an 8 hour working day (120/8=15). This means that a participant has to spend at least 15 minutes of each hour standing or moving. Therefore, if the user reports 45 minutes or more of sitting each hour they receive an automated message to stand and/or move. The progress made toward reaching their goal each day is displayed in the form of a goal visualisation section. This allows users to check if they had met their “sit-less” goals. Five stars are presented on the screen, as recommended by Hartin and colleagues (2016) as a variant of a points-earning system. The use of a familiar five star rating system is also in keeping with the guidelines for optimising user interface design (Nielson, 1995; Shneiderman, 2014; Apple, 2018). The stars are designed to encourage behaviour change (Hartin et al., 2016). As the user meets their hourly goals the stars change from white to blue to represent how often they meet their goal each day i.e. if four of eight hourly goals are met, 2.5 stars are shaded blue. All recorded values in the logs are normalised to within a range of 0-5 in relation to the goal (Hartin et al., 2016); i.e. if a user meets every hourly goal over an eight hour work day, five stars are presented, however, if a user meets four of eight hourly goals, 2.5 stars are presented.

All participants received an educational fact and tip at the end of each day when they enter their last data entry report for that day. These included a visual graphic with a snippet of health education advice and a practical tip to reduce their SB at work (Appendix R).

4.3 Discussion

“Worktivity” is a novel, theory based, and user informed mobile app intervention designed to reduce occupational SB. Its development was inspired by the growing health concerns regarding prolonged sitting in office workers (Van Uffelen et al., 2010;) De Rezende et al., 2014), the potential for technology to intervene (Stephenson et al., 2017), plus the lack of existing theoretically based app interventions (Bastawrous and Armstrong, 2013; Pagoto et al., 2013; Middelweerd et al., 2014; Watkins and Xie, 2014), specifically targeting SB reduction.

“Worktivity”’s step by step development and refinement draws on findings from previous chapters, wider evidence, behaviour change theory and user-centred design, in order to address the issues mentioned above. This formative and iterative development process ensured the content and format of “Worktivity” was developed to meet the needs of end users. It also allowed for issues of acceptability and credibility to be ironed out prior to its widespread implementation, thus ensuring the best chance of developing new and effective tools to improve health (Whittaker et al., 2012; Davies, 2016; Simons et al., 2018).

Worktivity is centred on the key component of self-monitoring SB. The data obtained from this is then used to deliver individually tailored behavioural prompts and feedback to office staff to modify SB in real-time. Educational facts and tips were also a feature of the app. These components were selected based upon user preference and theoretical underpinning. Education and self-monitoring have been used successfully in other app based interventions to bring about successful behaviour change

Self-monitoring has successfully been used as part of app based interventions targeting a number of health behaviours including drug and alcohol use (Aharonovich et al., 2017), diabetes prevention in at risk adults (Fukuoka et al., 2015), weight loss and vegetable consumption (Mummah et al., 2016 b). Educational features have also been successfully incorporated into apps, positively targeting health behaviours such as smoking cessation, sun exposure and lifestyle factors associated with stress urinary incontinence (Buller et al., 2013; Asklund et al., 2016; BinDhim, McGeechan and Trevena, 2018).

It is important that apps developed for research purposes match the usability and sophistication that users expect from other "real-world" apps (White et al., 2016). Based on the findings of the "think-aloud" interviews, "Worktivity" was generally deemed to be a well-accepted tool and users were positive about the app features. Usability is one of the main barriers to the adoption of mobile health systems, (Zapata et al., 2015). This is particularly important for "Worktivity" as a digital tool will likely be rejected if it is not perceived as creating any user benefit or if it has usability problems (Eysenbach, 2005).

It has also been suggested that app usability is closely related to engagement, whereby positive experiences of usability can entice users to engage more with the app (Milward et al., 2017).

Amongst the strengths of this work is the collaborative design team involved. Efficient, relationships between a multidisciplinary team including behavioural scientists and computer scientists is recognised as being essential for the success of a digital behaviour change project (West and Michie, 2016). This work also includes a detailed report of the intervention development process, usability evaluations and an in-depth description of the final intervention components. There has been a call for intervention developers to publish processes and outcomes from their development of digital interventions (Whittaker et al., 2012). Sharing these processes will provide design teams with an enhanced grounding of how to use technology to better engage populations in adopting and maintaining health behaviours (Kirwan et al., 2010) and allows for continued learning to improve the quality of interventions (Whittaker et al., 2012). Therefore, the development processes used to design "Worktivity" may be useful to other digital behaviour change researchers.

A limitation of the usability study concerns the representativeness of the sample. The purposive recruitment method used meant the sample lacked heterogeneity. The sample was small (n=5), however, "think-aloud" studies can be performed with small numbers of participants. It has been noted that after five test subjects 77-85% of problems can be detected (Nielsen, 1994). It has also been suggested that some participants may find it difficult to generate "think-aloud" interviews while carrying out a new task or a task that involves a lot of cognitive processing (Branch et al.,2000), however to overcome this the participants were asked after using the app for any comments and suggestions to improve the app. Another limitation to this study is that the "think aloud" analysis was undertaken with a compressed version of the "Worktivity" app and not the full working version. Additionally, the app's key component is hinged around self-monitoring of occupational SB; this input may be subject to recall bias and, moreover, will only be available at the times that users volunteer them (Lathia et al., 2013). In an attempt to address this, "Worktivity" delivers a reminder to log sitting if a log is not completed. To address recall bias, the users are only asked to recall on their sitting over the last 60 minutes, which was deemed by the research team to be an appropriate time frame for accurate recall.

In conclusion, the development of "Worktivity" was informed by a systematic application of behaviour change theory, scientific evidence, end user and stakeholder input, computer science and expert consensus. These processes follow a best practice approach to app development (White et al., 2016). The resulting app is a theory-driven, user-informed mobile app that provides behavioural support to office workers to reduce SB, incorporating carefully considered strategies to increase user engagement.

To our knowledge, “Worktivity” is the first app that was specifically designed for office workers to reduce their SB by delivering tailored feedback on SB and not inactivity, in an almost real time manner. This research also adds to the literature by describing the rigorous design and development of methodology which may prove useful to other digital behaviour change intervention developers. The feasibility of using the “Worktivity” app as part of an intervention to reduce occupational sitting will be discussed in the next chapter.

Chapter 5 - The feasibility of a mobile app based intervention to reduce occupational sitting, delivered with and without access to sit-stand work desks

5.1 Introduction

Office work generally consists of high amounts of sitting and as discussed in Chapter 1, sedentary activities have been shown to compromise up to 82% of time at work in industrialised countries (Parry and Straker, 2013). These high levels of SB are exposing workers to the associated negative health risks (Van Uffelen et al., 2010). Therefore, sedentary work has now become an emergent workplace health and safety issue (Straker et al., 2016), and employers are expressing interest in exploring options to address this issue (Chapter 3). Due to the sedentary nature of desk-based office work, the workplace is seen as an appropriate environment in which to target interventions to change SB (Clemes et al., 2014; Kazi et al., 2014).

There has been a growing interest in identifying ways to reduce occupational sedentary time and promote breaks in sitting (Mantzari et al., 2016). It has been suggested that interventions to reduce SB at work including environmental restructuring may be most promising (Gardner et al. 2015). Specifically, there is evidence to support and recommendations for the use of SSWDs used in conjunction with other behavioural intervention approaches such as management support, health coaching, goal setting, self-monitoring, use of prompts and problem solving, workplace policy changes, and informational components (O'Connell et al., 2015; Chu et al., 2016; Gardner et al. 2017; Munir et al., 2018; Shrestha et al., 2018). Combining SSWD with motivational behaviour change strategies may provide the environmental opportunity necessary to undertake desk work while standing, and the motivation and capability to displace sitting with standing (Gardner et al., 2017). Results from two systematic reviews and meta-analyses suggest interventions using SSWD, either alone or in combination with other behavioural strategies appear to be effective in reducing workplace sitting ranging from 88.8 min/workday (Chu et al., 2016) to 100 min/workday (Shrestha et al., 2018).

Another promising approach is the use of mobile phone apps. It is estimated that by 2019, 67.1% of the global population will use a mobile phone (Statista, 2018). As mobile phones proliferate throughout society, so too does the opportunity to leverage these devices to influence health behaviour (Lathia et al., 2013). In 2017, there were 325,000 mobile health apps available for download (Research2guidance, 2017). While data supporting app efficacy across a variety of health behaviours is emerging (Bastawrous and Armstrong, 2013), there has been little evaluation of app-based interventions in relation to SB in the occupational setting. Previous research has reported that mobile interventions can be successful in reducing SB (Bond et al., 2014; King et al., 2016; Arroggi et al., 2017). These studies have been conducted in overweight/obese individuals (Bond et al., 2014), underactive midlife and older adults (King et al., 2016) and healthy sedentary adults (Arroggi et al., 2017). None of these app interventions were specifically targeting occupational SB. A Cochrane systematic review and meta-analysis exploring workplace interventions for reducing sitting at work, further highlights the dearth of evidence in this area (Shrestha et al., 2016; Shrestha et al., 2018).

Concerns have been noted that workplace health interventions may distract workers from their day-to-day duties, negatively impacting productivity (Goetzel and Ozminkowski, 2008; Gilson et al., 2011; Gilson et al., 2012, Hadgraft et al., 2016 b) and therefore unlikely to be supported by employers. Pedersen et al. (2009) suggest that although health may be important for the employee, employers can be more interested in work productivity. As detailed in the qualitative chapter (Chapter 3), potential threats to productivity posed by workplace interventions is a concern to both employees and employers. Participants from the qualitative work (Chapter 3) mentioned concerns that their mood may be affected, with some concerned a mobile app intervention may impact mood by increasing feelings of stress, frustration and guilt. It has been noted that there is a dearth of evidence relating to the impact of SB reduction interventions on productivity and mood related outcomes (Mackenzie et al., 2015).

There remains a paucity of evidence exploring how mobile app interventions can be used to reduce SB in office workers and how an app's behaviour change potential can be supplemented by the introduction of SSWD. There is a lack of strong evidence available on the direct influence of workplace sitting on productivity (Healy et al., 2012). In order to advance the knowledge in this area further high quality RCTs are required. However, for novel pieces of technology such as the app ""Worktivity"" described in Chapter 4, feasibility trials are more valuable than efficacy only trials. They allow for a deeper understanding of how and why a system is used, ultimately advancing the ability to develop systems effectively for behaviour change (Klasnja, Consolvo and Pratt, 2011). Outcome focused studies dominate this research area (Hall et al., 2015) and preliminary evaluation has been largely overlooked in the development and testing of sitting-reduction interventions to date (Gardner et al., 2017). Developing effective sedentary reduction interventions depends on understanding both what works in changing SB and why (Gardner et al. 2015). A process evaluation can assist with this, to explain discrepancies between expected and observed outcomes, to understand how context influences outcomes, and to provide insights to aid implementation (Craig et al., 2008).

5.1.1 Aims and Objectives

The aim of this study was to assess the feasibility of a mobile app intervention to promote sitting time reductions in office workers tested over an 8 week intervention period, with or without SSWD, relative to a comparison condition.

This consisted of three primary objectives

1. To conduct a process evaluation of recruitment procedures and how interventions were delivered and received,
2. To conduct a preliminary evaluation of responses to the interventions/control conditions in terms of sitting time, productivity and mood,
3. To assess the feasibility of data collection procedures and outcome measures.

A secondary objective was to

1) To explore the incidence of adverse events and technical issues.

5.2 Methods

This was a three-arm cluster-randomised controlled feasibility study with process evaluation. Ethical approval was granted by Ulster University's School of Sport Ethics Filter Committee (Appendix N). As this was a feasibility trial, no formal sample size calculation was carried out. The target sample size was determined by other feasibility studies with similar aims (Kozey-Keadle et al., 2012; Martin et al., 2017). It was also based upon resource considerations. The research team had access to a limited amount of mobile phones and SSWD. It was agreed that a total of three sites with 20 participants per site (total n=60) was adequate.

5.2.1 Recruitment

Recruitment began in July 2017 and ended in September 2017. Email invitations were sent to managers in companies with desk-based office workers, informing them of the study and inviting them to participate. Details on the aims of the study and measurement procedures, an outline of the participant's involvement and the potential benefits of participating in the study were provided. When a manager responded to the email expressing interest in the study, further information was provided via email/phone. For those remaining interested, a worksite visit was arranged. At this visit, a researcher (AS) met with the corresponding manager(s) and delivered a presentation via PowerPoint. During this presentation, study purpose and the practicalities involved if the study were to be implemented within the organisation were explained and any questions were answered. The managers who expressed interest, were then given information sheets to be passed on to their staff (Appendix S). Potential participants were asked to read the information and consider participation. Participants were made aware of what the study entailed. They were also informed that all research would be conducted in confidentiality and that they were free to withdraw at any stage, without giving a reason. Approximately one week later, the research team returned to the worksites to screen for eligibility (Appendix T) amongst those interested. Recruitment was carried out on a first come, first serve basis. If the inclusion criteria were met, participants were asked to provide informed written consent (Appendix U).

5.2.2 Inclusion Criteria

Participants who met the following criteria were deemed eligible for inclusion:

- Predominantly desk-based office workers (self-reported $\geq$ 50% seated working hours)
- Working full time hours ($\geq$ 30 hours per week)
- Aged 18–65 years
- Fluent English

5.2.3 Exclusion Criteria

Participants were excluded from participation for the following reasons:

- Pregnancy (reasons they sit/stand at work may be pregnancy related)
- Planned absence of $\geq$ 5 consecutive working days over the course of the intervention
- Unable to read and understand English
- Non-ambulant or severely incapacitated with existing conditions restricting ability to stand/move
- Currently participating in a study to reduce SB/increase PA

Those eligible and consenting to participate in the study were invited to complete a baseline assessment. This was conducted in a private designated testing room at the respective worksites by trained researchers (AS, RW, SC, LR). The measurements are discussed further in the latter stages of this methods section.

5.2.4 Randomisation

To control for contamination between intervention and control participants randomisation was done on a cluster level (Torgerson, 2001). Randomisation was at the level of the study worksite. Participants were assigned to one of three arms. The three worksites and the three allocations were concealed in sealed opaque envelopes. An independent researcher, with no links to this project, selected one envelope which contained the worksite name and another envelope which contained the assigned group. The worksite was matched with the corresponding group allocation. This was conducted twice more until randomisation was complete. The worksites were randomised to one of three groups:

1) Mobile phone app (MA)
2) Mobile phone app plus height adjustable work desk (MA+SSWD)
3) Control (C)

Those in the MA group were from a software company with 104 staff members, the MA+SSWD group were from a software company with 52 employees and the control group were from a computer consultancy company with 70 employees.

Figure 5-1 details the study time line for the three groups. The intervention commenced in October 2017 and finished in December 2017.

Figure 5-1 Study time line

Baseline Measures Demographics, Height, weight, mood, given activPAL™ (7 days, Office Audit			Week 0
Wear activPAL™ for 7 consecutive days. respond to productivity texts/email, complete BRUMS			Week 0
Randomisation			Week 0
Buffer week			
C Maintain normal work practices	MA Used app for 10 working days	MA+SSWD Used app for 10 working days	Week 1-2
C Maintain normal work practices	MA Set “sit-less” goal Continue with app	MA+SSWD Set “sit-less” goal Continue with app Install SSWD	End Week 2
Continuation with assigned allocation			Week 3
Midpoint measures activPAL™ (7 days), productivity, BRUMS			Week 4
Continuation with assigned allocation			Week 4-8
Endpoint measure activPAL™ (7 days), productivity, BRUMS			Week 8
C Office audit	MA Office audit Satisfaction survey	MA+SSWD Office audit Satisfaction survey	End week 8

C= control group, MA= mobile app group, MA+SSWD= mobile app plus sit-stand work desk group, BRUMS= Brunel mood scale

Due to the nature of the study, blinding of participants and researchers to intervention or control arm was not possible. Following randomisation, the control group were informed of their allocation and were advised to maintain their normal work practices for the duration of the study.

For logistical reasons there was a "buffer week" between randomisation and the beginning of the interventions. This was to allow researchers to attend the workplaces to deliver the mobile phones, chargers and information sessions. Those in the MA and MA+SSWD groups received their phones during this buffer week and were asked to use the app for two workdays that week to familiarise themselves with the app function and features before the intervention commenced officially.

Those in the MA and MA+SSWD groups attended an information session (approximately 15 minutes in duration) which was delivered by AS, at their worksite. A study phone (Motorola XT1068 Moto G (Second Generation)) and charger with the free app already downloaded was provided by the research team to each participant. The bespoke app ""Worktivity"" (which is described in detail in Chapter 4) was designed specifically for this study to promote a reduction in office sitting. There was no SIM card, phone credit or data allowance on the phone. The phone did have access to the internet via Wi-Fi connection, however participants were asked not to use the phone for any purposes other than the intervention or to remove the phone from the workplace. Participants were given a short group tutorial and provided with information on how to use the app's features and settings (Appendix V). All participants with the app were asked to register as an app user by inputting their name and to set their regular working hours. This was to allow for tailoring of the app features to the participants working schedule.

As described in detail in Chapter 4, the app targeted behaviour change by incorporating a sitting self-monitoring section and real time feedback allowing users to become informed of their sitting behaviour. As the app provided a platform to allow users to self-report their sitting behaviour at work, both MA and MA+SSWD groups were asked to use the app to self-report their sitting at work for the next ten working days. The app prompted the user to self-monitor sitting time at work. From this input, a progress report of a graph representing how much time of the day is spent in sitting was available to be viewed by the users, at any time.

After the two-week period of self-monitoring, participants used the app's inbuilt summary graphs to visualise how much time they spent sitting at work and consider what "sit-less" goal to set based on the feedback. Users were supported in setting this goal by a member of the research team (AS, RW, LR, or SC) (Appendix W). The goal setting decisions were based upon the ten days of self-monitored sitting and current recommendations on office SB (Buckley et al 2015). The participants were able to retrospectively view their sitting behaviour at work over the previous ten work days using the app feedback function. The researchers also explained the current recommendations (Buckley et al 2015), which suggest desk-based workers should "*initially progress towards accumulating at least 2 h/day of standing and light activity (light walking) during working hours, eventually progressing to a total accumulation of 4 h/day".* Using these sources of information, a "SMART" "sit-less" goal (Doran, 1981) detailing in hours how much they would like to reduce their sitting by over an average work day, was set by the participant under researcher guidance.

The researchers had access to a password protected section of the app where they updated the participant's personalised goal on their behalf. Once a sitting reduction time goal was set, the app calculated when prompts occurred (based on their working hours) to assist participants in achieving their goal. Based on the personalised goal and the continued real time self-monitoring, a prompt appeared with advice to break their sitting if their sitting time was too high. Once this goal setting feature was enabled, the original self-monitoring and feedback aspects continued, but with the addition of a goal visualisation feature and educational tips and facts section. Once participants logged their eighth and final hourly sitting time each day they received an educational fact/tip (Appendix R).

Following goal setting, the MA+SSWD group were provided with a SSWD (Workfit-T, Ergotron, MN, USA) to place on their existing work desk for the remainder of the intervention. Researchers installed the desks and instructed them on the correct use of the desk. The SSWD allowed the user to alternate between sitting and standing postures at their desk, giving them further opportunity to reduce sitting time at work (Chau et al., 2014).

5.2.5 Demographic Measures

Socio-demographic characteristics were obtained via paper based questionnaire (Appendix X) designed specifically for this study. The question relating to occupational category was adapted from the “World Health Organisation Health and Performance Questionnaire (HPQ): Clinical Trials Baseline Version” questionnaire (Kessler et al., 2003). The question relating to educational levels was adapted from the NI direct government services website (nidirect.gov.uk, 2017). Height (cm) was measured without shoes, using a portable stadiometer (Seca stadiometer 220/222, Hamburg, Germany). Weight (kg) was measured using digital scales (Seca scales 899, Hamburg, Germany). Participants were asked to remove shoes and heavy outerwear, and to ensure their pockets were empty before stepping on to the scales. BMI was then calculated using the formula: kg/m^2. These demographic and anthropometric measures were obtained at baseline only.

The evaluation of this intervention was guided by a logic model (Appendix Y). This portrays the logical “roadmap” that was used by the research team to plan the evaluation of this intervention. It describes the projection of the relationship between how each project element will work, what the anticipated results will be and how the sequence of elements will lead to the expected outcomes (Cavill, Roberts and Ells, 2015).

In addition, a process evaluation will describe how the intervention was carried out in practice; help to understand how the programme was delivered and why it achieved/did not achieve the anticipated outcomes (Bauman and Nutbeam, 2014). It is desirable to use a theoretical framework approach when performing a process evaluation (Volker et al., 2016), therefore the approach used in this study is based upon the recommendations of Bauman and Nutbeam (2014).

The process evaluation framework is broken into five elements and the process measures used in this study are described in Table 5-1. This process evaluation addressed the intervention groups only, therefore focused on the participants of mobile app only group (MA) and the mobile app plus SSWD (MA+SSWD) groups, with the exception of the evaluation item "context" which also addressed the control condition.

5.2.6 Process Evaluation and Outcome Measures

5.2.6.1 Exposure

Whether participants were aware of the issue being addressed, received the programme or were aware of the messages being communicated (Bauman and Nutbeam, 2014) was determined by app analytics. For the purposes of this study, exposure focused on how users responded to the app prompts to self-monitor sitting time over the intervention period (the number of acknowledged prompts and the response time to these prompts). This analysis was completed at the end of the study by a member of the research team (MGC) and not the PhD researcher (AS), as the app analytics required the skills of an expert computer scientist. It is included in this PhD thesis for completeness.

5.2.6.2 Participation

The effectiveness of recruiting participants to the programme (Bauman and Nutbeam, 2014) was calculated from logs detailing recruitment and retention rates and participant flow through the study.

5.2.6.3 Delivery

Information on whether or not the programme was delivered using the methods and materials as designed (Bauman and Nutbeam, 2014) was gathered throughout the study from researcher logs detailing any deviation from protocol, and also from the satisfaction survey.

5.2.6.4 Programme satisfaction and usage

Participant satisfaction with the interventions and the extent to which participants used resources (Bauman and Nutbeam, 2014) was measured using a satisfaction scale and questionnaire designed specifically for the study, which asked participants to what extent they agreed with statements exploring various study elements on a five-point scale (Strongly agree, Agree, Neither agree nor disagree, Disagree or Strongly disagree). The questionnaire also included open-ended qualitative questions for a deeper understanding of participants' experiences of the intervention and to complement the quantitative data. The questionnaire was administered at the end of the study. All intervention participants were asked about the mobile app component, whilst only those randomised to the MA+SSWD group were questioned about the usage of the SSWD. Appendix Z details the exact questions asked.

5.2.6.5 Context

Reasons why the programme was implemented as it was (Bauman and Nutbeam, 2014) were examined. For the purposes of this study, context aimed to describe the environmental context in which the intervention was delivered. This was measured using an environmental audit designed for this study (Appendix AA). The tool assessed environmental aspects of the worksite which may impact upon SB such as office furniture, presence of stairs/elevators and location of office facilities. The PhD researcher (AS) conducted these audits before the intervention commenced, and again at the end of the intervention. The researcher spoke with the manager who assisted with recruitment, to obtain data on aspects of the environment such as normal working hours and lunch breaks, which could not be visually audited.

The preliminary evaluation of responses to the interventions/control conditions in terms of SB, PA, productivity and mood were collected at three time points; baseline, midway through the intervention period (week four) and over the last week of the intervention (week eight).

5.2.6.6 Sedentary Behaviour/Physical Activity

In order to assess SB/PA, all participants were given an activPAL™ (activPAL™; PAL Technologies, Glasgow, Scotland). This is a thigh-worn accelerometer-inclinometer device which was to be worn for seven consecutive days (24 hours per day) at each measurement time point, as recommended by Edwardson et al. (2017). The activPAL™ directly measures the postural aspect of SB. Using proprietary algorithms, accelerometer-derived information about thigh position and acceleration are used to determine body posture (i.e., sitting/lying and upright), transitions between these postures and stepping (Edwardson et al., 2017). The activPAL™ has shown to be a valid, accurate and precise tool to measure components of SB in free-living environments and is sensitive to reductions in sitting time (Kozey-Keadle et al., 2011; Lyden et al., 2012)

The outcomes of interest as measured by the activPAL™ included:

- Total sitting, standing and stepping time
- Total number of steps
- Number of sit to stand transitions
- Time spent in prolonged sitting bouts
- Percentage of the workday spent sitting, standing and stepping

At each of the measurement periods, participants were given an activPAL™ and shown how to position and use it. They were also given an instruction sheet (Appendix BB) for further reference, if required. The activPAL™ was to be secured to the skin at the anterior mid-line of either the left or right thigh, about a third of the way down from the hip, using hypoallergenic adhesive patches (e.g Hypafix®/Tegaderm) which were also provided by the research team. Additional adhesive patches were given to participants for them to be changed as required. Participants were advised that the device must be removed for swimming and bathing, contact sports or if any skin irritation occurred. Participants were asked to keep a written diary during the activPAL™ measurement periods, to record the time they got up in the morning, when they went to bed at night and when they started and finished work. Reasons for removal of the device and any other comments were also to be logged (Appendix CC). After the seven-day measurement period, a researcher (AS) collected the activPAL™ and logs from the participating workplaces.

5.2.6.7 Productivity

Productivity was measured using a form of ecological momentary assessment (EMA). EMA involves repeated sampling of participants' current behaviours and experiences in real time (i.e. work productivity) and in the participants' natural environments (i.e. the workplace) (Shiffman, Stone and Hufford, 2008). This EMA based approach was chosen over a questionnaire based measure to minimise recall bias and maximise ecological validity (Shiffman, Stone and Hufford, 2008). On each of the five work days during each measurement period, researchers sent the participants a message via text or email (based on their preferred delivery method determined at baseline) , towards the end of their work day (approximately between 15.30-16.30 h). This text or email asked them to rate their overall productivity for that day on an 11-point scale from 0-10 and respond to the message sent by the research team. The message sent was: “On a scale from 0 to 10, where 0 is the lowest and 10 is the highest, how would you rate your work productivity today [insert date]? (Please reply with the number that best corresponds to your productivity today [insert date])”. If the participant did not respond on that day, a follow up message was sent the morning of the next working day. A similar procedure has been used to assess productivity in a workplace setting (Pronk et al., 2004). At least two of five possible responses at each data collection period were required to be included in the analysis.

5.2.6.8 Mood

Mood was measured using the Brunel Mood Scale (BRUMS) (Terry et al., 1999; Terry, Lane and Fogarty, 2003) (Appendix DD), which has been derived from the Profile of Mood States (McNair, Lorr and Droppleman, 1971). It was developed to provide a quick assessment of mood states among adolescent and adult populations (Terry, Lim and Parsons-Smith, 2013). Arguably BRUMS is the most comprehensively validated mood measure available in sport and exercise psychology literature (Lane, 2007). It has been validated for physically active and healthy populations showing consistent results, with good reliability and construct validity (Brandt et al., 2016). BRUMS is a 24-item questionnaire of simple mood descriptors. It consists of six subscales, with each of the subscales containing four mood descriptors. The subscales are anger, confusion, depression, fatigue, tension, and vigour (Terry, Lim and Parsons-Smith, 2013).

- Anger: annoyed, bitter, angry, bad tempered
- Confusion: confused, mixed up, muddled, uncertain
- Depression: depressed, downhearted, unhappy, miserable
- Fatigue: worn out, exhausted, sleepy, tired
- Tension: panicky, anxious, worried, nervous
- Vigour: lively, energetic, active, alert

At each measurement time point participants were asked to indicate the extent to which they had experienced the feelings described by the 24 mood descriptors over the last week. They were specifically asked “How you have felt during the past week including today?”. Responses were recorded using a five-point Likert scale, where ‘0’ = ‘Not at all’, ‘1’ = ‘A little’, ‘2’ = ‘Moderately’, 3 = ‘Quite a bit’, and ‘4’ = ‘Extremely’ (Terry, Lim and Parsons-Smith, 2013). The participants were asked to complete the form when they removed the activPAL™ after the seven-day measurement period.

In addition to these primary outcome measures, completion rates of data collection at baseline and each follow-up point were recorded; incidences of adverse events and technical issues were logged.

5.2.6.9 Completion rates and usable data

This was assessed by keeping a log of completion rates and useable data at baseline and each follow-up point.

5.2.6.10 Adverse events and technical issues

Any issues arising from the data collection procedures or interventions were gathered using logs. All corresponding managers and participants were asked to contact the researcher (AS) by phone or email, in the case of incident arising relating to the intervention.

Table 5-1 Process evaluation and measures used

Component	Description	Evaluation tool	Evaluation points	Groups
Exposure	Assessing whether participants were aware of the issue being addressed, received the intervention or were aware of the messages being communicated	App analytics *	Throughout intervention	MA MA+SSWD
Participation	Identifying how well participants were recruited to the intervention and adhered to the intervention?	Recruitment and retention logs	Throughout intervention	MA MA+SSWD
Delivery	Assessing whether or not the intervention was delivered using the methods and materials as designed	Changes, updates/revisions to the protocol Satisfaction survey	Throughout intervention	MA MA+SSWD
Programme satisfaction and usage	Intervention satisfaction, relevance and the extent to which participants used resources	Satisfaction survey	Post intervention	MA MA+SSWD
Context	Examining why the intervention was implemented as it was	Office environmental audit	Pre and post intervention	MA MA+SSWD C

SB	Preliminary evaluation of responses to the interventions/control conditions in terms of SB	ActivPAL^{TM}	Baseline Midpoint Endpoint	MA MA+SSWD C
Productivity	Preliminary evaluation of responses to the interventions/control conditions in terms of productivity	EMA	Baseline Midpoint Endpoint	MA MA+SSWD C
Mood	Preliminary evaluation of responses to the interventions/control conditions in terms of mood	BRUMS	Baseline Midpoint Endpoint	MA MA+SSWD C
Completion rates and usable data	Identifying how many participants completed data collection and how much of the data was useable	Completion and usable data logs	Baseline Midpoint Endpoint	MA MA+SSWD C
Adverse events and technical issues	Any issues arising from the data collection procedures or interventions	Incidents log	Throughout intervention	MA MA+SSWD C

*This work was completed by MGC

C= control group, MA= mobile app group, MA+SSWD= mobile app plus sit-stand work desk group, EMA=.ecological momentary assessment, BRUMS= Brunel mood scale

5.2.7 Data analysis

Feasibility and process outcome data were analysed quantitatively and qualitatively. As this is a feasibility trial inferential statistical tests were not deemed appropriate (Leon, Davis, & Kraemer, 2011). Demographic and quantitative outcome data were entered into a Microsoft Excel 2010 spreadsheet. All data were visually inspected to identify irregularities or errors. The data were analysed using SPSS, Version 23.0 and Microsoft Excel 2010 and reported as descriptive statistics (mean, standard deviation, percentages). In the instance where a participant's baseline data were obtained but not deemed valid, the mid and endpoint data for this participant was excluded from analysis for failure to meet minimum data collection requirements. If missing data occurred at mid or endpoint follow-up for participants with baseline data, the missing data was not imputed. For SB, mood and productivity outcomes the magnitude of change between measurement periods was calculated by subtracting follow up scores from baseline scores.

Qualitative data from the open-ended questions of the satisfaction survey were transcribed and entered into an Excel spread sheet. The responses were summarised thematically (Braun and Clarke, 2006). Thematic analysis was used to systematically identify, organise, and offer insights into patterns of meaning i.e. themes (Braun and Clarke, 2012). The thematic analysis procedure used here was the same as the process used in Chapters 3 and 4 where it was discussed in detail. Briefly, the responses were read thoroughly multiple times to familiarise the researcher with the content. Codes were applied to the data set by one researcher (AS). These codes were then used to devise an initial set of themes which were revised iteratively before producing a final thematic framework summarising participants' experiences of the intervention relevant to their assigned condition (i.e., MA or MA+SSWD). Quotes that were deemed to best represent the essence of each theme were then extracted.

ActivPAL^{TM} data were downloaded from the devices using activPAL^{TM} software (activPAL^{TM} version 7.2.32; PAL Technologies, Glasgow, Scotland) to create events files. The resulting activPAL^{TM} event files contained a chronological list of all bouts of sitting/lying, standing, and stepping (Edwardson et al., 2017), which was then processed using an algorithm (Winkler et al., 2016), in STATA (STATA IC Version 15.0). This algorithm has been validated using free-living data from Australian adults showing 'almost perfect' agreement with a diary recorded SB method for most individuals (88%) (Winkler et al., 2016). This algorithm based approach was developed for use with 24-hour wear protocols in adults. It is an automated approach classifying activity bouts recorded in activPAL^{TM} event files as sleep or non-wear (or not) and on a valid day (or not). The approach excludes long periods without posture change/movement, adjacent low-active periods, and days with minimal movement and wear based on a simple algorithm (see rule below) (Winkler et al., 2016).The rules used by the algorithm in the present study are the same as those employed in the development and validation study (Winkler et al., 2016). Winkler et al. (2016) summarise the rules as follows:

"The algorithm's first step finds long periods that are most likely to be sleep or non-wear. Sleep/non-wear bouts were identified as (1) the longest bout per 24h period (from noon-to-noon each day) that lasts ⩾2 h, or (2) any very long bouts lasting ⩾5h. This allows sleep/non-wear to occur at any time, any number of times (including never) within a 24 h window. Because sleep can register as multiple periods of sitting/lying interspersed with real or erroneously detected posture changes and stepping, the next step iteratively examines surrounding bouts and determines whether they are more likely additional sleep/non-wear (limited movement) or waking wear (more movement). Bouts were 'surrounding' if any portion was within a 15min window before or after a sleep/ non-wear bout. All bouts in the sleep window were classed as sleep/non-wear when the window contains any of these: a sitting/lying or standing bout that is long (⩾2 h), or moderately long (⩾30min) with very few (⩽20) steps in between; a sleeping/non-wear bout; or, posture changes without intervening steps. This step repeats until no more sleep/non-wear is found. The third step identifies invalid days from limited wear and movement, using wear criteria typical of the literature and movement criteria loosely based on prior approaches (Mutrie et al., 2012). Specifically, days were classed as non-wear if they met any of these criteria: limited variation in activities (⩾95% of waking wear in any one activity); limited stepping (<500 steps); or, limited waking wear time (<10 hours)".

To maximise the amount of data available to analyse from the small sample size in this study, two valid workdays from each measurement period were required. Following the steps of the algorithm, output variables included averages over the seven-day measurement period for:

- Wear time
- Valid days
- Sitting, standing and stepping time
- Total number of steps
- Number of sit to stand transitions
- Time spent in prolonged sitting bouts

The output data was visually checked against the diary data for unusual episodes. If no sleep was identified in the output file, but was recorded in the diary, the data for that particular day was removed from the analysis. (Note: If the removed day's corresponding work hours met the specific workday wear time criteria (discussed in next section), the data was used in the workday analysis).

Further processing of data was required in order to isolate the periods of interest (i.e. time spent at work). It has been noted that this isolation process is a necessity for high quality data, but there is an absence of validated, accurate methods to isolate these periods of interest (Edwardson et al., 2017). The isolation process used in this study is suggested by Edwardson et al. (2017). The algorithm produced a file containing the activity events for each day. Each participant's diary detailed what time they started and ended work each day. Often, activity event data does not match the diary reported start and end of the workday. Therefore, a rule is required to decide if the bout is to be included in the analysis. A suggested rule by Edwardson et al. (2017) is to include the bout if ≥ 50% of that bout is within the period of interest. For example, if a bout of sitting is detected from 16.50 to 17.20, but the diary data reports they left work at 17.00, this bout would be excluded from the full day analysis as <50% of the bout is within the period of interest. In instances where participants did not fill in the start and end of work time in the diaries, the normal work hours they reported in their demographic baseline questionnaire were used. Two valid days of data with ≥ 4 hours wear time at work were required for workday analysis. As each participants' work day duration varied, the time at work data were expressed as a percentage of the day in sitting, standing and stepping, based on the participants' average working day.

5.2.8 Data security

Steps were taken to ensure confidentiality of the data throughout the project. All data were stored on AS's Ulster University home directory for personal file storage. This was password protected and only the researchers had access to it. Questionnaire based data were stored in a locked filing cabinet at Ulster University, only accessible to the researchers.

5.3 Results

5.3.1 Demographic analysis

56 consenting participants (61% male) were randomised to the control (n=16), MA (n=20) and MA+SSWD (n=20) arms. The characteristics of these participants are presented in Table 5-2. The mean BMI score was 27.37 ± 4.94 (SD) kg/m^2, indicating an "overweight" sample according to the National Health Service (NHS) obesity classifications (NHS, 2018). All participants were full time employees working 39.27 ± 3.16 (SD) hours/week and worked day shifts Monday to Friday. 86% of the sample were educated to Level 6 (e.g. Bachelor's Degree) or above and 63% of the sample earning between £20,000-39,999 per annum.

Table 5-2 Demographic details

	Control (n=16)		MA (n=20)		MA+SSWD (n=20)		Total (n=56)	
Age (years)	37.94 ± 10.63		36.65 ± 10.19		33.60 ± 8.93		35.93 ± 9.88	
Sex	9 F 7 M		4 F 16 M		9 F 11 M		22 F 34 M	
Height (cm)*	1.67 ± 0.10		1.75 ± 0.08		1.74 ± 0.10		1.73 ± 0.10	
Weight (kg)	84.0 ± 15.3		82.5 ± 13.1		78.6 ± 16.6		81.5 ± 15.0	
BMI (kg/m^2)*	30.23 ± 6.44		26.95 ± 3.72		25.79 ± 4.14		27.37 ± 4.94	
Hours worked per week	38.22 ± 1.25		39.48 ± 3.51		39.90 ± 3.73		39.27 ± 3.16	
Education	Level 7	9	Level 7	5	Level 7	7	Level 7	21
	Level 6	6	Level 6	10	Level 6	11	Level 6	27
	Level 5	0	Level 5	1	Level 5	0	Level 5	1
	Level 4	0	Level 4	1	Level 4	0	Level 4	1
	Level 3	1	Level 3	3	Level 3	1	Level 3	5
	Level 2	0	Level 2	0	Level 2	1	Level 2	1
Occupation category *	Executive	2	Executive	5	Executive	3	Executive	10
	Profession-al	7	Profession-al	8	Profession-al	14	Profession-al	29
	Technical support	6	Technical support	4	Technical support	2	Technical support	12
	Sales	0	Sales	0	Sales	1	Sales	1
	Clerical	0	Clerical	3	Clerical	0	Clerical	3
Income per year	£60,000+	2	£60,000+	3	£60,000+	3	£60,000+	8
	£40,000-59,999	2	£40,000-59,999	3	£40,000-59,999	4	£40,000-59,999	9
	£20,000-39,999	12	£20,000-39,999	12	£20,000-39,999	11	£20,000-39,999	35
	£0-19,999	0	£0-19,999	2	£0-19,999	2	£0-19,999	4

Note: * There were no height or BMI measures for 2 control participants. One control participant did not provide an occupational category.

5.3.2 Exposure

The “Worktivity” app sent hourly prompts each working day, totalling 336 prompts (42 days x 8 working hours) over the course of the study. Table 5-3 details the mean results for acknowledgement of and response time to the app prompt alerts. The acknowledgement of a prompt alert meant that the participants reacted to a prompt alert by recording their sitting time during the previous hour. The response to the prompt meant the percentage of times the participants recorded their sitting time promptly ($\leq$1 min after prompt sent) or with a delay (>1 min after prompt sent). Participants in the MA group acknowledged the prompts to log sitting 66% of the time, more often than those in MA+SSWD (52%). They also responded to the prompts more quickly than the MA+SSWD; the mean response time for the MA group was 18.36 minutes compared to 19.54 minutes in the MA+SSWD group.

Table 5-3 Mean results for acknowledgement of and response time to prompt alerts

Group	No. acknowledged	% acknowledged	No. missed	% missed	% of timely responses ($\leq$1 min)	% of delayed responses (> 1 min)	Mean response times (min)
MA	221.95	66.06	114.05	33.94	34.87	65.13	18.36
MA+SSWD	173.28	51.57	162.72	48.43	30.45	69.55	19.54
Total	198.27	59.01	137.73	40.99	32.72	67.28	18.93

These results are also reported elsewhere (Garcia-Constantino et al., 2018)

C= control group, MA= mobile app group, MA+SSWD= mobile app plus sit-stand work desk group,.

5.3.3 Participation

The recruitment of the worksites is documented in Figure 5-2 and the recruitment of individual participants is documented in Figure 5-3. A total of 39 companies across two cities in NI were contacted via email, inviting them to participate in the intervention. After provision of further information, six companies remained interested. Of these, three did not believe they had the capability of recruiting 20 staff members to participate. The remaining three companies (all based in one city in NI) were recruited (i.e. 8% of all those approached).

Within three worksites, all employees were invited by email from their manager to participate. In the MA group 19% of the employees responded with interest, in the MA+SSWD group 44% responded and in the control group 26% responded with interest in participating. On provision of further information three of those in the MA+SSWD and two in the control group decided not to participate. All of those interested met inclusion criteria, consented and were recruited. This resulted in n=20 participants in both the MA and MA+SSWD groups, and n=16 in the control group. Recruitment was stopped at this point despite the recruitment target of n=60 (n=20 per group) not being met, due to time constraints within the project timeline. In terms of retention, 95% of participants in the MA group, 90% in the MA+SSWD group, and 81.25% in the control group remained in the study until the end.

Figure 5-2 Recruitment of worksites

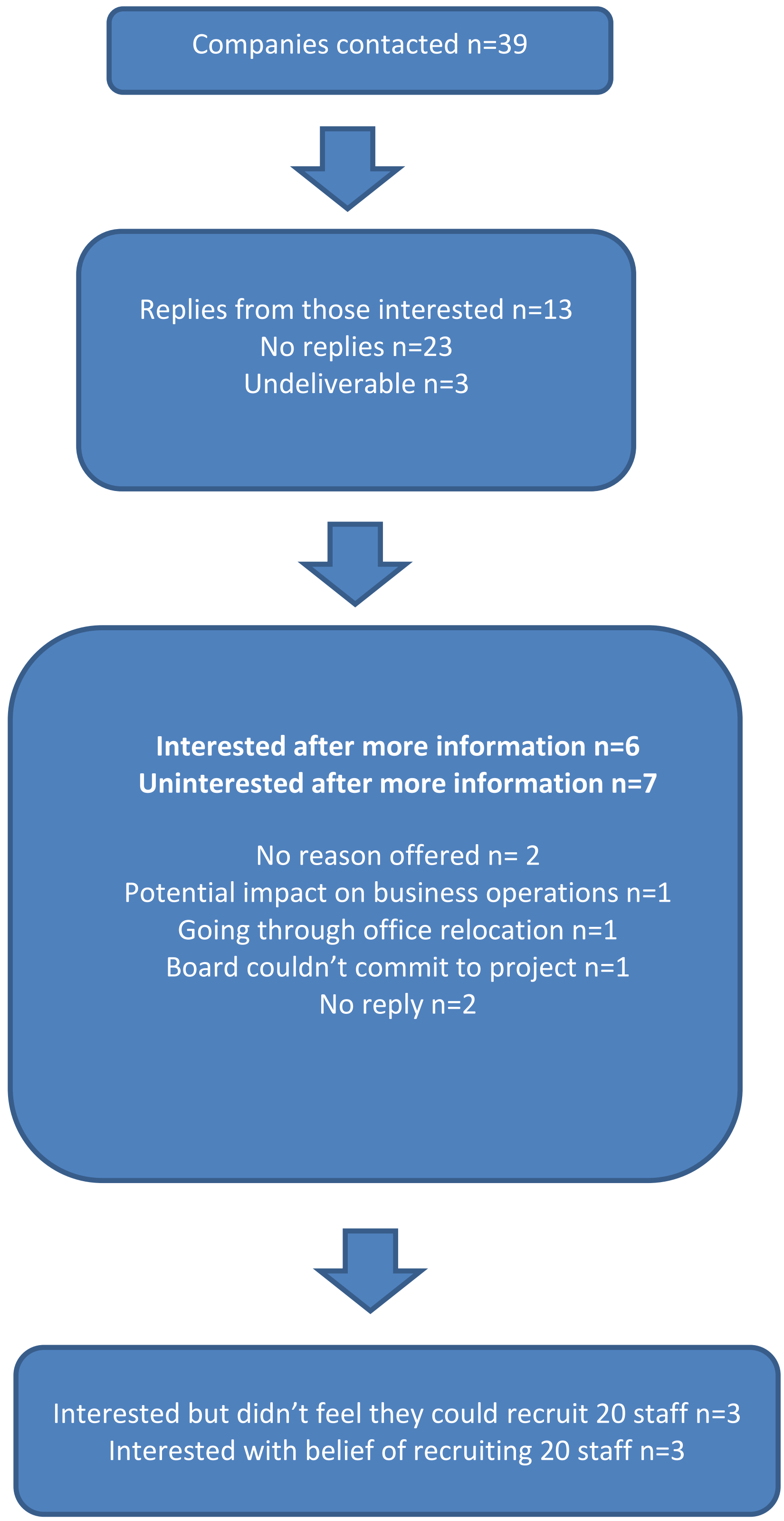
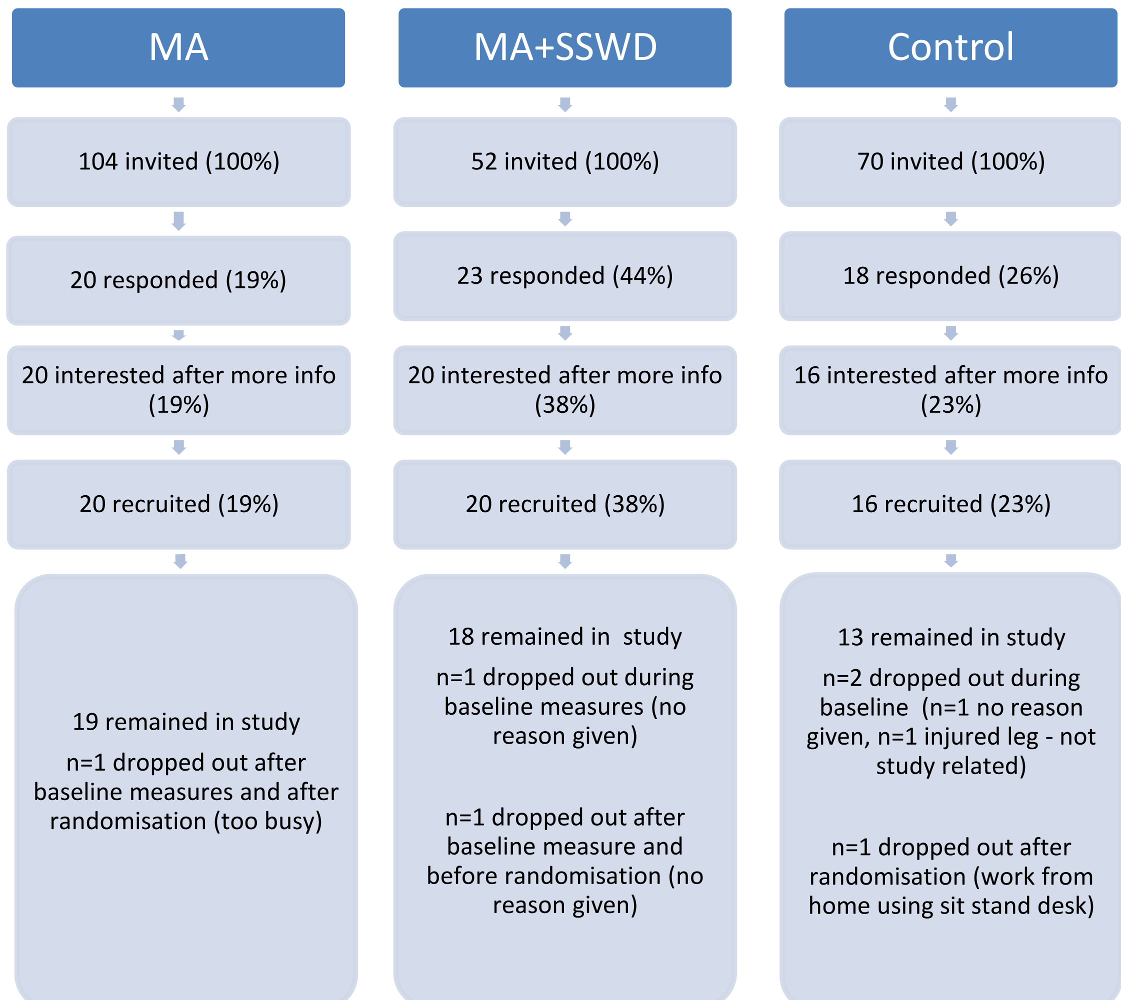


Figure 5-3 Flow of participants through study



5.3.4 Delivery

All participants in the MA and MA+SSWD groups received a mobile phone with the app downloaded and enabled the goal setting feature. All participants in the MA+SSWD group received the SSWD as per protocol. Data from the satisfaction survey revealed that a number of participants in both groups did not remember receiving the educational fact/tip (n=6 MA+SSWD, n=3 MA). Furthermore, a number also reported that even whilst having received the fact or tip, they ignored it (n=4 MA+SSWD, n=1 MA). In relation to delivery related technical issues, 26% of the MA group and 44% of the MA+SSWD group agreed or strongly agreed that there were many technical issues with the app (mainly prompts to log sitting at the incorrect times). Details of the technical issues are dealt with in the “implementation issues” section below.

5.3.5 Programme satisfaction and usage

5.3.5.1 Quantitative results

Table 5-4 presents the responses pertaining to the quantitative data from the satisfaction survey. It details the percentages of the participants who strongly agreed, agreed, neither agreed nor disagreed, disagreed or strongly disagreed with a list of statements relating to the relevant intervention arm.

Overall intervention satisfaction was moderate to low; with 58% of those in the MA group strongly agreeing or agreeing that they were satisfied with the overall intervention, compared to 39% in the MA+SSWD group. Similarly, 58% of those in the MA group strongly agreed or agreed they would recommend the intervention to a colleague, compared to 6% of those in the MA+SSWD group. Although satisfaction levels with the overall intervention were moderate at best; 72% of those in the MA+SSWD group strongly agreed or agreed that the programme was helpful in reducing their sitting, compared to 35% in the MA group.

Participants in both groups generally strongly agreed or agreed the mobile app was easy to use (MA 84%, MA+SSWD 72%). Additionally, 100% of those in the MA group and 94% of MA+SSWD strongly agreed or agreed that they were comfortable with mobile app technology. Only 17% of those in the MA group strongly agreed or agreed the self-monitoring reminders were annoying, compared to 72% of those in the MA+SSWD group. Only 26% of those in the MA group, and 22% of those in the MA+D group strongly agreed or agreed that they usually broke sitting upon receiving a prompt. No participants in either group strongly agreed or agreed they would like to use the app after the intervention ended.

A higher percentage of participants in the MA group (47%) strongly agreed or agreed they were satisfied with the daily educational facts and tips than the MA+SSWD group (36%). Satisfaction levels with the height adjustable desk were high. Of those who received the SSWD, 76% strongly agreed or agreed that they were satisfied with the desk, 94% strongly agreed or agreed that the desk was easy to use and 65% strongly agreed or agreed they would like to use it after the intervention period. The intervention was generally deemed suitable for integration into the workday; with 65% of those in the MA group and 72% of those in the MA+SSWD group having strongly agreed or agreed that the intervention was suitable for a workplace setting.

The perceived impact of the intervention on work productivity was low in the MA group with only 5% strongly agreeing or agreeing that their productivity at work was affected negatively by participating in the programme, compared to 29% of those in MA+SSWD group. There was no clear favourite intervention feature with 50% of the MA+SSWD selecting the "other" category as the preferred feature, while 33% of the MA group reported the app movement prompts as feature of preference. The most disliked feature in both groups was the app self-monitoring (MA 59%, MA+SSWD 81%). The majority of participants also felt the intervention period was too long (MA 56%, MA+SSWD 72%).

Table 5-4 a Responses to closed ended satisfaction survey

Overall Programme MA (n=20) MA+SSWD (n=18)	Strongly Agree (%)		Agree (%)		Neither agree nor disagree (%)		Disagree (%)		Strongly Disagree (%)	
	MA	MA+ SSWD	MA	MA+ SSWD	MA	MA+ SSWD	MA	MA+ SSWD	MA	MA+ SSWD
The programme was helpful in reducing my sitting time	5.00	16.67	30.00	55.56	35.00	22.22	30.00	0.00	0.00	5.56
I am likely to recommend the programme to a colleague	0.00	5.56	50.00	33.33	20.00	33.33	30.00	16.67	0.00	11.11
The programme is suitable for a workplace setting	20.00	16.66	45.00	55.56	15.00	11.11	20.00	16.67	0.00	0.00
I feel this intervention will have a lasting effect on reducing my sitting	5.26	5.56	47.37	22.22	10.53	44.44	31.58	22.22	5.26	5.26
I am satisfied with the overall intervention	5.26	5.56	52.63	33.33	26.32	33.33	15.79	16.67	0.00	11.11
The app helped me reduce my sitting	5.26	0.00	36.84	35.29	21.05	29.41	31.58	29.41	5.26	5.88
I am comfortable with using mobile app technology	42.10	72.22	57.90	22.22	0.00	0.00	0.00	0.00	0.00	5.56
The app is suitable for use in the workplace	0.00	0.00	73.68	33.33	15.79	16.67	10.53	38.89	0.00	11.11
It was easy to use the app	26.32	11.11	57.89	61.11	5.26	11.11	10.53	16.67	0.00	0.00
There were many technical issues with the app	5.26	11.11	21.05	33.33	26.32	11.11	42.11	22.22	5.26	22.22
I am likely to recommend the app to a colleague	0.00	0.00	57.89	5.56	10.53	38.89	21.10	27.78	10.53	27.78
Being able to set my own sitting goal was helpful	0.00	16.67	52.63	38.89	21.05	16.67	26.32	27.78	0.00	0.00
The reminders to self-report/log sitting time were too frequent	5.26	11.11	15.79	44.44	31.58	16.67	47.37	16.67	0.00	11.11
The reminders to self-report/log sitting were annoying	5.56	16.67	11.11	55.56	44.44	11.11	38.89	11.11	0.00	5.56
I responded to all of the reminders to self-report/log your sitting	0.00	0.00	31.58	22.22	10.53	11.11	36.84	33.33	21.05	33.33
The prompts to stand and move were helpful	0.00	0.00	42.11	38.89	31.58	27.78	21.05	16.67	5.26	16.67
The prompts to stand and move were annoying	0.00	11.11	10.53	38.89	36.84	38.89	42.11	11.11	10.53	0.00
After receiving a prompt to move/stand, I usually did	0.00	5.56	26.32	16.67	15.79	44.44	36.84	22.22	21.05	11.11

	Strongly Agree (%)		Agree (%)		Neither agree nor disagree (%)		Disagree (%)		Strongly Disagree (%)	
	MA	**MA+ SSWD**	**MA**	**MA+ SSWD**	**MA**	**MA+ SSWD**	**MA**	**MA+ SSWD**	**MA**	**MA+ SSWD**
I am satisfied with how the app presented feedback and information	0.00	0.00	57.89	33.33	31.58	27.78	10.53	27.78	0.00	11.11
I would like to continue using the app after the study	0.00	0.00	0.00	0.00	31.58	5.56	42.11	33.33	26.32	61.11
I am satisfied with the app	0.00	0.00	57.89	16.67	26.32	27.78	5.26	27.78	10.53	27.78
The educational facts and tips were helpful	0.00	0.00	47.37	12.50	26.32	56.25	15.79	6.25	10.53	25.00
The educational facts and tips were repetitive	0.00	7.14	42.11	28.57	36.84	57.14	15.79	7.14	5.26	0.00
The educational facts and tips were annoying	0.00	7.14	0.00	28.57	36.84	57.14	52.63	7.14	10.53	0.00
I understood the information provided in the educational facts and tips	5.26	7.14	73.68	42.86	21.05	50.00	0.00	0.00	0.00	0.00
After reading the educational facts and tips, I actually applied them as well.	0.00	0.00	21.05	14.29	47.37	71.43	21.05	7.14	10.52	7.14
I am satisfied with the daily educational facts and tips	0.00	0.00	47.37	35.71	47.37	57.14	0.00	0.00	5.26	7.14
I am satisfied with the height adjustable desk	n/a	52.94	n/a	23.53	n/a	5.88	n/a	17.65	n/a	0.00
The height adjustable desk helped me reduce my sitting	n/a	58.82	n/a	17.65	n/a	5.88	n/a	11.76	n/a	5.88
I am comfortable with using a height adjustable desk at work	n/a	47.06	n/a	41.18	n/a	0.00	n/a	11.76	n/a	0.00
The height adjustable desk is suitable to be used in the workplace	n/a	47.06	n/a	35.29	n/a	0.00	n/a	17.65	n/a	0.00
It was easy to use the height adjustable desk	n/a	58.82	n/a	35.29	n/a	0.00	n/a	5.88	n/a	0.00
There were many practical issues using the height adjustable desk	n/a	5.88	n/a	11.76	n/a	11.76	n/a	41.18	n/a	29.41
I am likely to recommend the desk to a colleague	n/a	23.53	n/a	41.18	n/a	11.76	n/a	23.53	n/a	0.00
I would like to continue using the desk after the study	n/a	41.18	n/a	23.53	n/a	0.00	n/a	23.53	n/a	11.76
My productivity at work was affected negatively by participating in the programme	5.26	5.88	0.00	23.53	10.53	11.76	68.42	47.06	15.79	11.76

	Strongly Agree (%)		Agree (%)		Neither agree nor disagree (%)		Disagree (%)		Strongly Disagree (%)	
	MA	MA+ SSWD	MA	MA+ SSWD	MA	MA+ SSWD	MA	MA+ SSWD	MA	MA+ SSWD
My productivity was affected negatively by receiving the reminders to log sitting throughout the day	0.00	0.00	10.53	41.18	15.79	23.53	57.90	29.41	15.79	5.88
My productivity was affected negatively by responding to the reminders to log sitting throughout the day	0.00	0.00	10.53	52.94	10.53	17.65	63.16	29.41	15.79	0.00
My productivity at work was affected negatively by using the height adjustable desk	n/a	0.00	n/a	11.76	n/a	0.00	n/a	52.94	n/a	35.29

MA= mobile app group, MA+SSWD= mobile app plus sit-stand work desk group

Table 5-5 b Responses to closed ended satisfaction survey

Other	MA (%) (n=20)	MA+SSWD(%)(n=18)
Which aspect of the programme did you like best?	App self-monitoring 22.2	App self-monitoring 6.25
	App stand prompts 33.33	App stand prompts 37.5
	Educational tips 22.22	Educational tips 6.25
	Other 22.22	Other 50
Which aspect of the programme did you like least?	App self-monitoring 58.82	App self-monitoring 81.25
	App stand prompts 17.65	App stand prompts 6.25
	Educational tips 5.88	Educational tips 6.25
	Other 17.65	Other 6.25
What did you think about the intervention length?	Too short 5.56	Too short 5.56
	Too long 55.56	Too long 72.22
	Appropriate length 38.89	Appropriate length 22.22
What did you think about the amount of educational facts and tips you received?	Too few 16.67	Too few 10.00
	Too many 11.11	Too many 30.00
	Appropriate amount 72.22	Appropriate amount 60.00

MA= mobile app group, MA+SSWD= mobile app plus sit-stand work desk group

5.3.5.2 Qualitative Results

Analysis of the open-ended questions resulted in three main themes being identified which were: 1) Intervention benefits, 2) Intervention barriers and 3) Suggestions for improvements. These themes were further broken into sub themes and are presented below and in Appendix EE, along with representative quotes for the identified themes. The theme "Intervention benefits" was further broken into three subthemes which were evident across the two groups: 1) Awareness, 2) Productivity 3) Simplicity, and a further subtheme which emerged from the MA+SSWD group: 4) Choice of posture.

5.3.5.3 Intervention Benefits

1. Awareness

Participants in both groups generally acknowledged that the intervention increased their awareness of occupational SB. Some participants reported that once they became familiar with how to self-monitor they did not require constant interaction with their app, and prompts were less likely to be acknowledged or acted upon.

"It made you aware of the amount of time you spent sitting down" MA group

"While I was still using the sit/stand desk I didn't still need reminding to stand after 4 weeks" MA+SSWD group

2. Productivity

Some participants believed the intervention increased their concentration and helped improve their productivity.

"The programme encouraged me to take breaks but this was not counterproductive, if anything it helped my productivity" MA group

Participants in the MA+SSWD indicated that use of the desk allowed for better collaboration between work teams by raising the computer screen it was easier for multiple team members to congregate around a screen for discussion.

"At work we often collaborate in small groups in an ad hoc manner. The standing desks were an excellent point to meet together without kneeling at others desks or blocking pathways in the office" MA+SSWD group

3. Simplicity

Participants generally found the app simple to use and understand. The height adjustable desks were also deemed easy and simple to operate.

"The UI (app user interface) was basic and easy to understand" MA+SSWD group

"The mechanism (height adjustable desk) is very easy to use" MA+SSWD group

4. Choice of posture (MA+SSWD only)

Having the choice to sit or stand was considered a benefit and the height adjustable desk enabled users make the decision for themselves.

"I enjoyed having the option to stand" MA+SSWD group

It was this lack of choice that was missing from the MA group.

"It can be difficult to take more breaks from sitting without the use of a standing desk" MA group

The "Intervention barriers" theme consisted of two subthemes across both groups, including 1) Time priorities at work, 2) Inaccuracies with self-report and technology. Two further subthemes were evident from the MA group: 3) Environment, and 4) Frustration/guilt, and three from the MA+SSWD group: 5) Space/Cabling, 6) Preference to sit and 7) Novelty effect. The final theme to emerge from the data was "Suggestions for Improvement". Subthemes across both groups included 1) Fix technical bugs with app, 2) More automation of app, 3) Context specific app. One further subtheme from the MA+SSWD group was 4) Larger surface area for desk worktop.

5.3.5.4 Intervention barriers

The barriers to participation in this intervention were broken into seven subthemes.

a) Time priorities at work

Participants in both groups noted that work demands posed the biggest challenge to the consistent use of both interventions (app and desk), particularly the hourly interaction with the app. The intervention was not a main priority for participants whilst at work and had potential to become a source of distraction.

"Wasn't always possible to drop what I was currently doing at work" (to interact with the app) MA group

b) Inaccuracies with self-report and technology

The accuracy of the app was hampered by technical problems which interfered with data entry. If data entry was inaccurate the resulting feedback and prompts were therefore inaccurate. Accuracy was also impacted when the hardware of the supplied devices failed and if the participants were too busy to input data. Glitches in accuracy led to a reliance on delayed recall of sitting behaviours or missed data entry (due to being busy or technical errors) which was deemed to impact usefulness.

"I found it to be too intrusive to have to interact hourly and it was then inaccurate if you missed a marker" MA+*SSWD group*

"(App) crashed occasionally, reminders were sporadic, going off too often, not going off at all" MA+SSWD group

c) Environment (MA only)

A major barrier to reducing sitting in the MA group was linked to the office environment. Without access to furniture which encouraged standing whilst working, sedentary reduction was deemed to be very difficult.

"I tried at the start (to reduce SB) however in the absence of a proper standing desk I was improvising and it was uncomfortable." MA group

d) Frustration/guilt (MA only)

The increased awareness of the negative health consequences associated with prolonged SB and the belief that little occupational SB reduction cannot be achieved without access to height adjustable furniture caused feelings of frustration and guilt.

"The need of hourly swiping annoyed me. Especially that I realised how little I stand when at work but still was not able to make change as the whole office life is sitting orientated" MA group

"Without use of a standing desk it was frustrating as I knew I needed to stand more but was busy with work" MA group

e) Space/Cabling (MA+SSWD)

Although generally satisfied with the height adjustable desk, there were some cases where the worktop of the desk was too small especially if the participant was using multiple screens, or paperwork.

"I didn't particularly like the desk - possibly better if bigger- i.e. the same size as your normal desk" MA+SSWD group

There were also some issues noted with cabling. In some instances when the table was raised the cables were too short to allow full extension of the desk.

"Cable management tricky with shorter cables, some problem with cables, but not too bad" MA+SSWD group

f) Preference to sit (MA+SSWD),

Some participants reported a preference to sit whilst working and did not want to stand and work.

"I feel in the job I do and my personal preference. I concentrate better when I'm sitting" MA+SSWD group

g) Novelty effect (MA+SSWD)

It was reported that a number of participants used the intervention at the beginning but as time went on the novelty wore off, which resulted in a subsequent loss of interest.

"I think after the novelty wore off, I wasn't fussed (with the intervention)" MA+SSWD group

5.3.5.5 Suggestions for Improvement

Participants shared feedback on how to optimise the overall intervention experience. This was broken into four main categories.

a) Fix technical bugs with app

Participants noted issues regarding the timing of prompts. Further lab testing of the app would allow this issue to be rectified.

"I wouldn't use the app (again) until all of the technical issues have been resolved and it is more user friendly" MA+SSWD group

b) More automation of app

Participants felt the manual data entry method carried user burden and could be deemed time consuming in the work environment. A more automated data entry approach was seen to be desirable.

"Hook it up (app) to a fitness tracker to monitor standing, sleeping etc. to automate the process. If you didn't have to input the data - if this could be automatically done by a sensor? If not, it's inaccurate" MA+SSWD

c) Context specific app

The users suggested that a more flexible app would be better for use in an occupational setting. An app which allowed you to change your working hours, prompting frequency and a system which would disable prompts at inappropriate times (e.g. during meetings)

"Found it difficult at times with the app when I was out at meetings" MA group

d) Larger surface area for desk worktop

A small number of users suggested the particular model of desk was quite small and limited their workspace. Allowing users to choose their own height adjustable desk, specific for their space requirements was seen to be desirable.

"The desk slowed me down as less space- I use a lot of paper work and the desk got in the way at times" MA+SS

5.3.6 Context

The full pre-post intervention results of the audit are detailed in Appendix FF. There were no changes within each office set up before and after the intervention. Table 5-5 describes the environmental context in which the intervention was delivered and the differences between the worksites. All three worksites were based in one urban city setting in NI. The three offices were open plan, with low noise levels and good natural lighting. The control and MA+SSWD groups had their offices spread over one floor, whereas the MA group had offices spread over two floors in the same building. The control group offices were located on the third floor of a four storey building. The MA group's offices were on floor three and four of a five storey building. The MA+SSWD offices were on the first floor of a two storey building. All offices were accessible by stairs and elevator. The desks provided to employees were large fixed rectangular workstations. There were no formal "sit-less" opportunities or initiatives in place in any of the organisations. All staff had assigned desks within the open plan setting, with the exception of the MA organisation where some had their own private offices (2 of which were involved in this study). All staff in the MA and MA+SSWD groups were given access to a desk top computer and laptop, while the control group only had laptop access. All staff in the control group had cordless phone access and headsets, but only a small amount of those in the other offices had access to these.

Across all three worksites, the printers and photocopiers were located centrally. The MA+SSWD group had bins at each workstation. The MA and C offices had bins in a central location. None of the office buildings had a centralised canteen, but they all had a small kitchen for their staff, to the side of the office floor (one on each floor of the MA group offices). Both the MA and MA+SSWD groups had toilets on the same level as the office.

The control group had no toilet access on the level of their office and had to use toilets two floors below their office. These were accessible by stairs or elevator. The MA and MA+SSWD groups had their meeting rooms along the perimeter of the main office floor. The control group had their meeting spaces on a mezzanine level above the main office floor. This was only accessible by stairs. All worksite meeting rooms consisted of a large table surrounded by chairs. All offices were located in areas of the city where there were walkways for lunchtime PA. The control group were within walking distance to the city centre. The MA and MA+SSWD groups had showering facilities on site. There were no shower facilities at the workplace of the control group.

Table 5-6 Workplace environment audit

	C	MA	MA+S SWD
Is the office open plan?	Green	Green	Green
Are the desks communal?	Red	Red	Red
Are the desks booth-like?	Red	Red	Red
Do staff have their own offices?	Red	Yellow	Red
Are the offices centralised to one area?	Green	Green	Green
Is there the opportunity to stand in the office?	Red	Red	Red
Do staff have their own desktop PC?	Red	Green	Green
Do staff have access to a work laptop?	Green	Green	Green
Do staff have access to their own laptop?	Red	Red	Red
Do staff have access to mobile devices such as I pads/tablets?	Red	Red	Red
Do staff have a work mobile phone?	Yellow	Yellow	Yellow
Are staff permitted to use their own mobile at work?	Green	Green	Green
Do staff have a work landline on their desks?	Green	Green	Yellow
Do staff have access to a cordless landline?	Green	Yellow	Red
Do staff have access to a headset for phone calls?	Green	Yellow	Yellow
Do staff have their own printer at their desk?	Red	Red	Red
Does the office have communal printers?	Green	Green	Green
Does the office have communal photocopiers?	Green	Green	Green
Do staff have their own bin at their desk?	Red	Red	Green
Does the office have communal bins?	Green	Green	Green
Do staff have their own filing/storage space at their desk?	Green	Green	Green
Does the office have communal filing/storage space?	Green	Yellow	Green
Is there/ are there elevators in the building?	Green	Green	Green
Can the offices be accessed by elevator?	Green	Green	Green
Are there stairs in the building?	Green	Green	Green
Can the offices be accessed by stairs?	Green	Green	Green
Is there a central canteen/kitchen in the building?	Red	Red	Red
Is there a kitchen or break room for staff?	Green	Green	Green
Are the tables and chairs in the kitchen/break room?	Green	Green	Green
Is there the opportunity to stand in kitchen/break room?	Red	Red	Red
Are there tables and chairs in the meeting room?	Green	Green	Green
Is there the opportunity to stand in the meeting rooms?	Red	Red	Red
Are there shower/changing facilities in the workplace	Red	Green	Green
Are the lights controlled by movement sensors?	Red	Green	Yellow
Is temperature regulated to remain constant?	Red	Red	Green
Do staff have flexible working/lunch hours?	Green	Green	Green

Green=Yes, Red=No, Yellow=Some

5.3.7 Sedentary behaviour/physical activity

Tables 5-6 presents the data for each group detailing the outputs from the activPAL™ analysis for the full day at baseline, midpoint (4 weeks) and endpoint (8 weeks). Wear time was high; with no group mean, at any time point, less than 15 hours wear time per day (excluding sleep and non-wear time).

In terms of daily SB, a group mean difference of +2 min/day was detected from baseline to midpoint and -29.4 min/day from baseline to endpoint in the control group. The group mean difference for SB in the MA group was +7 min/day from baseline to midpoint and +16 min/day from baseline to endpoint. In the MA+SSWD group, the group mean difference was -63 min/day from baseline to midpoint and -41 min/day from baseline to endpoint. The number of sedentary bouts and length of sedentary bouts remained relatively stable within all groups over the duration of the study period. Figure 5-4 shows the individual differences in whole day SB from baseline to end point follow up.

The group mean difference for time spent standing per day in the control group was -8 mins/day from baseline to midpoint and + 8mins/day from baseline to endpoint. In the MA group, the group mean difference in standing time was -48 mins/day from baseline to midpoint and –6 mins/day from baseline to endpoint. In the MA+SSWD group, the group mean difference was +50 mins/day from baseline to midpoint and +41 mins/day from baseline to endpoint.

The group mean difference in time spent stepping per day in the control group was –5 mins/day from baseline to midpoint and + 7mins/day from baseline to endpoint. There was no group mean difference baseline to midpoint and -2min/day group mean difference from baseline to endpoint in the MA group. In the MA+SSWD group the group mean difference was + 7 mins/day from baseline to mid and endpoints.

Overall step count was low across all three groups. The group mean difference in the control group was -101 steps/day from baseline to midpoint and +191 steps/day from baseline to endpoint. The group mean difference in the MA group was -38 steps /day from baseline to midpoint and -312 steps/day from baseline to endpoint. In the MA+SSWD group the group mean difference was +264 steps per day from baseline to midpoint, and +88 steps/day from baseline to endpoint.

Table 5-7 presents the data for each group detailing the percentage of the workday in sitting, standing and stepping, based on the participants' average working day. The group mean difference in the percentage of time at work spent sitting was -0.15% from baseline to midpoint and -1.5% from baseline to endpoint in the control. The group mean difference in the percentage of time at work spent sitting in the MA group was +3.11% from baseline to midpoint and +3.43% from baseline to endpoint. The MA+SSWD group's mean difference in the percentage of time at work spent sitting was -14.37% from baseline to midpoint and -10.17% from baseline to endpoint. Figure 5-5 shows the individual differences in percentage of the workday in sitting, from baseline to end point follow up.

The group mean difference in the percentage of time at work spent standing in the control group, was +0.4% from baseline to midpoint and +1.18% from baseline to endpoint. The group mean difference in the percentage of time at work spent standing in the MA group was -3.71% from baseline to midpoint and -3.83% from baseline to endpoint. The MA+SSWD group's mean difference in the percentage of time at work spent standing was +13.95% from baseline to midpoint and +9.63% from baseline to endpoint.

The group mean difference in the percentage of time at work spent stepping in the control group, was -0.25% from baseline to midpoint and +0.32% from baseline to endpoint. The group mean difference in the percentage of time at work spent stepping in the MA group was +0.59% from baseline to midpoint and +0.41% from baseline to endpoint. The MA+SSWD group mean difference in the percentage of time at work spent stepping was +0.42% from baseline to midpoint and +0.51% from baseline to endpoint.

Table 5-7 Mean sitting, standing and stepping times for each arm at the predefined time points after removal of sleep and non-wear (activPAL^{TM} derived)

	Baseline			Mid			End		
	C (n=14)	MA (n=19)	MA+ SSWD (n=18)	C (n=13)	MA (n=18)	MA+ SSWD (n=14)	C (n=11)	MA (n=16)	MA+ SSWD (n=16)
Average wear time/day (h)	15.21 ± 1.23	15.46 ± 1.05	15.30 ± 0.89	15.04 ± 1.08	15.48 ± 1.21	15.19 ± 1.22	15.00 ± 1.20	15.41 ± 1.12	15.40 ± 1.18
Average sitting time/day (h)	11.00 ± 1.76	9.98 ± 2.80	11.03 ± 1.61	11.03 ± 1.27	10.10 ± 1.86	9.98 ± 1.19	10.51 ± 1.39	10.24 ± 1.61	10.34 ± 1.46
Proportion of wear time in sitting (%)	72.64 ± 11.70	64.19 ± 16.73	72.10 ± 9.96	73.76 ± 9.91	65.29 ± 10.76	65.79 ± 7.04	70.25 ± 8.65	66.65 ± 10.88	67.37 ± 10.29
Average standing time/day (h)	3.03 ± 1.77	4.03 ± 2.40	2.98 ± 1.31	2.90 ± 1.68	3.23 ± 1.61	3.81 ± 0.78	3.17 ± 1.21	3.77 ± 1.60	3.67 ± 1.37
Proportion of wear time in standing (%)	19.59 ± 10.62	26.47 ± 16.79	19.53 ± 8.96	18.93 ± 9.74	25.45 ± 10.54	25.15 ± 5.33	21.07 ± 7.85	24.31 ± 10.22	23.71 ± 9.02
Average stepping time/day (h)	1.19 ± 0.33	1.45 ± 0.54	1.28 ± 0.38	1.11 ± 0.31	1.45 ± 0.42	1.40 ± 0.55	1.31 ± 0.38	1.41 ± 0.67	1.39 ± 0.55
Proportion of wear time in stepping (%)	7.78 ± 1.97	9.35 ± 3.20	8.38 ± 2.41	7.32 ± 1.82	9.28 ± 2.37	9.07 ± 3.10	16.29 ± 26.44	9.04 ± 4.06	8.91 ± 3.00
Average sit to upright transitions (breaks)	45.40 ± 11.13	41.39 ± 11.13	46. 69 ± 9.95	45.28 ± 11.37	41.12 ± 9.62	45.79 ± 9.99	47.55 ± 9.17	42.53 ± 8.93	46.82 ± 10.27

	Baseline			Mid			End		
	C (n=14)	MA (n=19)	MA+ SSWD (n=18)	C (n=13)	MA (n=18)	MA+ SSWD (n=14)	C (n=11)	MA (n=16)	MA+ SSWD (n=16)
Average number of sitting bouts/day 0-30 mins	38.87 ± 12.16	35.31 ± 8.02	39.93 ± 10.93	39.07 ± 12.42	35.12 ± 9.18	40.39 ± 10.46	41.78 ± 9.51	36.51 ± 8.57	40.99 ± 10.65
Average number of sitting bouts/day 30-60 mins	4.56 ± 1.46	4.41 ± 1.66	4.91 ± 1.37	4.37 ± 1.45	4.29 ± 1.48	3.95 ± 1.48	4.38 ± 1.11	4.45 ± 1.58	3.97 ± 1.37
Average number of sitting bouts/day 60+ mins	2.30 ± 1.06	1.85 ± 0.92	2.15 ± 1.01	2.11 ± 0.77	1.92 ± 0.69	1.72 ± 0.67	1.78 ± 0.70	1.84 ± 0.87	2.07 ± 0.58
Average number of sitting bouts/day	45.73 ± 11.14	41.58 ± 8.84	46.98 ± 9.94	45.54 ± 11.33	41.33 ± 9.70	46.05 ± 9.98	47.95 ± 9.21	42.79 ± 8.90	47.03 ± 10.27
Average time sitting bouts/day 0-30 mins	4.49 ± 1.09	4.21 ± 1.22	4.55 ± 1.33	4.81 ± 1.17	4.29 ± 1.19	4.58 ± 1.20	4.78 ± 1.00	4.41 ± 0.91	4.55 ± 1.01
Average time sitting bouts/day 30-60 mins	3.20 ± 1.05	3.10 ± 1.18	3.42 ± 0.94	3.08 ± 1.06	3.03 ± 1.04	2.77 ± 0.56	3.04 ± 0.81	3.15 ± 1.09	2.74 ± 0.92
Average time sitting bouts/day 60+ mins	3.31 ± 1.69	2.67 ± 1.26	3.07 ± 1.46	3.14 ± 1.25	2.79 ± 1.08	2.71 ± 1.05	2.70 ± 1.56	2.68 ± 1.25	3.05 ± 0.84
Average number of steps/day	2995.34 ± 912.55	3566.07 ± 1516.45	3247.12 ± 1019.26	2893.82 ± 954.65	3527.35 ± 1128.55	3511.14 ± 1453.00	3186.05 ± 991.35	3253.95 ± 1712.40	3335.37 ± 1303.44
Number of valid days	5.71 ± 1.49	6.11 ± 1.41	6.17 ± 1.29	5.08 ± 1.80	5.83 ± 1.38	6.43 ± 0.76	6.09 ± 1.45	5.94 ± 1.48	5.69 ± 1.62

C= control group, MA= mobile app group, MA+SSWD= mobile app plus sit-stand work desk group

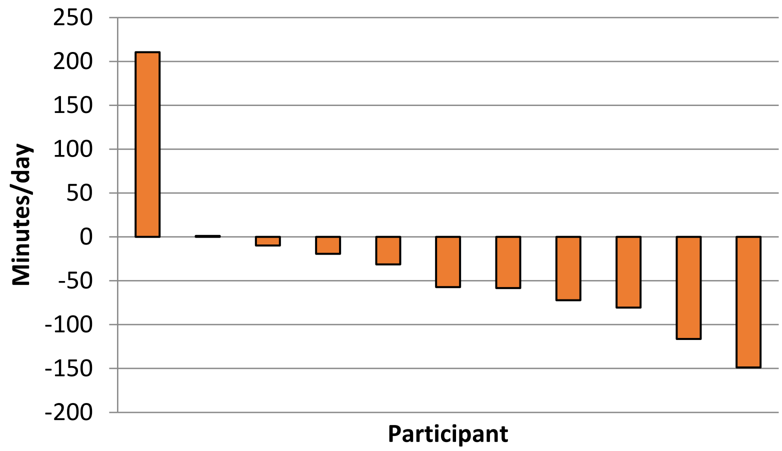
Table 5-8 Mean percentages of sitting, standing and stepping times at work for each arm at the predefined time points (activPAL^{TM} derived)

	Baseline			Mid			End		
	C (n=13)	MA (n=19)	MA+SSWD (n=18)	C (n=11)	MA (n=18)	MA+SSWD (n=14)	C (n=10)	MA (n=16)	MA+SSWD (n=16)
Sitting at work (%)	74.06 ± 20.34	70.44 ± 22.54	76.80 ± 16.57	73.91 ± 17.7	73.55 ± 12.52	62.43 ± 13.39	72.56 ± 23.29	73.87 ± 15.75	66.63 ± 20.86
Standing at work (%)	19.97 ± 19.17	23.94 ± 22.67	17.62 ± 16.65	20.37 ± 17.16	20.24 ± 13.01	31.57 ± 13.90	21.15 ± 22.88	20.11 ± 15.22	27.25 ± 21.24
Stepping at work (%)	5.97 ± 2.13	5.61 ± 1.91	5.58 ± 2.87	5.72 ± 1.98	6.20 ± 2.57	6.00 ± 3.14	6.29 ± 2.64	6.02 ± 2.74	6.12 ± 3.09
No of valid days	4.00 ± 1.15	4.32 ± 0.89	4.44 ± 0.78	3.82 ± 1.33	4.39 ± 0.78	4.64 ± 0.65	3.80 ± 1.03	4.06 ± 0.77	4.13 ± 0.89

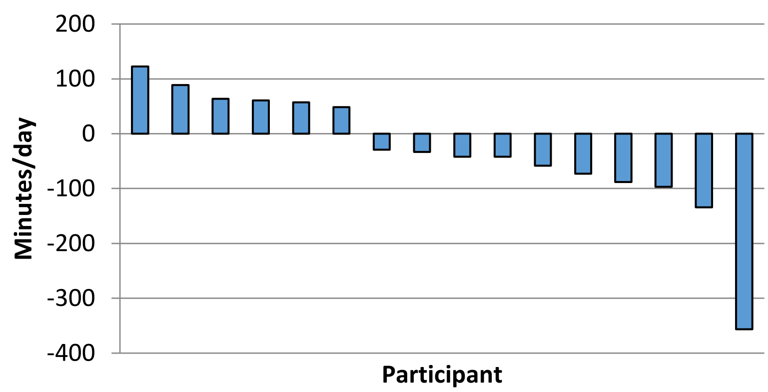
C= control group, MA= mobile app group, MA+SSWD= mobile app plus sit-stand work desk group

Figure 5-4 Individual differences in whole day SB from baseline to endpoint

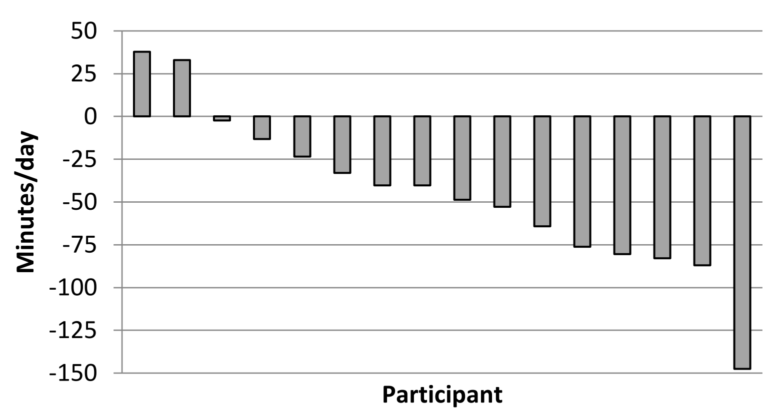
(i)



(ii)



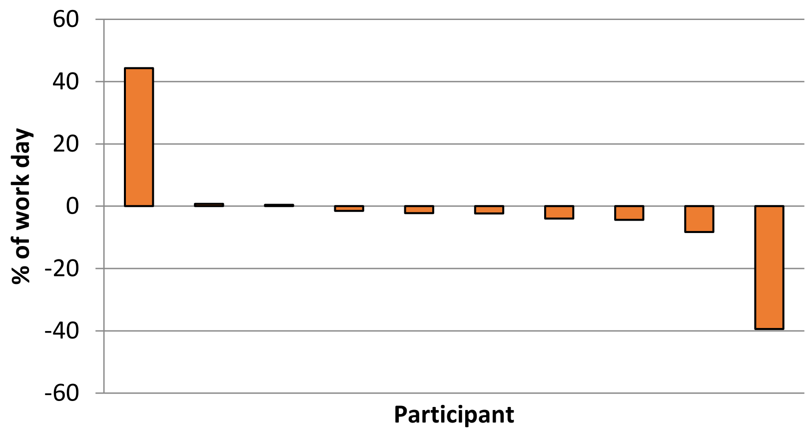
(iii)



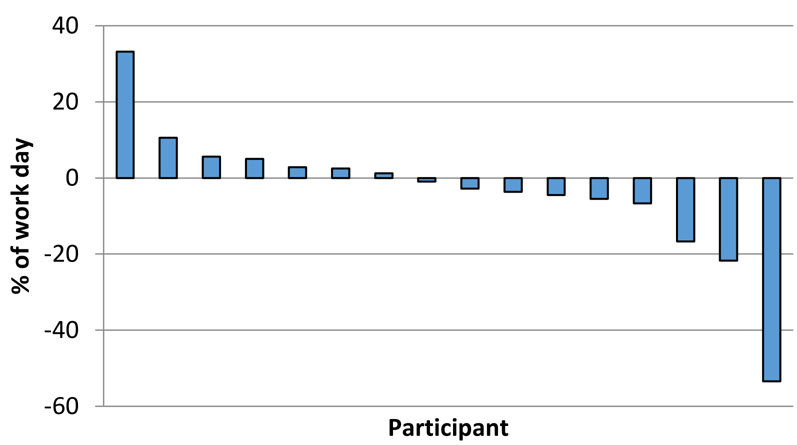
(i) Control group n=11, (ii) MA group n=16 and, (iii) MA+SSWD group n=16. Data are individual mean change.

Figure 5-5 Individual differences in percentage of time at work in SB from baseline to endpoint

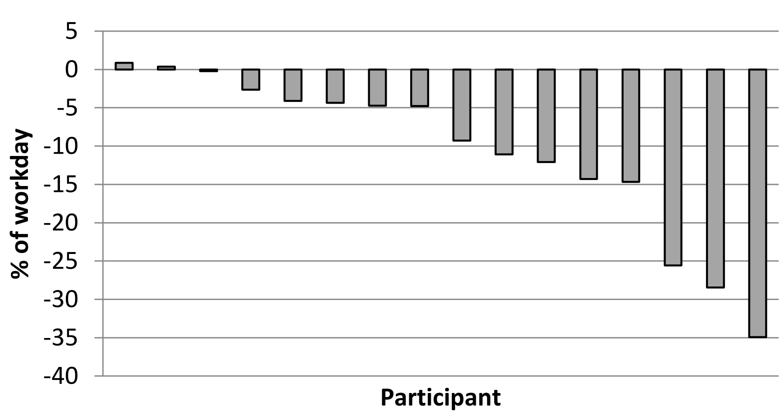
(i)



(ii)



(iii)



(i) Control group n=10, (ii) MA group n=16 and, (iii) MA+SSWD group n=16. Data are individual mean change.

5.3.8 Productivity

Overall group mean differences in productivity was minimal (Table 5-8). The group mean differences showed a slight initial rise in productivity from baseline to midpoint (C=+4%, MA=+0.04%, MA+SSWD=+1.5%). The group mean difference in productivity from midpoint to endpoint in the control and MA+SSWD indicated an increase in productivity (C=+0.08%, MA+SSWD=+0.70%). The group mean difference in the MA group suggest a decline in productivity from baseline to endpoint (-4.70%).

5.3.9 Mood

Few group mean differences were observed within groups over the duration of the study for mood (Table 5-9). The group mean difference from the anger subscale in the MA+SSWD group showed a notable increase in anger levels from baseline to midpoint (+7.75%), however this returned to below the baseline value at endpoint (-4.56%). The group mean difference in the depression subscale for both the intervention groups (MA and MA+SSWD) showed a notable increase in depression levels from baseline to midpoint (MA=+7.00% MA+SSWD=+10.13%), with a subsequent drop in depression group mean difference from baseline to endpoint in the MA+SSWD group (-4.25%). Although the group mean difference in the MA group from baseline to endpoint suggests an elevated score from baseline (+3%), it is lower than it had been at midpoint. There was also a notable increase in tension in the control group from baseline to midpoint (+7.81%) and baseline to endpoint (+5.88%).

Table 5-9 Mean productivity scores for each arm at the predefined time points

Productivity	Baseline			Mid			End		
	C (n=14)	MA (n=20)	MA+ SSWD (n=19)	C (n=13)	MA (n=19)	MA+ SSWD (n=17)	C (n=13)	MA (n=19)	MA+ SSWD (n=17)
	6.90 ± 1.07	7.23 ± 1.00	7.31 ± 0.90	7.30 ± 0.97	7.27 ± 1.00	7.46 ± 1.70	6.98 ± 0.88	6.76 ± 1.25	7.38 ± 0.85
No of valid days	4.79 ± 0.43	4.85 ± 0.49	4.58 ± 0.69	4.92 ± 0.28	4.95 ± 0.23	4.42 ± 0.94	4.46 ± 0.97	4.37 ± 0.90	4.76 ± 0.44

Note: 0=lowest productivity levels

C= control group, MA= mobile app group, MA+SSWD= mobile app plus sit-stand work desk group

Table 5-10 Mean mood scores (BRUMS) for each arm at the predefined time points

BRUMS	Baseline			Mid			End		
	C (n=16)	MA (n=20)	MA+SSWD (n=20)	C (n=12)	MA (n=18)	MA+SSWD (n=16)	C (n=13)	MA (n=18)	MA+SSWD (n=18)
Anger	3.56 ± 3.27	2.70 ± 2.77	2.45 ± 1.82	3.00 ± 3.19	2.44 ± 2.01	3.69 ± 3.36	3.77 ± 4.02	2.17 ± 1.58	1.72 ± 2.27
Confusion	2.50 ± 2.31	1.60 ± 1.43	1.70 ± 1.98	3.25 ± 4.58	2.22 ± 2.46	2.63 ± 3.30	2.77 ± 3.83	1.61 ± 2.03	1.67 ± 2.50
Depression	3.00 ± 3.03	0.85 ± 1.31	1.85 ± 2.11	2.75 ± 3.44	2.06 ± 2.46	3.47 ± 4.03	2.85 ± 3.24	1.33 ± 2.17	1.17 ± 1.79
Tension	3.75 ± 3.45	2.65 ± 1.98	3.00 ± 2.96	5.00 ± 4.43	3.22 ± 2.71	3.38 ± 3.96	4.69 ± 3.28	2.33 ± 2.03	2.22 ± 2.24
Fatigue	6.81 ± 3.51	5.90 ± 2.95	5.80 ± 3.25	6.58 ± 4.10	5.67 ± 2.52	6.63 ± 4.77	6.23 ± 3.27	5.39 ± 2.89	5.17 ± 2.98
Vigour	8.31 ± 2.73	8.55 ± 2.48	8.40 ± 1.93	9.08 ± 2.68	7.72 ± 3.86	8.19 ± 3.15	8.69 ± 2.56	8.56 ± 3.00	7.89 ± 2.32

Note: Lower scores indicate having less experience of the feelings described by the mood descriptors over the last week

C= control group, MA= mobile app group, MA+SSWD= mobile app plus sit-stand work desk group

5.3.10 Completion rates and usable data

This data is displayed for all outcomes at baseline, mid and end-point in their respective results tables 5-7, 5-8 and 5-9, by way of n values. At baseline, all participants provided demographic measures. In the control group, 12.5% did not provided height or BMI measures and 6.25% did not provide an occupational category (Table 5-2). At endpoint follow-up, completion rates for the satisfaction survey ranged from 90-100% (Table 5-4). 100% of the workplaces agreed to an audit being performed at baseline and endpoint.

In terms of productivity data (Table 5-8), completion rates ranged from 87.5-100% at baseline, 81.25-95% at mid and endpoints. The number of valid days of productivity data in each group was high, no group mean at any time point was less than 4.37 days per five-day data collection period. At baseline all participants (100%) provided BRUMS data (Table 5-9). Completion rates ranged from 75-90% at midpoint and 81.25-90% at endpoint.

In terms of valid activPAL^{TM} data for the overall day (Table 5-6), valid data ranged from 87.5-95% at baseline, 70-90% at midpoint and 68.75-80% at endpoint. The number of valid days of data in each group was high (Table 5-6), no group mean at any time point was less than 5.08 days per seven-day data collection period. In terms of percentage of the work day spent sitting, valid data ranged from 81.25-95% at baseline, 68.75-90% at midpoint and 62.5-80% at endpoint. The number of valid days of data in each group was good (Table 5-7), no group mean at any time point was less than 3.80 days per five-day data collection period.

5.3.11 Adverse events and technical issues

Over the course of the study no serious adverse events were recorded, however there were a small number of minor incidents with the activPAL™ devices (Table 5-10). Over the course of the intervention period there were 17 cases where participants recorded in their diaries that their ActivPAL™/adhesive patch caused some slight skin irritation. These 17 cases consisted of 13 individuals (n=1 reported irritation at all three measurement points, n=4 reported issues at two measurement points). There were 6 instances where participants removed the device due to the irritation. There were also ten identified cases of ActivPAL™ battery malfunction (i.e. battery did not hold charge for the full seven day measurement period). Two mobile devices had to be replaced due to charging issues. There were also five instances where participants contacted the researcher to report issues with the timing of prompts, which led to the app being updated.

Table 5-11 ActivPAL^{TM} issues

	Baseline			Mid			End			Total
	C	MA	MA+SS WD	C	MA	MA+SS WD	C	MA	MA+SS WD	
ActivPAL^{TM}/dressing irritation (kept device on)	1	1	2	1	0	2	2	2	0	11
ActivPAL^{TM}/dressing irritation (took device off)	0	0	3	1	0	1	0	0	1	6
ActivPAL^{TM} Battery malfunction	0	5	1	0	0	1	0	2	1	10

C= control group, MA= mobile app group, MA+SSWD= mobile app plus sit-stand work desk group

5.4 Discussion

The aim of this study was to assess the feasibility of a mobile app intervention to promote sitting time reductions in office workers. The feasibility study and process evaluation suggest that the "Worktivity" app intervention, delivered in combination with access to a SSWD, results in short term improvements in workplace sitting time. Using the "Worktivity" app alone, however, failed to reduce SB. This suggests that environmental facilitators may be necessary in order to reduce workplace SB however, without a SSWD only intervention arm, it is not possible to confirm if the Worktivity app has a contributory effect or not. Changes in self-assessed productivity and mood within groups were minimal, suggesting the intervention did not have a negative impact on the everyday work of the employees.

The process evaluation suggests that the "Worktivity" app may have failed to bring about positive reductions in SB due to several technical issues. Results showed that the mobile app intervention could be delivered as per protocol, with moderate exposure, in a workplace setting. Recruitment of office staff was somewhat possible, however only 93% of the target sample was recruited. Of those recruited, retention in the study was good, although satisfaction with the interventions was mixed. Sufficient usable data were collected at all-time points. There were no serious study related adverse events but there were a number of participants noting some slight irritation from the ActivPAL^{TM}/adhesive dressing. The feasibility study highlighted several areas for improvement, particularly with the app. “Worktivity” has potential to be modified based the information gathered and may benefit from further rounds of testing. Based on the process evaluation the MA intervention appears to be more acceptable than the MA+SSWD intervention.

The “Worktivity” app alone did not appear to be effective in reducing SB. These results contrast to findings from other behavioural interventions at work (activity trackers, computer prompts) without SSWD strategies where sitting reductions were noted (Evans et al., 2012; Brakenridge et al., 2018; O’Dolan et al., 2018). Although other studies using mobile apps have shown promise in reducing SB, none of these were conducted in the workplace setting (Bond et al., 2014; Kendzor et al., 2016; King et al., 2016, Arrogi et al., 2017). In this study, the failure of the app alone to have a beneficial impact on reducing SB may be explained by a number of factors. Firstly, at baseline, the MA group was generally less sedentary than the other two groups. This may have imposed a ceiling effect, lessening the impact of the intervention (White et al., 2017). Secondly, the app alone as a single component intervention, may not have been sufficient to elicit behaviour change. The participants in the MA group reported that, while the intervention made them more aware of negative sitting patterns, the office environment did not allow them to change their behaviour which led to them being frustrated with the intervention. This is further supported by the observed reduction in SB in the participants who had a SSWD during the intervention. This may suggest that environmental facilitators are a necessity in interventions targeting workplace sitting.

Another reason for the lack of effectiveness may be explained by environmental and contextual differences between the workplace clusters. For example, the MA group had flexible working hours whereas the MA + SSWD group had fixed hours. If employees availed of flexible hours (i.e. by taking fewer or shorter breaks throughout the day so as to leave early) they would have reduced opportunity for breaks in SB throughout the day compared with those adhering to fixed hours. In addition, as there were no scheduled breaks during the day, participants in the MA group may have feared they were being judged for slacking or avoiding work by colleagues and mangers, if they were seen to be away from their desk.

The effects of the current intervention on the MA+SSWD group of -63 min/day at 4 weeks, and -41 min/day at 8 weeks is similar to another multicomponent intervention using technology (internet-delivered programme) and environmental changes (portable pedal machine) to target occupational SB which resulted in a 58 min/day reduction in SB at 12 weeks (Carr et al., 2013). Results from the current study showed the MA+SSWD group reduced the percentage of time sitting at work by 10% from baseline to endpoint. This is similar to the 7% reduction seen in Danquah et al. (2016) who also used multicomponent interventions using technology (emails and texts) and environmental changes (high meeting tables in meeting rooms, offices and corridors), targeting occupational SB, over a 12-week time frame. These reductions are higher than that reported by Maylor et al. (2018) (-3.98% per work day) who also used a combined approach involving technology (computer prompts) and environmental strategies (decentralisation of facilities e.g. bins/printers) to reduce workplace sitting time over an 8-week period. The variation in results between the current study, Carr et al. (2013), Danquah et al. (2016) and Maylor et al. (2018) may be explained by the different types of interventions, outcome measures, duration of interventions used and office contexts.

Maylor et al. (2018) speculate the smaller reduction in sitting time in their study is due to inadequate environmental changes, which may also be the case for the MA group in the current study. Physical office environment was also seen to be a barrier to SB reduction in a previous office based intervention with no environmental aspect (Mackenzie et al., 2015). In the current study, the MA+SSWD group did reduce their SB and appear to have replaced time spent sitting with standing, rather than stepping. This replacement has also been noted in other studies using SSWDs to reduce SB at work (Alkhajah et al., 2012, Neuhaus et al., 2014 b). These results reiterate that in the absence of infrastructure that facilitates performance of work tasks while standing or moving, workers are unlikely to reduce their sitting (Gardner et al., 2017). However, the lack of a SSWD only arm means at this stage, it is not possible to determine whether the desk alone was responsible for the change in SB or whether the additional behavioural support provided by the “Worktivity” app increased the effectiveness of the desk.

A systematic review exploring the efficacy of interventions that use apps to improve diet, PA and SB found multi-component interventions (apps in conjunction with other intervention strategies) to be more effective than stand-alone app interventions (Schoeppe et al., 2016). Recent meta-analyses also have concluded that multi component intervention strategies are successful in reducing occupational SB (Chu et al., 2016; Shrestha et al., 2016; Shrestha et al., 2018). However, Shrestha et al. (2016 and 2018) found insufficient high quality evidence to draw definitive conclusions on multi versus single component interventions. The use of multiple intervention strategies to achieve long-term health behaviour change has previously been recommended (De Bourdeaudhuij et al., 2011; Appleton et al., 2016; Rodrigues et al., 2016). However, the most effective approach or combination of approaches to reduce SB remains to be tested in future trials.

The reduction in workplace sitting time found in the MA + SSWD group should be interpreted with caution due to the modest reduction in SB observed in the control group. The slight decrease in sitting time observed in the control group may be due to contamination of the group (i.e. their adoption of SB reduction activities). It has been noted that contamination of the control condition to aspects of the active condition is not uncommon (Lewis, 2015; Ehlers et al., 2016) and it is believed to be relatively easy for participants assigned to a control condition to became contaminated in an intervention as such (Courneya et al., 2002). Participants consenting to a behaviour change study are also likely to have an interest in changing their behaviour, and thus, participation might be a motivator (Lewis, 2015). The workplace audit revealed more opportunities to reduce sitting and incorporate PA during the work day in the control workplace than the other two settings. These include having access to laptops; toilet facilities located on other floors; and offices being in closer proximity to local amenities. The slight reduction in SB seen in the control group may have been the result of their heightened awareness of occupational SB by simply participating in the study and taking advantage of these existing opportunities.

The number of prolonged sedentary bouts and sedentary to upright transitions remained relatively stable within all groups over the duration of the study period. The reduction in the number of prolonged bouts (>30 mins) was the greatest in the MA+SSWD group (-1.02 bouts). This is slightly higher than the reduction in prolonged bouts reported by Maylor et al (2018) (-0.59 bouts) but lower than that reported by Arrogi et al (2017) who reported a reduction in the number of prolonged bouts (-2.8 bouts) following a 2-week app based "sit-less" intervention (Arrogi et al., 2017), albeit not in the workplace. The minimal changes observed in the current study in relation to sedentary to upright transitions were also seen in a study exploring the use of computer prompts at work to break-up SB (Júdice et al., 2015). There was minimal change in the total number of sedentary to upright transitions, despite successfully reducing sitting time and increasing time spent standing, as was noted in the current study. In the current study, the amount of time in prolonged sitting bouts reduced in both the control (-46.2 min/day) and MA+SSWD groups (-44.4 mins/day) from baseline to endpoint. This suggests that participants reduced their sitting time by taking longer, but fewer, standing/PA breaks rather than multiple shorter breaks.

Results from Chapter 3 highlighted concerns amongst employers and employees regarding the impact of SB reduction interventions on mood and productivity. Despite these concerns, the present study revealed negligible changes in these outcomes across all three groups (i.e. a neutral effect). These preliminary findings are positive and should serve to reassure employers and employees that reducing sitting during the workday may not compromise output or negatively affect mood. Other interventions to reduce SB have also reported no negative impact on productivity (Dutta et al., 2014 Neuhaus et al, 2014 b, Thorp et al., 2014), although no improvement was detected in these outcomes either. This may be explained by high levels of productivity at baseline and the tools used not having the sensitivity to detect improvements as a result of the interventions (Pereira et al., 2015). Productivity and mood are difficult outcomes to measure in this population and setting as they are likely to fluctuate greatly throughout the workday and are subject to unpredictable and uncontrollable external influences.

The understanding of the concept of workplace productivity is still growing and validity and reliability of various qualitative productivity outcomes need to be established (Pereira et al., 2015). Due to the subjective nature of self-report questionnaires, more comprehensive methods of quantifying productivity should be considered (Pedersen et al., 2009). Objective measures of productivity (e.g. key strokes per minute) and proxy measures from employers regarding employee productivity may be worth considering for future studies.

In relation to mood, a similar study using a web-based intervention to reduce SB also showed no distinctive effect on employees´ mental well-being (Puig-Ribera et al., 2017). In contrast, other “sit-less” interventions have reported decreases in fatigue and increases in wellbeing and overall mood (Dutta et al., 2014; Thorp et al., 2014; Bergouignan et al., 2016). Differences in the results are most likely attributed to the variation in intervention, intervention time frame and measurement instruments used. The effect of reducing time spent sitting at work on mental health outcomes remains unclear, and further studies to understand the relationship between SB at work and mental health/mood outcomes are recommended (Tobin, Leavy and Jancey, 2016).

Besides the preliminary effectiveness scores, many practical feasibility considerations were discovered. Recruitment of both worksites and individual participants proved to be a challenge, resulting in the target sample size not being met. These challenges were also reported in another feasibility study targeting workplace SB using education and prompts that used similar email based recruitment strategies (O'Dolan et al., 2018). As echoed by O'Dolan and colleagues (2018), it may be beneficial for future work with this population to explore alternative recruitment methods. Despite recruitment challenges in the current study, retention was good (89%). Similar retention rates were found in another workplace SB reduction intervention (86%) (O'Dolan et al., 2018). This suggests that initial contact with employers is the largest barrier to recruitment and could be improved by the education of the employers to the benefits of their employees participating in workplace SB reduction interventions (O'Dolan et al. 2018).

The process evaluation results indicate that the app component of the intervention was not entirely implemented as the researchers had intended, with delivery of some aspects somewhat compromised. Data from the satisfaction survey revealed that a number of participants in both groups (higher numbers in the MA+SSWD group) did not remember receiving, or ignored, the educational facts and tips as time went on. This most likely affected the effectiveness of the intervention as the educational aspects were designed to support users in reducing their sitting time (Gardner et al., 2017). In particular, this may have limited the effectiveness of the intervention on the MA group as they were more reliant on the app than the group who had access to a SSWD. It is speculated that one reason participants did not remember receiving the educational facts and tips could be because the educational prompt was set to be sent at the end of each work day (after the 8th log) and in instances where participants did not adhere to each hourly log (i.e. logged their sitting <8 times), the educational prompt was not sent. Others reported that although they received the facts and tips, they ignored them. Participants ignoring digital intervention content sent to encourage SB reduction has also been reported elsewhere (O'Dolan et al., 2018). Apps tend to have a natural time course for use. A survey of app retention averages reported that 21% of users will only use an app once (Localytics, 2017). Of those who continue to engage, after 8 weeks 66% of users and after 12 weeks 71% of users disengage with an app (Localytics, 2017). This again highlights the engagement struggles that are inherent in digital interventions.

Participants in the MA group acknowledged the prompts to log sitting more often than those in the MA+SSWD group (66% v 52%). This result is comparable to exposure seen in another recent app based self-monitoring intervention to improve health behaviours (including SB reduction) in a sample of US veterans (Buman et al., 2015). The veterans logged approximately 60% of their SB on the app over the 8-week intervention. Qualitative data from the exit survey in this study suggest that the moderate levels of exposure in this study may be due to work tasks taking priority. The lower exposure levels in the MA+SSWD group may be resulting from the higher reports of app technical issues in this group and more reports of not receiving the educational facts and tips.

Satisfaction with the interventions was at best modest, with the MA group more satisfied with their intervention than the MA+SSWD group. For both groups, factors influencing adherence to the intervention included better awareness of their sitting behaviours, perceived positive impact on productivity and an easy to use intervention. These were also reported in similar studies investigating factors that impact SB interventions at work (Gilson et al., 2011; Grunseit et al., 2013; Mackenzie et al., 2015). Those in the MA+SSWD group generally deemed the SSWD to be acceptable. This is comparable to other studies assessing acceptability of SSWD to reduce occupational SB (Grunseit et al., 2013; Graves et al., 2015).

In the current study, the modest overall satisfaction with the intervention is believed to be due to the app. Mixed user experiences and modest overall satisfaction with a self-monitoring app based intervention has been reported elsewhere (Buman et al., 2015). While other interventions using apps to assist in SB reduction have reported good satisfaction rates (Bond et al., 2014; King et al., 2016), none of these were based in an occupational setting. The lower rates of satisfaction with the app in the MA+SSWD compared to MA group may be due to the greater number of technical issues reported by these participants. Technical malfunctions appear to be common in technology enhanced health interventions (Cooley, Pedersen and Mainsbridge, 2013; Brakenridge et al., 2016; Van Drongelen et al., 2016; Brackenridge et al., 2018), which may impact upon satisfaction rates (Van Drongelen et al., 2016). The ability to deliver satisfying smartphone experiences by minimising technical glitches, may drive continued engagement with the intervention (Kim, Kim and Wachter, 2013). Therefore, echoing Osmond and Cohn (2015), technical challenges can and do happen and researchers in this area should have IT support readily available throughout the intervention design and implementation process in order to avoid such issues.

Both groups (more so MA+SSWD group) found the app to be an inconvenience in an already demanding workplace environment. This has been widely reported as an issue in other workplace health interventions (Wierenga et al., 2013; Hadgraft et al., 2016 b; Brakenridge et al., 2018; O'Dolan et al., 2018). Although self-monitoring in SB reduction interventions has been shown to be one of the more promising intervention techniques (Gardner et al., 2015), it was deemed a highly disliked feature of the current study. The intervention was designed to be non-invasive with minimal user input, yet it is possible that the hourly self-monitoring prompts were too frequent, resulting in a high user burden, as has been reported elsewhere (Rosenberg et al., 2015). This is a common problem with app self-monitoring (Dennison et al., 2013; Simons et al., 2018), therefore, reducing the frequency of the self-monitoring prompts and increasing automation may be worth considering. In particular, an app sensitive to detecting when a person may be most responsive to a prompt (e.g. when less busy and at a location where it is possible to break their sitting) would be more useful.

To further address the issue of work demands, future SB reduction interventions could explore content atypical to traditional SB reduction interventions by including time and stress management features. It has also been suggested that if difficulties in participating in interventions as such due to work demands and workload arise, staff should be encouraged to discuss this with their manager (Wierenga et al., 2013). Another approach is to ensure that managers are educated on the importance of SB reduction from a health and safety point of view and therefore encourage their staff to participate.

Data from the satisfaction survey highlighted mixed acceptability of the interventions. Some participants liked the SSWD, while others felt it too small to accommodate their computer monitors. Other participants found the prompts to move to be motivational, while others found them irritating and distracting. Some participants were more motivated by meeting their daily goals, whilst others preferred viewing their feedback charts. These results are not surprising as office workers will likely differ in what motivates and encourages behaviour change (Gardner et al., 2017). Researchers must also be cognisant of individual idiosyncrasies in how participants feel, think, look, behave or respond at any particular time (Corbett, 2017) and in this population it may be due to their specific work tasks and their own personal values. In the future, the most appropriate approach may be stepping away from uniform intervention content, and offering something more personalised such as a behaviour change “recipe” or “menu”, where users can select components of their own preference and tailor their own intervention. Allowing the user to alter and evolve app content as their behaviour begins and continues to change, may also prevent disengagement.

The results of this study should be interpreted in the context of several limitations, notably a small sample size. This sample was drawn from one area in NI, limiting generalisability of results. It is also evident from the individual level data that there are some participants with data falling more distant to the other values. After visualising the data and checking for errors, there was no reason to believe this data was erroneous and therefore was kept in the data set. These more “extreme” values may have impacted upon the group mean differences observed. The sample target size was also not met. It could also be argued that those who consented to participate were more motivated to change SB than the general population. It was not possible to blind the participants and researchers due to the nature of the trial. However, the use of device based measures (ActivPAL™) and participant reported measure of mood and productivity minimises researcher bias.

The use of participant reported outcomes for productivity, mood and satisfaction data may have incorporated an element of social desirability bias. The participants may have given overly positive satisfaction feedback due to a potential researcher-participant relationship. However, given the low to modest satisfaction scores given, this is not thought to be the case. Participants may also have responded to the mood and productivity questions in a biased manner as they were aware of the study aims. Whilst cluster randomisation was used to minimise contamination between groups, it may also mean that behavioural patterns were influenced by neighbouring colleagues rather than solely the impact of the intervention (O'Dolan et al., 2018).

The main strengths of the study are the randomised controlled design with a thorough and systematic process evaluation using both qualitative and quantitative data. The interventions used were also based upon behaviour change theory. Measures of SB were measured using a device based instrument. The findings also provide us with improvements to be used to inform the development of in a fully powered randomised cluster controlled trial. The process evaluation data highlights the opportunities and challenges met during the course of this research which should be of benefit to other researchers in this area, enhancing the knowledge base.

5.4.1 Conclusions

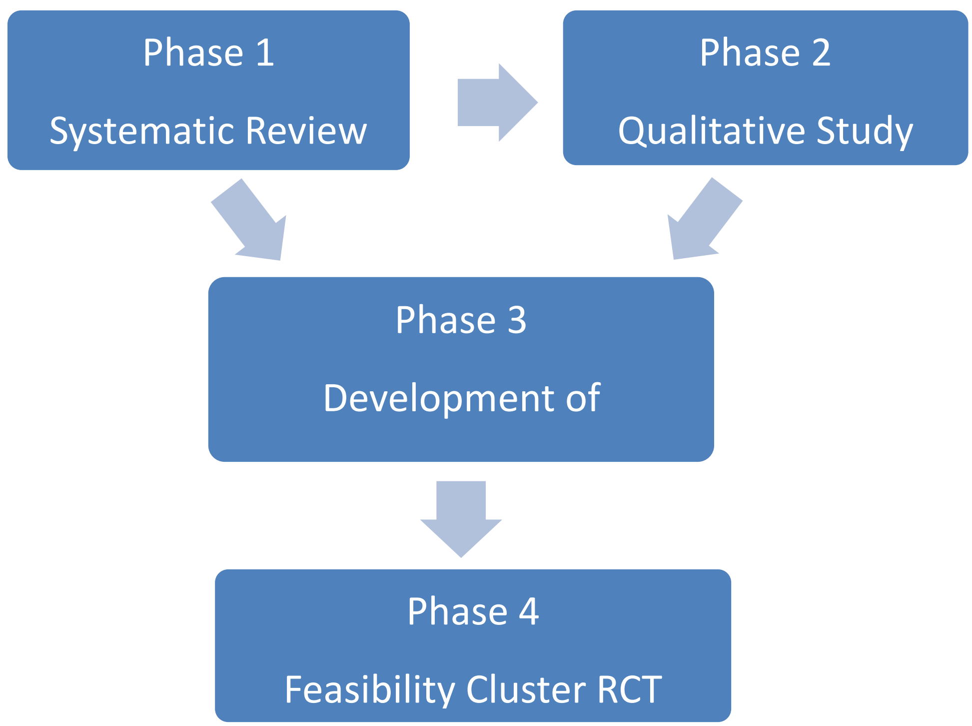
The findings of this study suggest that it is feasible to implement an app based intervention with the addition of a SSWD for desk-based office workers. The MA+SSWD intervention has the potential to evoke change in SB, however a larger RCT including a desk only arm is required to confirm these findings. Progress with "Worktivity" would be subject to significant improvements with the app. The low acceptability of the app, particularly due to its perceived impact on work demands, and technical issues with the mobile app may have limited its ability to impact behaviour change. The process evaluation has provided insight into the acceptability of and barriers to the implementation of a mobile app intervention with or without a SSWD component. Any future expansion of this work should consider the recommendations of the evaluation and refinement of the app and possible incorporation of a device-based self-monitoring alternative to reduce user burden, before being adapted and used as a tool to reduce occupational SB.

Chapter 6 - Overall Conclusions

6.1 Summary of Findings

The overarching aim of this programme of PhD research was to explore how digital technology may be used to reduce occupational SB. In order to meet this aim, a stepwise, iterative process was undertaken which is displayed in Figure 6-1.

Figure 6-1 Phases involved in overall research programme



Phase one involved undertaking a systematic review and meta-analysis exploring the effectiveness of behaviour change interventions using computer, mobile and/or wearable technologies aimed at reducing SB in healthy adults. From this phase, information on the types of technology and BCTs used in SB reduction interventions were identified. In the first instance, the systematic review and meta-analysis, presented in Chapter 2, indicated that it may be possible to intervene and reduce occupational SB by approximately 40 minutes per day using technology enhanced interventions. Key BCTs being used in technology supported interventions to reduce SB both at work and outside work included: "prompts and cues", "self-monitoring of behaviour", "social support (unspecified)" and "goal setting (behaviour)". Data extraction procedures identified a lack of consistency with reporting of BCTs within the included interventions, a finding that has been noted elsewhere (Soltani et al., 2016), which made classification of BCTs difficult. Future research should endeavour to improve the reporting of BCTs used in interventions so as to benefit the evidence base on computer, mobile and wearable technology enhanced interventions. It was identified that the technologies used to reduce occupational SB in these interventions were predominately computer prompts, emails, texts, e-coaching and websites. There was no evidence available regarding more modern technologies such as smartphone apps and wearable devices to reduce occupational sitting. Considering the broad range of technology options available to reduce SB, and the lack of evidence for their use to reduce SB in the workplace, it was clear that there was a need to identify potentially relevant strategies before intervening to reduce occupational SB using digital technology.

In order to bridge this identified gap in the literature, phase 2 explored employee, employer and company board member perceptions on the barriers and facilitators to reducing sitting at work and beliefs regarding the practicality of strategies with an emphasis on technology supported approaches. Qualitative analysis revealed the main barrier to reducing occupational sitting to be job-related tasks taking primary priority. Furthermore, office workers were concerned that reducing SB may impact upon their work performance. Fears of how these interventions could negatively impact on employee work performance have been echoed elsewhere (Goetzel and Ozminkowski, 2008; Gilson et al., 2011; Gilson et al., 2012, Hadgraft et al., 2016 b). Other barriers included the office design centred around sitting, reliance on IT to complete work tasks, feelings of being judged as avoiding work and a lack of knowledge on how and why to reduce SB. Facilitators included an open plan office with centralised facilities and standing friendly furniture, “brain breaks” to refresh mind-set, using opportunities within the work day to build in PA, supportive colleagues and managers, relief of musculoskeletal pain and a robust evidence-based business case with buy in from management to reduce SB. Potential strategies such as SSWD, education on the negative health consequence associated with SB and ways to reduce SB, workplace health policies and active breaks were suggested. Technology was generally seen to be a useful tool;

particularly valuable in providing prompts and as a platform to allow behavioural self-monitoring via smartphone apps. Digital interventions with low user burden, causing little disturbance, delivered in a personalised, accurate and non-patronising fashion were perceived to be preferable. This participatory approach helped the research team understand the perceived barriers, facilitators and preferred strategies of potential users and important stakeholders. The beliefs, preferences and assumptions about reducing SB at work and the impact of technology based strategies as a solution to reducing occupational SB identified during this phase were used to guide the intervention development phase (Phase 3).

Phase 3 consisted of merging the results from the preceding two phases with wider relevant literature and the BCW, while considering the APEASE criteria to develop the most appropriate digital intervention to reduce occupational SB. In light of available resources, the research team concluded that a smartphone app that allows individuals to monitor their SB by self-report would be the best approach. This would overcome previously identified issues relating to device based measures of SB, such activity trackers inaccurately capturing SB (Tudor-Locke, Camhi and Troiano, 2012) and available research grade inclinometers lacking a user-friendly interface, rendering them inappropriate for everyday consumer use. In addition, mobile apps to reduce SB were deemed potentially acceptable from the qualitative work in phase 2. In keeping with the findings of phase 2, the development process focused on minimising impact on work tasks, highlighting opportunities to break SB during the work day so as not to compromise productivity, educating employees regarding the negative health consequences associated with prolonged SB. Following “Think- aloud” usability testing, the app was refined and led to the development of “Worktivity”, a bespoke, theory based and user informed mobile app designed to help reduce occupational SB. The core component of “Worktivity” was self-monitoring and feedback of SB at work, which was complemented by additional features focusing on goal setting, prompts to break sitting and educational facts and tips.

Phase 4 explored the feasibility of using the newly developed app, with or without the use of a SSWD, to reduce occupational SB. The app was tested within a cluster RCT design to identify its effectiveness in reducing SB at work, but also if there were any effects on mood and work productivity. This phase also included a process evaluation, based upon the recommendations of Bauman and Nutbeam (2014), to describe how the intervention was carried out in practice, help to understand how the programme was delivered and explain the observed outcomes.

The findings of this study suggest that it is feasible to implement an app based intervention with the addition of a SSWD for desk-based office workers. This type of multicomponent intervention has the potential to evoke a positive change in SB, as evidenced by the 41 min/day reduction in SB reported in Chapter 5. Similar results have also been seen in other SB reduction interventions using the combined approach of technology alongside environmental changes (Carr et al., 2013; Danqauh et al., 2016). Providing the mobile app alone failed to reduce SB, which was likely due to the app alone being insufficient to elicit behaviour change and that environmental facilitators may be required in interventions targeting workplace sitting.

Furthermore, the low acceptability of the app, particularly due to its perceived impact on work demands, and technical issues may have limited its ability to impact behaviour change. Despite concerns regarding the interventions' impact on productivity and mood, the study revealed negligible changes in these outcomes across all groups (i.e. a neutral effect) which should serve to reassure employers and employees that reducing sitting during the workday may not compromise output or affect mood. The process evaluation provided insight into the acceptability of and barriers to the implementation of a mobile app intervention with or without a SSWD component and the findings can be used to inform modification to enhance both interventions. Satisfaction with the interventions was at best modest, which is believed to be due to the app. Barriers to effective implementation included technical issues when using the app. Due to these technical issues, some app components of the intervention were not entirely implemented as the researchers had intended. With the delivery of some aspects somewhat compromised, the effectiveness of the app intervention may have been limited. Participants also found the app to be an inconvenience in an already demanding workplace environment. Those who received the MA alone reported that while the intervention made them more aware of negative sitting patterns, the office environment did not allow them to change their behaviour which led to them being frustrated with the intervention. Any future expansion of this work should consider the recommendations of the evaluation and refinement of the app before being adapted and used as a tool to reduce occupational SB.

6.2 Considerations for future research

6.2.1 Physical office environment

Results from this thesis suggest that the office physical environment is a key consideration in developing SB reduction interventions in the workplace. This reinforces the views of Healy et al. (2012) where it is noted that the built environment plays an important part in reducing occupational SB. In this thesis (Chapters 3 and 5), an inadaptable seated environment was seen as a major barrier to reducing SB. Participants felt that standing friendly furniture e.g. SSWDs were particularly promising strategies as they allowed a reduction in SB without impacting on productivity. These results suggest that, in the absence of infrastructure that facilitates performance of work tasks while standing or moving, workers are unlikely to reduce their sitting (Gardner et al., 2017).

6.2.2 Multi-component interventions

Results from Chapter 5 suggest that multicomponent interventions harnessing technology delivered prompts to remind people to use environmental strategies e.g. SSWD may maximise the effectiveness of these intervention approaches. There is evidence to support and recommendations for the use of sit-stand work desks (SSWD) used in conjunction with other behavioural intervention approaches (O'Connell et al., 2015; Chu et al., 2016; Gardner et al. 2017; Munir et al., 2018; Shrestha et al., 2018). A multicomponent intervention combining SSWD with motivational behaviour change strategies may provide the environmental opportunity necessary to undertake desk work while standing, and the motivation and capability to displace sitting with standing (Gardner et al., 2017). Multicomponent interventions using environmental and technology aspects have been associated with a reduction in SB of 59 min/day (Carr et al., 2013) and 48 min/day at work compared to a control (Danquah et al., 2016).

6.2.3 Personalised and tailored interventions

The importance of a personalised and tailored SB intervention, as identified in Chapter 3, was the underpinning rationale for the development of "Worktivity". Technology offers the ideal opportunity to tailor and personalise the content of interventions to each participant or group of participants (West and Michie, 2016). Office workers will likely differ in what motivates and encourages their behaviours to change (Gardner et al., 2017). Results from the qualitative work in Chapters 3 and 5 suggest that in the future, the most appropriate approach may be stepping away from uniform intervention content, and offering something more personalised such as a behaviour change “recipe” or “menu”, where users can select components of their own preference and tailor their own intervention regarding how and when they reduce SB. This approach has also been recommended by Gardner et al. (2017), who are currently conducting a pilot study where participants choose from a ‘menu’ of BCTs tailored to self-declared barriers to sitting reduction, effectively co-producing and personally tailoring their intervention. Other workplace health promotion studies (including SB reduction) (Gilson et al., 2011; Tsiga, Panagopoulou and Niakas, 2015) further strengthen the argument for even more tailored and personalised approaches to reducing occupational SB due to different office based roles, as well as individual employee preferences.

6.2.4 Low user burden/automated approaches

The findings from this thesis highlight the importance of low burden interventions in the work place. Qualitative results from Chapters 3 and 5, indicate that while at work participants place priority on their work tasks and do not want to be disrupted regularly by an intervention to reduce workplace SB. The “Worktivity” intervention was designed to be non-invasive and requiring minimal user input, yet it is possible that the hourly self-monitoring prompts were too frequent and intrusive, resulting in a high user burden. Results from the satisfaction survey (Chapter 5) highlighted how some participants felt the manual data entry method carried user burden and was potentially time consuming in the work environment. The need for a more automated data entry approach was seen to be desirable. The results of a study examining health app usage among mobile phone owners in the US reported that disengagement with app interventions was primarily due to high data entry burden (Krebs and Duncan, 2015). However, as reported in Chapter 4, there is a lack of commercially available devices that accurately detect sitting posture and supply immediate feedback to the user, therefore, manual self-monitoring of SB via an app was deemed necessary for this programme of research. Future exploration of this area should leverage advances in technology in order to address this issue. A possible solution may be a more flexible, context specific app that allows users to modify working hours and prompt frequency, and a system which can disable prompts at inappropriate times (e.g. during meetings) or indeed uses information gathered on user behaviours to predict or model what would be most appropriate. This has been recognised as a way of encouraging timely engagement with digital interventions (Dennison et al., 2013). A possible future approach may be to integrate wearable technology with customisable software. This may be a solution to the user burden associated with self-monitoring in an environment where job-related tasks take priority. It has been suggested that more sophisticated feedback and automated health tracking can significantly improve engagement with digital interventions including apps (Pagoto and Bennett, 2013; Kim et al., 2016). However, as noted by Simons et al. (2018), automatically generated tailored information would require substantial input and time from computer science experts, and considerable financial resources.

6.2.5 Rapid technological growth and review update

Innovations in digital health are emerging in the increasingly smart and connected world in which we now live (Michie et al., 2017). Digital health interventions need to constantly evolve and be updated just to remain useful, let alone improve in functionality (Murray et al., 2016). It is difficult for researchers to keep abreast of the digital advancements, as technological development often out-paces academic research (Agarwal et al., 2016).

The systematic search (Chapter 2) was undertaken in June 2016. In order to explore advancements in the area of digital health and SB, the same key word search for studies published between June 2016 and August 2018 was conducted in August 2018 using the Pubmed database. There were 2286 hits, with an additional 11 studies meeting our inclusion criteria. As the original study (Chapter 2) contained only 17 eligible studies from inception of the database to 2016, an additional 11 eligible studies in 26 months highlights the rapid growth of computer, mobile and wearable technology supported interventions to reduce SB. Of the 11 studies, four focused on reducing overall SB (Cotten and Prapavessis, 2016; Arrogi et al., 2017; Lyons et al., 2017; Spring et al., 2018) and seven on reducing SB in the workplace (Healy et al., 2016; Taylor et al., 2016; Barbieri et al., 2017; Li et al., 2017; Dunning et al., 2018; Maylor et al., 2018; O'Dolan et al., 2018). In those studies exploring overall daily SB, the interventions used in the updated studies are similar to those used in the original review reported in Chapter 2 (activity trackers, companion apps and emails). However, in the updated studies there was one study using an app “stAPP” specifically designed for their study to reduce overall daily SB (Arrogi et al., 2017. The “stAPP” app appears to be a promising intervention tool to interrupt and reduce prolonged sitting behaviour. However, the “stAPP” research team also encountered similar difficulties as reported by the developers of “Worktivity”. Using the in-built phone accelerometer did not allow for a reliable measure and delivery of SB related information and therefore participants were asked to wear a bulky device (Shimmer, Dublin, Ireland) on their thigh to forward inclinometer derived information to the app, which is not suitable for long-term or commercial use. The authors also call for further research to harness technological advancements to produce a reliable and more commercially appropriate measure of and feedback on SB.

In relation to interventions specifically targeting workplace SB, the updated results suggest that computer prompts are still the most explored option (n=5), with one study exploring emails and one additional study exploring the use of text messages. There remains no evidence available regarding the use of apps to reduce occupational SB.
The results of these 11 studies in general, support a short term reduction in SB in favour of technology supported interventions. Again, there is wide heterogeneity in study durations (2 weeks to 12 months), intervention (various types of technology platforms), and SB measurement tools (subjective, device based and proxy measures).

6.2.6 Public health campaign to boost recruitment

Recruitment of both worksites and individual participants proved a challenge, resulting in the target sample size in Chapter 5, not being met. Recruitment challenges in occupational SB reduction interventions have been reported elsewhere (O'Dolan et al., 2018). A potential solution to this issue may be via larger public health campaigns which focus on raising awareness of the problem of prolonged sitting (Arrogi et al., 2017). Results from Chapter 3 suggest that people have some understanding of the negative health consequences associated with prolonged SB, yet did not see SB as an issue and therefore felt no pressing need to change the behaviour. Arrogi et al., (2017) found that, most people are convinced of the benefits of a physically active lifestyle but many people underestimate the problem of SB. A widespread public health campaign focusing on the importance of reducing SB, may encourage the gatekeepers (employers) to consent to SB research being conducted with their employees and also encourage employees to take part.

6.2.7 Measurement considerations

The activPAL™ device is a valid, accurate and precise tool to measure components of SB in free-living environments and is sensitive to reductions in sitting time (Kozey-Keadle et al., 2011; Lyden et al., 2012). However, it is not a comprehensive data processing or analytical tool, and therefore excluding periods of non-wear or isolating periods of interest e.g. time at work requires processing the data outside of the activPAL™ software

(Edwardson et al., 2017). There is no gold standard data processing and analysis procedure and studies rarely provide sufficient information on data processing methods (Edwardson et al., 2017). In Chapter 5, a thorough and transparent report of how the activPAL™ data were reduced and analysed was presented. Due to space constraints in journal articles, researchers often cannot provide the full level of detail required to replicate studies and make judgements regarding comparability of study results. As echoed by Edwarsdson et al. (2017), a full account of all data processing methods should be included in a supplementary appendix or file alongside manuscripts to allow other researchers to reproduce the specific methodology employed. Automated algorithms allows for a lower researcher burden when processing and analysing activPAL™ data. The algorithm used in Chapter 5 of this thesis allowed for a low burden removal of sleep and non-wear time from the data, however the algorithm was not able to successfully isolate specific periods of interest (i.e. time spent at work). Therefore, a manual approach (matching the algorithm generated data with self-reported diary entries) was undertaken in an attempt to isolate the periods of interest. This was a complex, time and resource intensive, high burden data isolation process and an accurate and valid automated approach would be of great benefit for future work.

There also remains a lack of knowledge regarding the interaction between total sitting time, breaks in prolonged sitting time and the impact of both on health. Understanding patterns of SB is crucial to further maturing the research field (Loudon and Granat, 2015). This is difficult to achieve given the current lack of analysis guidelines, cut-points and gold standards and should be addressed in future work. Chastin et al. (2015) have suggested a compositional data analysis approach. They propose that time spent on a physical behaviour (SB) is co-dependent on the other ones (e.g. PA, sleep etc.) and, therefore, it should be analysed and conceptualised within a compositional paradigm to obtain meaningful and accurate inferences (Chastin et al., 2015).

6.3 Strengths of the research programme

Smart phones and mobile apps have many potential advantages for health promotion, however many have not been subjected to careful user-centred design and in turn rigorous evaluation processes (Buller et al., 2013). A major strength of this PhD is the thorough methodological procedures used to develop a mobile app intervention, involving rigorous, iterative, intervention development and evaluation methods. This included a formative evaluation approach with the target population, key stakeholders and end users input at various points of the intervention conceptualisation and development stages. It is important to use a stepwise and iterative approach when developing new smartphone apps (Simons et al., 2018). This ensures that interventions are responsive to users' needs and preferences, and are designed "from the ground-up" rather than based on developers' preconceptions (Pagliari, 2007; Michie et al., 2017). This process also provided a basis for sequential formative testing and outcome evaluation which enabled the users and stakeholders to guide the development process of the intervention by providing input and feedback alongside the research team (Lee et al., 2018). Consulting the employees, employers and board members before conceptualisation of the intervention provided information which influenced its development. It allowed for exploration of design considerations and to obtain feedback from key personnel. The data from the "think-aloud" study enabled identification and removal of problems. Target group input at the design stage can significantly contribute to the development of interventions (Howes et al., 2018). This ongoing participatory approach and user involvement enabled adaptation to the specific needs and preferences of the target end user and key stakeholders (Pagoto and Bennett, 2013). It allowed for a wide range of adjustments in conceptual design and adaptations in technical, visual, and practical elements (Lee et al., 2018). It also ensured issues of acceptability, usability and credibility were addressed prior to implementation, thus ensuring the best chance of developing tools to improve health which are customised to the end-user (Whittaker et al., 2012; Davies, 2016; Simons et al., 2018).

The use of a systematic review and meta-analysis, focus groups, individual interviews, "think-aloud" and feasibility studies provided a broad source of both qualitative and quantitative data. The resulting integration of these methods highlights another strength of this project. The basic premise of this integrated methodological approach is that it permits a more complete and synergistic utilisation of data than do separate quantitative and qualitative data collection and analysis (Wisdom and Creswell, 2013).

This integration strengthened the rigor and enriched the analysis and findings of this thesis. The qualitative elements of the post intervention satisfaction questionnaire enabled confirmation of the quantitative data and a deeper understanding of the results (Giesbrecht, 2016).

Another strength of this study is the extensive design team used to develop the intervention. The team comprised collaboration between SB researchers, behaviour change experts, computer scientists, app developers, office workers, employers and company board members. Good research in the area of digital health development requires fertile multidisciplinary collaborations that draw on insights and experience from multiple fields, to optimise design and development to meet users' needs (Murray et al., 2016).

In regards to app development for health behaviour change, there is growing consensus that app interventions should be based on formative research with the target audience, but also with reference to behaviour change theory (Fjeldsoe et al., 2012; Pagoto and Bennett, 2013; Curtis, Lahiri and Brown, 2015). An advantage of using this integrative theoretical framework is that it ensures all the necessary elements are in place to optimise potential benefits (Munir et al., 2018)**.** Few workplace sedentary reduction interventions have utilised such a comprehensive approach (Munir et al., 2018). Furthermore, despite the clear recommendations for use of behaviour change theories in digital technologies (West and Michie, 2016), very few of the existing health focused apps are based on theoretical models (Arrogi et al., 2017). Basing the development of this programme of research upon principles of the Behaviour Change Wheel (BCW) is another methodological strength. The current project displays an approach by which the BCW (including TDF and BCT components) can be applied in the development of an app based intervention to reduce occupational SB. This approach was chosen to promote a systematic and comprehensive analysis of the available options using behaviour change theory and the available scientific evidence (West and Michie, 2015). The key benefit of using this framework was to allow the development team to be comprehensive in considering intervention options to and then to systematically select the most promising (Atkins and Michie, 2015).

Specifically, the BCW was used in this study in a number of manners:

1. By using the BCW and its components it was possible to gain an understanding of how BCTs are being used in digital interventions to reduce SB and enabled comprehensive thinking about existing interventions (Chapter 2).
2. In Chapter 3, the TDF framework provided a theory-informed approach to identify determinants of sitting behaviour (Atkins et al., 2017) and a comprehensive approach to identify the barriers and facilitators and potential strategies to reducing sitting time at work.

3. The BCW and BCTs were used to guide the development process and provide a basis for selecting the intervention components detailed in Chapter 4. It allowed for the provision of a clear rationale for the specific design and content of the intervention (Webster et al., 2015).

Using these methods, it is possible to provide a detailed report of the intervention content (Michie et al., 2013). Behaviour change interventions are often not well described, using inconsistent terminology which can constrain scientific replication (Michie et al., 2009). Using the shared vocabulary provided by the BCW and being explicit about the processes used adds to the knowledge base and may assist further understanding of behaviour change (Johnston, 2016; Webster et al., 2015). The shared vocabulary used in the current programme of research is in keeping with the importance of providing a transparent and robust rationale for developing intervention content and for clear and full reporting (Steinmo et al., 2015).

The systematic, thorough and transparent descriptions of the formative development and evaluation approaches used was a particular strength of this thesis. This level of detail is rarely provided by authors, but is essential if the field of behaviour change interventions is to advance (Fjeldsoe et al., 2012). Reporting of the procedures as such may pose as a template for development and process evaluation of interventions to reduce SB in the occupational setting, but also in other contexts and with other health behaviours (Buman et al., 2015). This may be particularly relevant as the potential of digital health interventions has scarcely been realised due to difficulties in generating a knowledge base for guiding the development of digital health tools (Murray et al., 2016). By transparently reporting more intervention development studies, scientific rigour can improve and it may stimulate debate and promote learning amongst researchers (Hoddinott, 2015). To date, few authors have reported on their intervention development methods, and published evaluations rarely provide enough detail to replicate the development methods, this suboptimal reporting is thought to be hampering progress in this area, and impeding knowledge translation (Eysenbach, 2011; Fjeldsoe et al., 2012).

6.4 Limitations of the research programme

A potential limitation to this study was that the participants in Chapter 3, 4 and 5 of this project were drawn from desk-based office workers across two cities in NI. Therefore "Worktivity" was developed for and evaluated in a small sub sample of the Northern Irish working population, potentially limiting generalisability of results. The perceptions and opinions of the participants may not reflect the views of those in other settings, areas or contexts. The small opportunistic samples in this series of studies may also limit representativeness; however the office workers involved in this programme of research were of varying professional backgrounds, career levels, ages and sexes and therefore deemed to be fairly representativeness of a typical office-based workforce. It could also be argued that those who consented to participation in the individual studies of this project were more motivated to change their SB than the general population.

The exploratory design of the feasibility study restricted the types of analyses that were appropriate and therefore no definitive recommendations can be made regarding the effectiveness of the intervention on SB, productivity and mood. Nevertheless the feasibility and process evaluation provided valuable information, showing recruitment was somewhat possible, study retention was good, both interventions could be delivered as per protocol, with moderate exposure and sufficient usable data, although satisfaction with the interventions was mixed.

Although the formative, sequential research approach undertaken in this PhD project is generally deemed to be a strength, the process is lengthy especially when considering the pace of innovation growth (Rodrigues, 2014). This is a particular issue in the field of digital health as technology tends to develop at a more rapid pace than public health research can (Agarwal et al., 2016). Each of the development and evaluation steps used in this project required considerable time and resources to implement. There is a possibility by the time “Worktivity” was evaluated in the feasibility study (Chapter 5), the users beliefs about app technology gained in Chapters 3 and 4, may have been outdated (Pagoto and Bennett, 2013).

Although the participatory development process was implemented, this PhD project was resource limited. All user recommendations gained in Chapters 3 and 4 could not be applied to the intervention. For the same reasons, only a certain number of iterations of the app could be evaluated and amended. These restrictions may have impacted on the effectiveness and user satisfaction scores of "Worktivity" in Chapter 5. The world of rapidly changing technologies challenge traditional research designs exploring digital health interventions such as RCTs with locked-down and lengthy intervention and analysis approaches (Michie et al., 2017). It has been recommended that the RCT design may be better to evaluate digital health tools at a more "mature" stage of development (Kumar et al., 2013). As such, this thesis may have benefited from further refinement using other methodological processes before progressing to RCT stage.

In order to address this, future study designs could consider using other more efficient research strategies such as SMART (Murphy et al., 2005), or MOST designs (Collins et al., 2005). The SMART experimental design was developed to aid in the construction and refinement of adaptive interventions via a multi-stage process that can be operationalised via a sequence of decision rules that recommend when and how the intervention should be modified in order to maximise long-term outcomes (Lei et al., 2012). A SMART involves multiple intervention stages where the participant moves through the stages and is randomly assigned to one of several intervention options with each stage corresponding to one of the critical decisions involved in the adaptive intervention (Lei et al., 2012). SMART designs are beneficial in addressing multiple concerns and hypotheses (Auyeung et al., 2009). By using the SMART design, complexities in both treatment choice and sequencing can be addressed, as well as understanding interactions that may occur due to synergistic effects of the intervention components (Auyeung et al., 2009).

In order to avoid the lengthy iterative design approach, another alternative may be a single trial of multiple stages (Crane, 2017). Crane (2017) recommends an app design process similar to the refining phase of MOST (Collins et al., 2005). This approach enables the interactions among the selected intervention components to be investigated in detail through the use of randomised experiments, in order to determine those that should be included in a trial and then allows fine tuning and optimal dosage levels to be determined (Collins et al., 2005; Collins, Murphy and Strecher, 2007; Crane, 2017). When properly implemented, these approaches can ensure that the principles under evaluation are enhanced by allowing optimisation to occur during the trial leading to the development of more potent digital interventions (Collins, Murphy and Strecher, 2007; Mohr et al., 2015).

6.5 Final Conclusions

This thesis presents a formative, iterative, participatory approach to developing and evaluating a digital intervention to reduce workplace SB, and transparently demonstrates how each stage was carried out. The app was designed in a systematic and thorough manner incorporating theoretical and methodological frameworks, evidence from the literature and perspectives from a range of stakeholders and target end users, to optimise its design. The resulting app “Worktivity” is the first of its kind developed with the primary aim of reducing occupational SB using digital self-monitoring.

The findings of this study suggest that it is feasible to implement an app based intervention with the addition of a SSWD for desk-based office workers. The combined app and desk intervention has the potential to evoke change in SB, however a larger RCT including a desk only arm is required to confirm these findings. Future research with the “Worktivity” app would be subject to significant improvements with the app and further iterations before being used as a tool to reduce occupational SB.

This thesis provides a template for others to follow when developing and evaluating technology supported behaviour change interventions, detailing barriers and considerations that should be observed by development teams. Although further research and testing is required, findings from this thesis further the understanding of how digital technology may be used to support behaviour change in relation to occupational SB.

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REVIEW **Open Access**

Using computer, mobile and wearable technology enhanced interventions to reduce sedentary behaviour: a systematic review and meta-analysis

Aoife Stephenson[1*], Suzanne M. McDonough[2,3,4], Marie H. Murphy[1], Chris D. Nugent[5] and Jacqueline L. Mair[1]

Abstract

Background: High levels of sedentary behaviour (SB) are associated with negative health consequences. Technology enhanced solutions such as mobile applications, activity monitors, prompting software, texts, emails and websites are being harnessed to reduce SB. The aim of this paper is to evaluate the effectiveness of such technology enhanced interventions aimed at reducing SB in healthy adults and to examine the behaviour change techniques (BCTs) used.

Methods: Five electronic databases were searched to identify randomised-controlled trials (RCTs), published up to June 2016. Interventions using computer, mobile or wearable technologies to facilitate a reduction in SB, using a measure of sedentary time as an outcome, were eligible for inclusion. Risk of bias was assessed using the Cochrane Collaboration's tool and interventions were coded using the BCT Taxonomy (v1).

Results: Meta-analysis of 15/17 RCTs suggested that computer, mobile and wearable technology tools resulted in a mean reduction of −41.28 min per day (min/day) of sitting time (95% CI -60.99, −21.58, I2 = 77%, n = 1402), in favour of the intervention group at end point follow-up. The pooled effects showed mean reductions at short (≤ 3 months), medium (>3 to 6 months), and long-term follow-up (>6 months) of −42.42 min/day, −37.23 min/day and −1.65 min/day, respectively. Overall, 16/17 studies were deemed as having a high or unclear risk of bias, and 1/17 was judged to be at a low risk of bias. A total of 46 BCTs (14 unique) were coded for the computer, mobile and wearable components of the interventions. The most frequently coded were "prompts and cues", "self-monitoring of behaviour", "social support (unspecified)" and "goal setting (behaviour)".

Conclusion: Interventions using computer, mobile and wearable technologies can be effective in reducing SB. Effectiveness appeared most prominent in the short-term and lessened over time. A range of BCTs have been implemented in these interventions. Future studies need to improve reporting of BCTs within interventions and address the methodological flaws identified within the review through the use of more rigorously controlled study designs with longer-term follow-ups, objective measures of SB and the incorporation of strategies to reduce attrition.

Trial registration: The review protocol was registered with PROSPERO: CRD42016038187

Keywords: Sedentary behaviour, Behaviour change, Randomised-controlled trials, Systematic review, Digital technology

* Correspondence: stephenson-a@email.ulster.ac.uk
[1]Shore Rd, Newtownabbey BT37 0QB, Northern Ireland
Full list of author information is available at the end of the article

Introduction

Sedentary behaviour (SB) has been defined as any waking behaviour characterised by energy expenditure of 1.5 metabolic equivalents (METs) or less, undertaken while in a sitting or reclining posture [1]. Modern society provides many opportunities for prolonged sitting in leisure, work and commuting [2]. Data from a range of industrialised countries suggest that SB is highly prevalent with the majority of people's time (55–69% of the day) spent in sedentary pursuits [3–6].

Prolonged SB is positively associated with a range of health concerns including all-cause mortality, cardiovascular disease, type 2 diabetes, metabolic syndrome and several types of cancers [7]. Although the precise physiological mechanisms by which SB is detrimental to health are not fully known, a sedentary lifestyle is associated with cardiovascular morbidity and mortality, defects in lipoprotein metabolism, early atherosclerosis, insulin resistance, and development of the metabolic syndrome [2].

Previous systematic reviews and meta-analyses suggest that it is possible to intervene to reduce SBs in adults through activity permissive work stations, height adjustable desks, health coaching, activity monitors, and prompts to break up sitting [8, 9]. Pooled results from these interventions range from 22 to 91 min/day reduction in sedentary time in the intervention groups compared with the controls. While technological advancements have contributed to a rise in SB [10], these reviews [8, 9] have identified that they are also being harnessed to reduce SB. Digital tools such as mobile phones, internet, text-messaging and wearable sensors can provide a platform to intervene to change health behaviours, however, there is a lack of evidence examining their role in reducing SB. These have been successfully applied to improve diet/Physical Activity (PA) [11, 12], sexual health behaviours [13], weight management [14], alcohol reduction [12] and smoking cessation [15, 16]. One systematic review and meta-analysis investigated the use of mobile phone based interventions on outcomes of PA and SB [17]. The main findings were that these interventions targeting PA and SB promote small reductions in free-living individuals' sitting time. However, only 5 of the 21 included studies reported a measure of SB.

Recent recommendations on prevention and management of non-communicable diseases stressed the need for research focused on behaviour change as the core component [18]. The identification and characterisation of behaviour change techniques (BCTs) allows for an understanding of mechanisms of behaviour change, leading to enhanced replication and implementation of effective interventions [19]. Whilst reviews of SB interventions and the BCTs used within these interventions have started to emerge, they are scarce and have lacked a clear aim to reduce SB exclusively [8, 9, 17, 20]. The effectiveness of interventions supported by computer, mobile and/or wearable technology aimed specifically at reducing SB, and the BCTs used within, have not yet been explored. The objectives of this review are to evaluate the effectiveness of behaviour change interventions using computer, mobile and/or wearable technologies aimed at reducing SB in healthy adults and to identify the BCTs used within these interventions.

Methods

The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) Guidelines and Cochrane Handbook for Systematic Reviews of Interventions were used as a methodological template for this review [21, 22] (Additional file 1).

Inclusion criteria

- Adults aged 18 years and over,
- Published RCTs of any duration with a main aim of reducing SB and with computer, mobile or wearable technology as any part of the intervention,
- RCTs with a comparison or control arm that consisted of no intervention control, usual care, or alternative treatment conditions,
- Pre-post objective, subjective or proxy measure of SB.

Exclusion criteria

- RCTs not published in English,
- Comparator intervention using computer, mobile or wearable technology to reduce SB or increase PA,
- RCTs where the main aim of the intervention was to increase PA,
- Interventions delivered in a hospital setting,
- Clinically diagnosed populations, with the exception of those who are overweight or obese.

Information sources and search strategy

Search strategies were developed for each electronic database; MEDLINE, EMBASE, CINAHL, PsycINFO and PubMed. The searches were based on the strategy developed for MEDLINE (Additional file 2) and revised appropriately for the other databases.

The search results were imported into EndNote X7 bibliographic software (Thompson Reuters, San Francisco, CA, USA) and duplicate studies were removed. The titles and abstracts of all identified studies were screened to identify potentially relevant papers. Studies that did not meet the inclusion criteria and titles/abstracts obviously not related to the topic of interest were excluded. Full text papers of potentially relevant studies were retrieved and assessed for eligibility by one member of the research team. Where uncertainties arose regarding study inclusion, consensus was achieved through discussion amongst the research team.

Data extraction

The following data were independently extracted from each article using a standardised form: author, year, study design, participants, intervention description, comparator description, SB outcome measures and longest follow-up.

Assessment of risk of bias in included studies

The risk of bias for each study was assessed using the Cochrane Collaboration's risk of bias tool [22]. Initially, a small sample of studies (n = 3) were assessed by two members of the research team, inconsistency in scoring was reviewed, and a consensus reached prior to the analysis of the remaining studies, by one author. The remainder of the risk of bias assessment was carried out independently by one member of the research team.

Studies that used an objective measure to assess SB were judged as being at low risk of bias for blinding of outcome assessment. Studies assessing SB with subjective and proxy measures were judged as being at high risk of bias, as there was potential for misreporting of time spent sitting. Where greater than 20% dropout in any group for outcomes up to one year and greater than 30% for outcomes greater than one year was reported, studies were judged as being at high risk of bias for incomplete outcome data. Studies were judged as being at low risk of bias for selective outcome reporting if the final publication of the trial followed what had been planned in a published protocol paper. In the case where no protocol paper was publicly available, studies were deemed as being at low risk for selective outcome reporting if they had reported all the outcomes mentioned in the methodology. A study was judged to be at low risk of bias overall when all domains had a low risk of bias. Conversely, a study was judged to have a high risk of bias when it reported a feature that would be judged as having a high risk of bias in any domain. As it is not possible to blind either in studies of this nature, we did not assess blinding of participants or personnel for overall risk of bias [23].

Coding of behaviour change techniques

All intervention procedures were coded using the BCT Taxonomy v1 [19]. Content was coded using the information reported within the methodology sections of identified studies and their protocol papers (where available) to identify the specific BCTs used in each intervention. BCTs targeting SB were coded for the entire intervention and then separately for the computer, mobile and wearable technology components. To minimise bias in interpretation of the tool, a small sample of studies were first assessed by two trained BCT coders (one coder was independent of the research team). Inconsistency in coding was reviewed and a consensus reached, prior to the analysis of the remaining studies, by one author. Where uncertainties later arose, the example was discussed with the wider remaining research team to achieve consensus.

Measures of treatment effect

Fifteen studies reported continuous outcomes for measures of SB across the same scale allowing meta-analysis of mean differences (MD). Statistical analysis was conducted in accordance with guidelines from the Cochrane Handbook for Systematic Reviews of Interventions [22]. SB data were transformed into minutes per day (e.g. 5 h/day = 300 min/day). Data were pooled to compare the post intervention mean differences and 95% confidence intervals (CIs) in sitting time (min/day) between intervention and comparison groups. Authors of the studies included were contacted by email up to three times for further information where required. Studies where the information was unavailable or that reported units that could not be converted to min/day were not included in the meta-analyses.

Where studies reported multiple follow-up points of the same outcome, data were extracted for subgroup analyses at the following time points: short-term (≤3 months), medium-term (>3 to 6 months), and long-term follow-up (>6 months). In studies where two data sets fell within one of these time points, the longest time point was used for data extraction. Where more than one measure of SB was available, objective data were given priority over subjective or proxy data. If more than one proxy measure of SB was available, the measure most representative of overall SB was given preference. If a study focused on reducing workplace SB, workplace SB data were prioritised over SB in other domains or overall SB. Conversely, where an intervention targeted overall daily SB, full day SB data were used in the analysis. Separate subgroup analyses were run for interventions targeting workplace sitting and overall daily SB for short, medium and long-term follow-up periods. Subgroup analyses were also conducted for objective and subjective outcome measures. Data were assessed for statistical heterogeneity. Values of the I^2 statistic that were 30% to 60% were considered to represent moderate heterogeneity and 50% to 90% substantial heterogeneity. Studies were pooled using a random effects model where heterogeneity was moderate to substantial; otherwise a fixed effects model was used.

Results

Figure 1 displays the PRISMA flow diagram of the literature search. Inclusion criteria were met by 17 studies, 15 of which provided adequate data to be included in a meta-analysis.

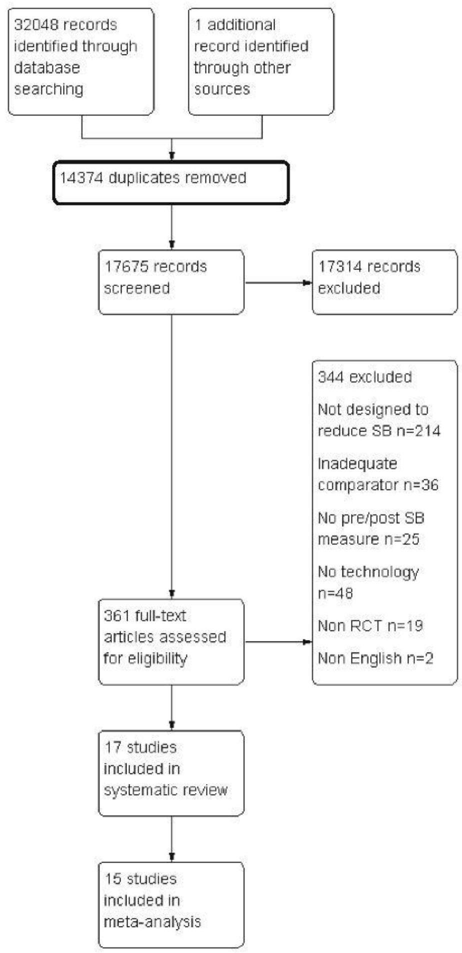

Fig. 1 PRISMA flow diagram

Study characteristics

Study and participant characteristics are summarised in Table 1. Of the 17 included studies (*n* = 1967 participants), 1323 participants (67%) reported being female. Four studies stated the ratio of male to female participants for the sample analysed and not the sample randomised [24–27]. Fifteen studies were carried out in mixed gender populations. Two studies were carried out amongst female participants only [28, 29]. Thirteen studies included any participants aged 18 years or over. One study targeted females aged 55–70 years [29]. The target population in two studies were young adults with an age range of 18–40 years [30, 31]. One study targeted undergraduate university students [25].

All studies were published between 2012 and 2016. Ten interventions were designed to reduce SB in the workplace and seven interventions aimed to reduce overall daily SB. Eleven studies were SB interventions alone [24–27 30, 32–37], and both PA and SB were targeted in three studies [29, 38, 39]. The remaining three were lifestyle interventions that included a SB reduction component [28, 31, 40].

All studies targeted SB using a mix of intervention approaches. Table 1 details the overall components of the interventions in addition to computer, mobile and wearable technology components. The studies targeting workplace SB utilised the following tools: software/computer prompts were used in seven studies [24, 27, 28, 32, 34, 35, 39]; emails were used in five studies [26, 27, 36, 39, 40]; websites to relay information and provide feedback to participants were used in three studies [36, 37, 40]; and text messages were used in one study [36]. In those interventions targeting overall sitting, emails were used in three studies [25, 33, 38], websites were used in two studies [31, 33] and text messages were sent to participants in three studies [30–32]. Activity monitors with an online companion were used in three studies [29, 30, 38]. One study used a mobile application intervention, and this was an optional component of the intervention [29].

The duration and intensity of the interventions varied. The intervention time ranged from five days [24, 28] to 24 months [31]. The type of control groups also varied between studies. Two studies used a wait-list control [33, 37], seven studies used a no intervention control group [25, 26, 28, 32, 36, 38, 39] and one study compared a stand-up desk combined with prompts with a stand-up desk alone [27]. Seven studies provided their control group with basic health information [24, 29–31, 34, 35, 40].

A variety of SB measurement tools were used. Three studies used more than one measurement tool [26, 30, 37]. Eleven studies used objective measures including; accelerometers [26, 27, 29, 30, 33, 36, 39] and inclinometers [24, 28, 30, 32, 37]. Subjective questionnaires were used in five studies [25, 26, 30, 37, 38]. Four studies used proxy measures where participants were asked to record the time they spent in the domains they were interested in for example computer time, TV time [31, 34, 35, 40].

Risk of bias of included studies

The assessment for each risk of bias item across all included studies, plus the additional domains assessed for cross over and cluster RCTs are presented in Figs. 2 and 3.

Table 1 Summary Table of included studies

Author/Year	Study design	Sample Size	Gender	Age	Health Risk	Setting	Aim	Intervention	Technology tool(s)	Comparison group	Outcome Measure	Longest follow-up
Ashe 2015	Pilot RCT	25	25F 0M	All: 64.1 ± 4.6 I: 64.8 ± 4.6 C: 63.1 ± 4.8	Healthy, not meeting PA guidelines	Community/ home	SB + PA	Group health education, PA/ SB, PA prescription, online activity monitor (Fitbit), Fitbit app, public transport tickets	Activity monitor (Fitbit) with online companion and app	Health information	ActiGraph™	6 months
Barwais 2013	RCT	33	11F 22M	All:27 ± 4.0 I:9.0 ± 4.4 C:26.4 ± 3.0	Self-reporting >7 h per day sitting	Community/ home	SB + PA	Gruve activity tracker with online companion, motivational emails	Gruve activity tracker with online companion, motivational emails	No intervention	7-day SLIPA Log	4 weeks
Biddle 2015	RCT	187	128F 59M	All:32.8 ± 5.6 I:32.4 ± 5.4 C:33.3 ± 5.8	Obese/overweight plus additional risk factor for diabetes	Community/ home	SB	Group education, Gruve activity tracker with online companion, motivational texts/calls	Gruve activity tracker with online companion, motivational texts	Health information + SB information	ActiGraph™, ActivPAL™, IPAQ, Marshall sitting questionna-ire	12 months
Carr 2013	RCT	40	36F 4M	All:44.7 ± 9.6 I:47.6 ± 9.9 C:42.6 ± 8.9	Apparently healthy, Self-reporting <60 min of moderate to vigorous PA per week, overweight, reporting a minimum of 75% of their work day sitting	Workplace + community/ home	SB	Pedal machine, commercial website (Walker Tracker, Portland, Oregon, USA), pedometer, motivational emails	Commercial website (Walker Tracker, Portland, Oregon, USA), motivational emails	Waitlist	StepWatch™	12 weeks
Danquah[a] 2016	Cluster RCT	317	210F 107M	All:46 ± 10 I:46 ± 10 C:45 ± 11	Employees who sit most of the workday	Workplace	SB	Active meetings, lecture, workshop, educational emails/texts, project website	Emails/text, project website	No intervention	ActiGraph™	12 weeks
De Cocker[a] 2016	RCT	213	146F 67M	All:40.3 ± 9.1 I:40.5 ± 8.6 C:39.3 ± 9.0	All employees	Workplace	SB	Web based feedback from project website	Web based feedback from project website	Waitlist	ActivPAL™, WSQ	12 weeks
Donath[a] 2015	RCT	38	23F 8M 7 no data	All:42.42 I:45 ± 12 C:40 ± 10	Free from cardio-vascular disease	Workplace	SB	Standing desks, computer prompts	Computer prompts	Standing desk	ActiGraph™	12 weeks
Dutta[a] 2014	Cross-over RCT	29	19F 9M 1 no data	All: 40.4 (no SD reported)	Employees who sit most of the workday	Workplace	SB	Standing desks, reminder emails	Reminder emails	No intervention	Modular Signal Recorder 145, Gruve, OSPAQ	4 weeks
Evans[a] 2012	RCT	30	22F 6M 2 no data	All: 44 I:49 ± 8 C: 39 ± 10	Healthy employees	Workplace	SB	Individual education session, software prompts	Software prompts	Health information + SB information	ActivPAL™	5 days
Judice 2015	Cross-over RCT	10	5F 5M	All:50.4 ± 11.5	BMI < 25.0 kg m − 2; not taking medication, not meeting PA guidelines, free from any major disease	Workplace + community/ home	SB	Computer prompts, step monitoring, motivational calls/texts	Computer prompts, motivational texts	No intervention	ActivPAL™	1 week
Laska 2016	RCT	441	298F 143M	All: 22.8 (no SD reported) I:22.9 C:22.8	BMI: 20–34.9 kg/m2	Community/home	Life style + SB	Educational course (online/ face to face/hybrid), project website, motivational texts/ calls	Educational course (online/ face to face/ hybrid), project website, motivational texts	Health information	Self-reported screen time behaviours	24 months

Table 1 Summary Table of included studies *(Continued)*

Maher 2015	RCT	195	89F 95M 11 no data	All: 20.4 (no SD reported)	All undergraduates	Community/home	SB	SB planning via email	SB planning via email	No intervention	IPAQ	7 days
Mainsbridge[a] 2014	RCT	29	24F 5M	All: 40.10 I: 36.73 ± 12.38 C: 42.28 ± 9.59	Employees who sit most of the workday, medically cleared to perform short bouts of PA	Workplace	SB	Group education, prompting software	Prompting software	Health information + SB information	Self-reported sitting	13 weeks
Pedersen[a] 2014	RCT	34	26F 8M	All: 43 I:41.50 ± 12.39 C: 43.88 ± 9.65	Employees who sit most of the workday, free from existing health conditions	Workplace	SB	Group education, prompting software	Prompting software	Health information + SB information	Self-reported SB	13 weeks
Schuna[a] 2014	RCT	41	40F 1M	All: 40.1 ± 10.1 I:40.0 ± 9.5 C: 40.3 ± 10.9	Overweight/obese office workers.	Workplace	SB + PA	Treadmill desk, computer prompts	Computer prompts, email	No intervention	ActiGraph™	12 weeks
Urda[a] 2016	RCT	48	48F 0M	All: 48 ± 10	Employees who sit most of the workday	Workplace	Life style + SB	Educational handout, computer prompt	Computer prompts	No intervention	ActivPAL™	5 days
Van Berkel[a] 2014	RCT	257	173F 84M	All: 45.5 I: 46.0 ± 9.4 C: 45.1 ± 9.6	All employees	Workplace	Life style + SB	Mindfulness sessions, nutrition support, e-coaching, intranet webpage	E-coaching (email), intranet webpage	Health information	Self-reported SB	12 months

RCT randomised controlled trial, *F* female, *M* male, ± standard deviation, *I* intervention, *C* control, *SB* sedentary behaviour, *PA* physical activity, *7-day SLIPA Log* 7-day Sedentary and Light Intensity Physical Activity Log, *IPAQ* International Physical Activity Questionnaire, *WSQ* Workforce Sitting Questionnaire, *OSPAQ* Occupational Sitting and Physical Activity Questionnaire
[a]denotes interventions targeting workplace sitting

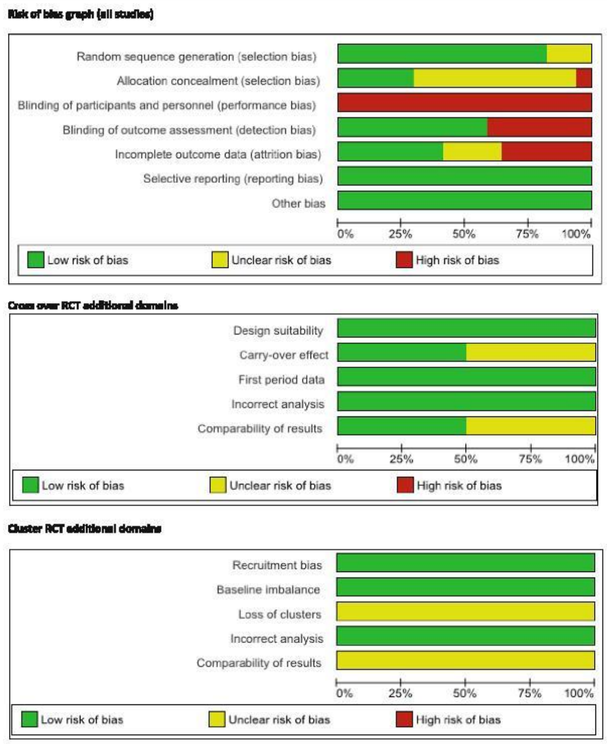

Fig. 2 Risk of bias graph

Overall risk of bias assessment

Overall, 13 studies were judged to have a high risk of bias based on: allocation concealment [26] blinding of outcome assessment [25, 31, 34, 35, 37, 38, 40], incomplete outcome data [27, 29, 30, 33, 37, 39]. Three studies were deemed to be at an unclear risk of bias due to incomplete outcome data [28, 36], allocation concealment [28, 32]. One study was judged to be at a low risk of bias [24]. Due to only one study being at low risk of bias, it was not possible to conduct a sensitivity analysis. Refer to Figs. 2 and 3 for a graph and summary of judgements about each risk of bias item for each included study.

Behaviour change techniques

A total of 104 BCTs were coded in the 17 included studies (Table 2). 20/93 unique BCTs were coded representing 21.5% of the taxonomy. The range of BCTs coded per study was one to 15. The most frequently coded BCT was "instruction on how to perform a behaviour" which was coded 15 times, "social support (unspecified)" (12 times), "prompts and cues" (11 times) and "adding objects to the environment" (11 times).

A total of 46 BCTs were coded in the 17 studies for the computer, mobile and wearable components of the interventions only. In these interventions, there were 14 unique BCTs coded, ranging from one to 10 per study. The most frequently coded BCTs were "prompts and cues" (10 times), "self-monitoring of behaviour" (7 times), "social support (unspecified)" (7 times) and "goal setting (behaviour)" (5 times).

Effects of intervention

Main analysis

Results of the main meta-analysis (n = 15; Fig. 4) suggest that SB reducing interventions incorporating computer, mobile and/or wearable technology tools resulted in a mean reduction of −41.28 min/day (95% CI -60.99, −21.58, I^2 = 77%, n = 1402), in the intervention group at end point follow-up.

In the eight studies which reported objective measures of SB [24, 28–30, 32, 33, 36, 39], the pooled analysis

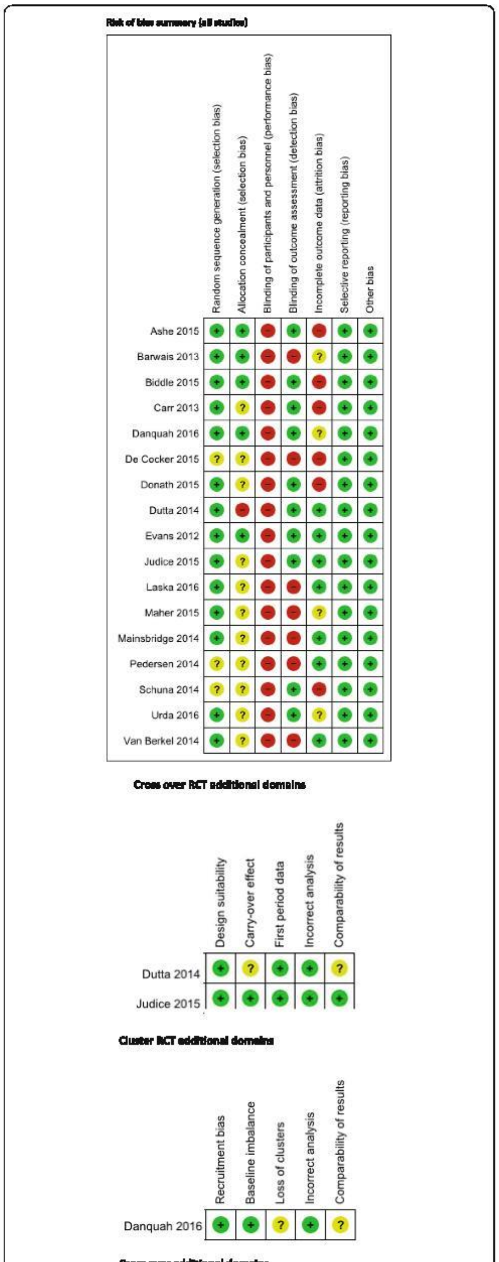

Fig. 3 Risk of bias summary

resulted in a mean reduction of −35.07 min/day (95% CI -46.57, −23.57, I^2 = 21%, n = 595) in favour of the intervention group. The seven studies which reported subjective measures of SB [25, 31, 34, 35, 37, 38, 40] showed a mean reduction of −52.66 min/day (95% CI, −93.63, −11.69, I^2 = 88%, n = 807).

Ten of the 15 studies included in the meta-analysis reported short-term measures (≤3 months) [24, 25, 28, 30, 32, 33, 36–39]. The pooled analysis showed a mean reduction of −42.42 min/day (95% CI -63.21, −21.63, I^2 = 61%, n = 760) in favour of the intervention group. Five interventions reported medium-term (>3 to 6 months) measures. The pooled effect showed a mean reduction of −37.23 min/day (95% CI -73.70, −0.75, I^2 = 85%, n = 691). Three studies reported long-term measures of SB (>6 months). The pooled analysis showed a mean reduction of −1.65 min/day (95% CI -14.77, 11.47, I^2 = 23%, n = 670).

Eight interventions included in the meta-analysis focused on reducing workplace SB [24, 28, 34–37, 39, 40] (Fig. 5). The pooled effect showed a mean reduction of −39.88 min/workday (time spent at work) (95% CI -59.58, −20.18, I^2 = 65%, n = 762) in favour of the intervention group at end point follow-up.

Five workplace SB studies [24, 28, 36, 37, 39] reported short-term measures, showing a mean reduction of −35.23 min/workday (95% CI -47.60, −22.86, I^2 = 0%, n = 477) in favour of the intervention group. Three workplace SB studies [34, 35, 40] included medium-term measures showing a mean reduction of −69.34 min/workday (95% CI -140.58, 1.91, I2 = 90%, n = 284). There were not enough data to conduct a meta-analysis on work place interventions with long-term measures.

There were seven interventions targeting overall daily sitting reporting measures of SB [25, 29–33, 38] (Fig. 6). Pooled effects showed a mean reduction of −45.11 min/day (95% CI -86.63, −3.60, I^2 = 82%, n = 640) favouring the intervention group at end point follow-up.

Five of these studies reported short-term measures [25, 30, 32, 33, 38] showing a mean reduction of −67.72 min/day (95% CI -132.82, −2.62, I^2 = 80%, n = 283) in favour of the intervention group. Two studies [29, 31] reported medium-term measures showing a mean reduction of −5.92 min/day (95% CI -21.32, 9.48, I^2 = 0%, n = 413). Two studies [30, 31] reported long-term measures showing a mean reduction of −4.71 min/day (95% CI -32.81, 23.40, I^2 = 55%, n = 448), with substantial heterogeneity in the observed effects studies.

Discussion

This systematic review and meta-analysis found that SB reduction interventions using computer, mobile and wearable technology resulted in a mean reduction of 41 min/day in the intervention group at end point follow-up.

Table 2 BCT coding and frequency

BCT LABEL	Ashe 2015	Barwais 2013	Biddle 2015	Carr 2013	Danquah 2016[a]	de Cocker 2016[a]	Donath 2015[a]	Dutta 2014[a]	Evans 2012[a]	Judice 2015	Laska 2016	Maher 2015	Mainsbridge 2014[a]	Pedersen 2014[a]	Schuna 2014[a]	Urda 2016[a]	Van Berkel 2014[a]	Total coded (whole intervention)	Total coded (technology)
1. Goals and planning																		25	10
1.1. Goal setting (behaviour)		x	x		x	x					x	x					x	7	5
1.2. Problem solving	xx		xx		x					x	x				x		x	9	2
1.4. Action planning	x		x			x						x						4	2
1.5. Review behaviour goal(s)	x		xx														x	4	1
1.7. Review outcome goal(s)					x													1	0
2. Feedback and monitoring																		10	8
2.2. Feedback on behaviour			x			x												2	1
2.3. Self-monitoring of behaviour		x	x	x						x	x	x	x	x				8	7
3. Social support																		13	8
3.1. Social support (unspecified)	x	x	xxx	x	x					x	xx						xx	12	7
3.2. Social support (practical)															x			1	1
4. Shaping knowledge																		15	4
4.1. Instruction on how to perform the behaviour	xx		x	x	x	x			xx	xx	xx		x	x		x		15	4
5. Natural consequences																		9	1
5.1. Information about health consequences			x		xx	x			xx				x	x		x		9	1
6. Comparison of behaviour																		2	1
6.1. Demonstration of the behaviour														x				1	0
6.2. Social comparison											x							1	1
7. Associations																		11	10
7.1. Prompts/cues			x	x	x		x	x	x	x			x	x	x	x		11	10
8. Repetition and substitution																		6	0
8.2. Behaviour substitution	x				x						x							3	0
8.7. Graded tasks	x				x			x										3	0
9. Comparison of outcomes																		1	1
9.1. Credible source											x							1	1
10. Reward and threat																		0	0
11. Regulation																		0	0
12. Antecedents																		12	3
12.3. Avoidance/reducing exposure to cues for the behaviour											x							1	0

Table 2 BCT coding and frequency *(Continued)*

12.5. Adding objects to the environment	$\underline{xx}$	$\underline{x}$	$\underline{x}$	xx	x	x	x	x	x	11	3
13. Identity										0	0
14. Scheduled consequences										0	0
15. Self-belief										1	0
15.1. Verbal persuasion about capability					x					1	0
16. Covert learning										0	0

BCT Behaviour change technique, $\underline{x}$ coded as part of the technology aspect, *x* coded as part of intervention (non-technology aspects)
[a]denotes interventions targeting workplace sitting

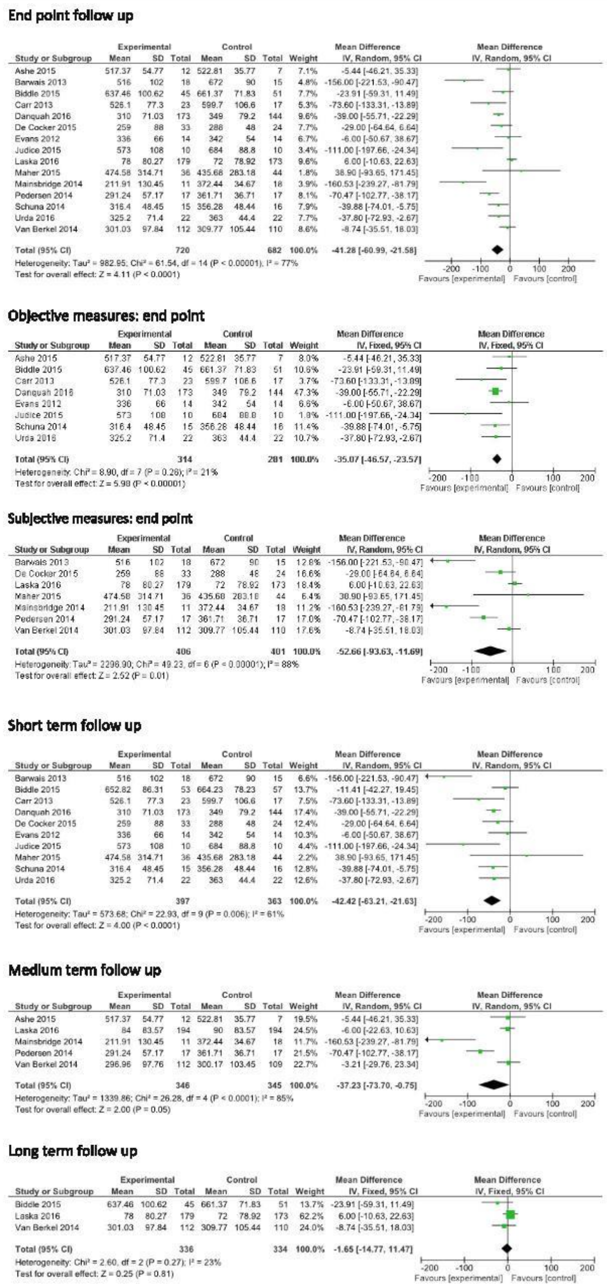

Fig. 4 Effects of intervention versus control on SB

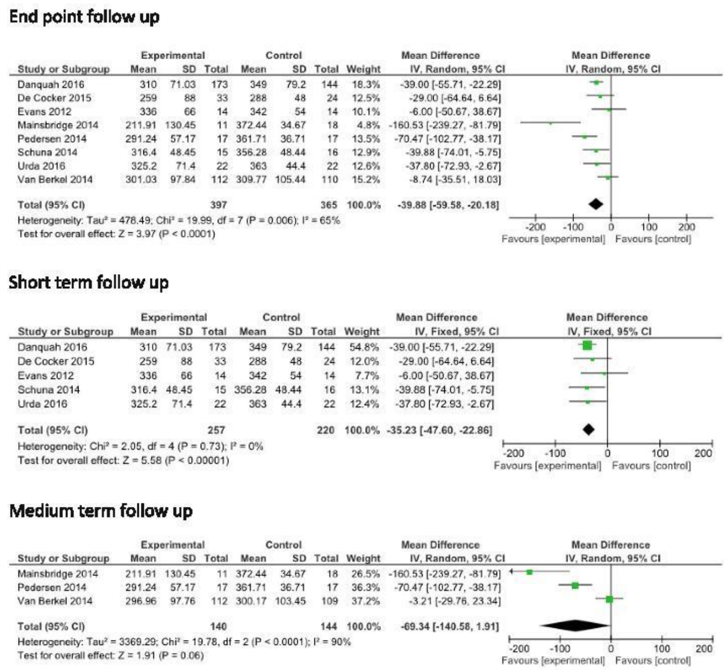

Fig. 5 Effects of workplace intervention versus control on workplace SB- short medium and long-term

Interventions focusing on workplace SB showed a mean reduction of 40 min/workday in the intervention group at end point follow-up. Interventions focusing on overall daily SB showed a mean reduction of 45 min/day in the intervention group at end point follow-up. Due to risk of bias issues, caution should be taken whilst interpreting these results. Nevertheless, these reductions are encouraging as it has previously been reported that every 30 min of SB reallocated to light PA results in a 2–4% improvement in triglycerides, insulin, beta-cell function biomarkers [41], suggesting clinically meaningful health outcomes.

The magnitude of the mean reduction in sedentary time in this review (41 min/day) is in line with a previous meta-analysis reporting a 42 min/day reduction [9], however, is well below the 91 min/day reduction reported by Prince et al. [8]. This inconsistency may be explained as Prince et al. included non-randomised trials and focused on any intervention that targeted PA and/or SB [8].

The reduction of approximately 40 min/workday in intervention group in this review echoes results from a similar meta-analysis which also showed a reduction of 40 min/workday in favour of the intervention group [42]. Other systematic reviews have shown slightly higher reductions in SB among intervention participants. For example, activity permissive workstation interventions have been reported to contribute to a reduction of 77 min/workday in favour of the intervention group [43]. It is likely that this larger reduction is due to intervention type investigated. These interventions allow participants to stand but also continue working. Although this represents a higher reduction than seen in our review, these work stations are costly to provide and their widespread deployment may not be feasible. From a public health perspective computer, mobile and wearable technology may hold promise for large-scale, cost-effective interventions [17, 44, 45].

The inconsistencies in the above comparisons may be explained by differences in inclusion criteria, as most of these reviews included studies that aimed to increase PA, and/or reduce SB or addressed interventions that reported on SB outcomes, however, did not necessarily target SB in the intervention [8, 9, 17, 20, 23, 42, 46, 47]. This may be relevant as intervention components that successfully increase PA, may not effectively reduce SB, and vice versa [20]. Furthermore, many of the studies in these other reviews were composed of small sample sizes, used different study designs and intervention durations, used a range of SB measurement tools and varying comparator groups.

these differences may introduce differences in the scale observed. The development and refinement of valid and reliable objective measures of SB which can incorporate the type and contextual factors, as well as clear guidelines on wear time and cut points are required [52]. This is the first review to collate BCTs used in SB change interventions using computer, mobile or wearable technology in adults. The aim was not to provide definitive conclusions regarding the most effective behaviour change intervention components, but code to identify which techniques have been used to reduce SB. It is, however, difficult to conceptually separate PA promotion and SB reduction components within an intervention [20]. In typical applications of BCT taxonomies in other literatures, a single behaviour is defined and targeted by the intervention, and the link to BCTs can be assumed to be explicitly related to changing that single behaviour [53]. The reality of the design and reporting of many interventions within this review is that they target multiple behaviours and outcomes. Thus, making it more difficult to link BCTs to specific behaviours. Moreover, there was a lack of clear and consistent reporting of which BCTs were undertaken within each intervention making classification of BCTs difficult [54]. Research is warranted to identify the 'active ingredients' of successful interventions to refine the design of optimal BCT use and produce an evidence base upon which SB interventions can be developed. In order to assess the impact of BCTs, the reporting of intervention content must be improved. Researchers should "clearly define and provide a rationale for all BCTs that have been included" with full intervention manuals being provided as supplementary electronic files [55]. In complex interventions, clearer delineation of strategies used to change PA and SB, respectively, in intervention reports is required.

The most frequently coded BCTs to reduce SB across the interventions as a whole were "instruction on how to perform a behaviour" "social support (unspecified)", "prompts and cues" and "adding objects to the environment". Whereas, the most frequently coded BCTs for computer, mobile and wearable components of the interventions were "prompts and cues", "self-monitoring of behaviour", "social support (unspecified)" and "goal setting". These differences suggest some BCTs may lend themselves well to certain modes of delivery and that the BCTs identified in the technology components might fruitfully be incorporated into future technology based interventions to reduce SB.

When comparing the computer, mobile and wearable components in workplace interventions and overall daily interventions, "prompts and cues" was more frequently coded in workplace interventions and "social support (unspecified)" was more frequently coded in overall daily interventions. This reflects the results in Gardner et al. [20] where it is suggested that workplace SB may be more receptive to planning and routinisation than non-workplace SB, which occurs in less predictable and structured contexts. This highlights the need for interventions to be chosen on the basis of what is most appropriate and feasible in the specific setting [56]. The high usage of the BCT 'prompts/cues' identified in this review and that of Direito et al. [17] illustrates that technology may be harnessed to facilitate intervention delivery, however, also to conduct intervention "top-ups" beyond the intervention core duration. This may be a vital component for interventions to prevent relapse.

This study has a number of strengths, including a comprehensive search strategy in multiple databases and the adherence to methodological criteria for high quality-systematic reviews and meta-analysis. In addition, the systematic detailing of BCT coding procedures using the most recent BCT taxonomy (v1), allows future researchers to replicate and review methods used in detail. However, non-English publications were excluded from review and the search was limited to peer reviewed publications. There was considerable heterogeneity of included studies with regard to intervention type, sample size, follow-up duration, type and outcome estimates and no meta-regression was performed. Baseline sitting levels varied across the studies, the scope for change post intervention may be influenced by how much participants sat pre intervention. It must also be noted that how central technology was to each intervention varied greatly. 13/17 included studies were of high risk of bias, with particular concerns in the areas of detection and attrition bias. Six studies were at high risk of attrition bias due to high dropout levels. SB measures used to determine intervention effects in this analysis were measured through subjective measures in seven studies and thus were at high risk for detection bias. These identified methodological flaws present a problem when trying to draw conclusions and evidence presented in the current review should be interpreted with caution. This review also included 'active' comparator groups which may contribute to smaller intervention effects. It was not possible to statistically analyse the individual effectiveness of BCTs or to assess the effectiveness of different combinations of behaviour techniques due to the number of different combinations of BCTs present within studies. In order to address this, future study designs could consider using adaptive interventions such as sequential multiple assignment trials (SMART) or multiphase optimization strategy (MOST) designs. Finally, technology development often outpaces academic research [57] and this review includes two studies using the Gruve activity monitor which is no longer commercially available.

This systematic review provides a useful overview of the effectiveness of computer, mobile and wearable technology interventions in reducing SB and has exposed important gaps in the current evidence base which warrant further attention. Future research should focus on attrition rates to reduce drop out and improve engagement. Such studies may consider using technology to refresh the intervention, varying the approach or introduce a new intervention as time passes to encourage long-term maintenance of SB reductions. Furthermore, research should aim to improve detection bias by using objective measurement tools of SB e.g. accelerometer/ inclinometer, in order to better detect intervention effects. The lack of long-term follow-up highlights the need for extended follow-up in future studies to examine potential long-term impacts of SB interventions. We also recommend including outcome measures that will be of interest to workplaces and policy makers to determine efficient use of resources such as the cost-effectiveness of technology supported strategies to reduce SB.

Conclusion

This review provides new knowledge regarding technology interventions incorporating BCTs for reducing SB. Our findings suggest that computer based, mobile and wearable technologies appear to be promising approaches to reduce SB. However, due to risk of bias issues, caution should be taken whilst interpreting these results. The reduction in sitting time appeared to be most prominent at short-term follow-up and attenuated over time, with the exclusion of interventions targeting work place sitting, where results were most prominent at medium-term follow-up. A range of BCTs were implemented in these interventions. Future studies need to improve reporting of BCTs within interventions and address the methodological flaws identified within the review through the use of more rigorously controlled study designs with longer-term follow-ups, objective measures of SB and the incorporation of strategies to reduce attrition.

Additional files

Additional file 1: PRISMA checklist (DOC 62 kb)
Additional file 2: Search strategy (DOCX 14 kb)

Abbreviations

7-day SLIPA Log: 7-day Sedentary and Light Intensity Physical Activity Log; AMSTAR: Assessment of multiple systematic reviews; BCT: Behaviour change technique; CI: Confidence interval; Hr/day: Hours per day; IPAQ: International Physical Activity Questionnaire; MD: Mean difference; MET: Metabolic equivalent; Min/day: Minutes per day; NICE: National Institute for Health and Care Excellence; OSPAQ: Occupational Sitting and Physical Activity Questionnaire; PA: Physical activity; PRISMA: Preferred Reporting Items for Systematic reviews and Meta-Analyses; RCT: Randomised-controlled trial; SB: Sedentary Behaviour; WSQ: Workforce Sitting Questionnaire

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Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

AS, SMD, MM, CN and JM formulated the research question and defined the search terms. AS carried out the electronic searches and carried out the search process. AS, MM, SMD finalised study inclusion. AS carried out the risk of bias assessment with assistance from MM. AS carried out the BCT coding, data extraction and meta-analysis. All authors were involved in writing, reviewing and providing feedback on the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Author details

[1]Shore Rd, Newtownabbey BT37 0QB, Northern Ireland. [2]Centre for Health and Rehabilitation Technologies, Institute of Nursing and Health Research, Faculty of Life and Health Sciences, Ulster University, Shore Rd, Newtownabbey BT37 0QB, Northern Ireland. [3]UKCRC Centre of Excellence for Public Health (Northern Ireland), Belfast, Northern Ireland. [4]School of Physiotherapy, University of Otago, Dunedin, New Zealand. [5]Computer Science Research Institute, Faculty of Computing and Engineering, Ulster University, Shore Rd, Newtownabbey BT37 0QB, Northern Ireland.

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Appendix B - BCT Taxonomy v1

Grouping and BCTs	Grouping and BCTs	Grouping and BCTs
1. Goals and planning	**6. Comparison of behaviour**	**12. Antecedents**
1.1. Goal setting (behavior) 1.2. Problem solving 1.3. Goal setting (outcome) 1.4. Action planning 1.5. Review behavior goal(s) 1.6. Discrepancy between current behavior and goal 1.7. Review outcome goal(s) 1.8. Behavioral contract 1.9. Commitment	6.1. Demonstration of the behavior 6.2. Social comparison 6.3. Information about others' approval	12.1. Restructuring the physical environment 12.2. Restructuring the social environment 12.3. Avoidance/reducing exposure to cues for the behavior 12.4. Distraction 12.5. Adding objects to the environment 12.6. Body changes
	7. Associations	
	7.1. Prompts/cues 7.2. Cue signalling reward 7.3. Reduce prompts/cues 7.4. Remove access to the reward 7.5. Remove aversive stimulus 7.6. Satiation 7.7. Exposure 7.8. Associative learning	
2. Feedback and monitoring		**13. Identity**
2.1. Monitoring of behavior by others without feedback 2.2. Feedback on behaviour 2.3. Self-monitoring of behaviour 2.4. Self-monitoring of outcome(s) of behaviour		13.1. Identification of self as role model 13.2. Framing/reframing 13.3. Incompatible beliefs 13.4. Valued self-identify 13.5. Identity associated with changed behavior
	8. Repetition and substitution	**14. Scheduled consequences**
	8.1. Behavioral practice/rehearsal 8.2. Behavior substitution 8.3. Habit formation 8.4. Habit reversal 8.5. Overcorrection 8.6. Generalisation of target behavior 8.7. Graded tasks	14.1. Behavior cost 14.2. Punishment 14.3. Remove reward 14.4. Reward approximation

2.5. Monitoring of outcome(s) of behavior without feedback
2.6. Biofeedback
2.7. Feedback on outcome(s) of behavior

3. Social support

3.1. Social support (unspecified)
3.2. Social support (practical)
3.3. Social support (emotional)

4. Shaping knowledge

4.1. Instruction on how to perform the behavior
4.2. Information about Antecedents
4.3. Re-attribution
4.4. Behavioral experiments

5. Natural consequences

5.1. Information about health consequences
5.2. Salience of consequences
5.3. Information about social and

9. Comparison of outcomes

9.1. Credible source
9.2. Pros and cons
9.3. Comparative imagining of future outcomes

10. Reward and threat

10.1. Material incentive (behavior)
10.2. Material reward (behavior)
10.3. Non-specific reward
10.4. Social reward
10.5. Social incentive
10.6. Non-specific incentive
10.7. Self-incentive
10.8. Incentive (outcome)
10.9. Self-reward
10.10. Reward (outcome)
10.11. Future punishment

11. Regulation

11.1. Pharmacological support
11.2. Reduce negative emotions
11.3. Conserving mental resources
11.4. Paradoxical instructions

14.5. Rewarding completion
14.6. Situation-specific reward
14.7. Reward incompatible behavior
14.8. Reward alternative behavior
14.9. Reduce reward frequency
14.10. Remove punishment

15. Self-belief

15.1. Verbal persuasion about capability
15.2. Mental rehearsal of successful performance
15.3. Focus on past success
15.4. Self-talk

16. Covert learning

16.1. Imaginary punishment
16.2. Imaginary reward
16.3. Vicarious consequences

environmental consequences 5.4. Monitoring of emotional consequences 5.5. Anticipated regret 5.6. Information about emotional consequences		

Appendix C - Sample Database Search

Medline Database Search

1. Internet/
2. Software/
3. Computer Communication Networks/
4. Online Systems/
5. Telemedicine/
6. Mobile Applications/
7. Cell Phones/
8. Smartphone/
9. Computers, Handheld/
10. Text Messaging/
11. Electronic Mail/
12. Reminder Systems/
13. Cues/
14. Wireless Technology/
15. Actigraphy/
16. Accelerometry/
17. (intranet or internet or website$ or web based or computer based or software or online).tw.
18. (ehealth or e health or mhealth or m health or electronic health or mobile health or telehealth or tele health or health technolog$).tw.
19. (mobile phone$ or smartphone$ or smart phone$ or cellphone$ or cell phone$ or cellular phone$ or hand held or digital device$ or digital technolog$ or mobile technolog$ or mobile device$).tw.
20. (mobile app or mobile apps or mobile application$ or mobile phone app or mobile phone apps or mobile phone application$ or smartphone app or smartphone apps or smartphone application$ or smart phone app or smart phone apps or smart phone application$ or phone app or phone apps or phone application$ or cellphone app or cellphone apps or cellphone application$ or cell phone app or cell phone apps or cell phone application$ or tablet app or tablet apps or tablet application$).tw.
21. (text messag$ or sms or short message service$ or email$ or e mail$ or electronic mail$ or remind$ or prompt$ or cue$ or cuing).tw.
22. (wireless or wearable$ or wristband$ or wrist band$ or wristworn or wrist worn or watch$ or smartwatch$ or smart watch$).tw.
23. (activity track$ or activity sens$ or activity monitor$ or movement track$ or movement sens$ or movement monitor$ or just in time adaptive intervention$ or lifelog$ or life log$ or quantified self or self monitoring device$).tw.

24. (pedomet$ or acceleromet$ or step count$ or inclinomet$).tw.
25. (pervasive technolog$ or pervasive comput$ or ubiquitous technolog$ or ubiquitous comput$).tw.
26. Sedentary Lifestyle/
27. (sedentar$ or sitting or seat$ or lying or reclin$ or recumben$).tw.
28. (screen time or screentime or computer time or TV time or television time).tw.
29. (self track$ or fitness track$).tw.
30. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 29
31. 26 or 27 or 28
32. 30 and 31

Ulster University

Information sheet

Prolonged sitting time: Qualitative study exploring barriers, facilitators and views of desk-based office workers and employers.

You are being invited to take part in a research study, which is part of a PhD project at Ulster University. Before you decide whether or not to take part, it is important that you understand what the research is for and what you will be asked to do. Please read the following information and do not hesitate to ask any questions about anything that might not be clear to you. Make sure that you are happy before you decide what to do. Thank you for taking the time to consider this invitation.

What is the purpose of the study?

An ongoing research project within Ulster University is investigating prolonged sitting in office workers. The aim of this project is to understand the attitudes and thoughts of desk-based office workers and employers in relation to employee sitting behaviours at work and how to change them. In order to facilitate this research, we hope to carry out focus group and interview work. Focus groups are group discussions involving a small number of people (5-8 participants per group). Members of the focus group are asked questions by a researcher and are asked to discuss their answers with each other. Interviews are a one to one discussion with the participant and the researcher. Your employer has agreed for us to conduct this research among employees.

Who will be invited to take part in the study?

Employees and employers and board members must be fluent in English to participate. Employees who work 3 or more days per week and spend most of the work day sitting at a desk, will be invited to be part of the study. Employees will not be invited to participate in the study if they have a medical condition that limits mobility or requires them to sit rather than stand at work. Pregnant employees will not be invited to participate.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part, you will be given this information sheet to keep. You will also be asked to sign a consent form. If you choose to take part, you can change your mind at any time and withdraw from the study without giving a reason.

What will the study involve?
If selected, you will be invited to attend a one off focus group discussion or interview, which is expected to last no more than 1.5 hours. Focus group participants will be expected to actively participate in this group session, along with 5-8 other staff members from your workplace. There will be separate focus group sessions run for management/employers and employees. The interviews will be a one to one interview with the researcher. A researcher will lead the discussion and the employee group will be asked to share their thoughts on sitting at work, what motivates them to sit less and what the barriers are to reducing sitting and how to modify this. The employer and board member group will be asked about their views on employee sitting, barriers and motivators to employee sitting and how to modify this. Focus groups and interviews will be audio and/or video recorded and all responses will be anonymised.

What are the potential benefits/risks?
It is hoped that you would benefit on an individual level from participating in this research and interacting with others. It is also an opportunity to contribute towards the advancement of research in the area.

What if something goes wrong?
It is very unlikely that something should go wrong during this study. However, if any issues or problems arise, Ulster University has procedures in place for reporting, investigating, recording and handling adverse events. Any complaints will be taken seriously. If you have any further concerns please contact Prof. Marie Murphy, Chief Investigator for this study

Will the information collected be kept confidential?
All the information that you provide us with will be treated in the strictest confidence. Participants will be asked not to discuss the information they hear within the focus group with other people. Only those conducting the research will have access to the data collected during this study. All recordings from the focus groups/interviews will be coded so that information is anonymous.

Who will carry out the research?
Prof. Marie Murphy (Chief Investigator), Miss Aoife Stephenson (PhD student), Dr. Jacqueline Mair, Prof. Suzanne McDonough, Prof. Chris Nugent. All members of the research team are based at Ulster University. This project is funded by a Vice Chancellors Research Scholarship (VCRS).

Who do I speak to if I have any questions?
If you have any questions or want more information, please contact Aoife Stephenson (details below).

What next?
If you wish to take part in this research, please complete the included consent forms and return to your workplace no later than xx/xx/2017, where they will be collected by the research team. The focus groups and interviews will take place between Feb 2017 and Aug 2017.

Contact details:
Prof. Marie Murphy Office: (028) 90366669
Email: mh.murphy@ulster.ac.uk
Miss Aoife Stephenson Office: (028) 90366987
Email: stephenson-a@email.ulster.ac.uk

Thank you for taking the time to read this information.

Appendix E - Consent Form Focus Groups and Interviews

A CONSENT FORM FOR PARTICIPANTS
(Note: one copy for subject and one for researcher)

Title of study: Prolonged sitting time: Qualitative study exploring barriers, facilitators and views of desk based office workers and employers.

Chief Investigator: Prof. Marie Murphy

Please initial each box

I confirm that I have been given and have read and understood the information sheet for the above study and have asked and received answers to any questions raised	
I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason and without my rights being affected in any way	
I understand that the researchers will hold all information and data collected securely and in confidence and that all efforts will be made to ensure that I cannot be identified as a participant in the study (except as might be required by law) and I give permission for the researchers to hold relevant personal data	
I agree to take part in the above study	

Name of participant (please print)	Signature	Date (dd/mm/yyyy)
Name of researcher (please print)	Signature	Date (dd/mm/yyyy)

Please retain this copy for your own records

Appendix F - Demographic Questionnaire (Employees)

Employees Demographic Information Form

Instructions: Please provide a response for each of the following questions

Name: ____

Age: ____

With what gender do you identify? (Please tick)

- **Female**
- **Male**
- **Other** (specify)______________________________________

Name of work company/organisation ___________________________

Occupation? ____

What would you determine your career level to be?

- Entry
- Junior
- Intermediate
- Senior
- Lead
- Other (specify)______________________________________

How long have you worked for this company

- 0-1 year
- 1-2 years
- 2-5 years
- 5-10 years
- 10 + years

Employment status

- Full time
- Part time
- Casual
- Other (specify)______________________________________

How many hours per week do you work (on average)? ______________________________

How many days per week do you work (on average)? ________________________________

How many hours per day do you spend sitting at work (on average)? ________________

Is your work primarily desk based?

- **Yes**
- **No**

What is you highest grade or level of school/education have you completed?

- Level 8 (e.g. PhD, Doctorate, Higher Doctorate)
- Level 7 (e.g. Master's Degree, PGCE, PGDip PGCert)
- Level 6 (e.g. Bachelor's Degree, Graduate Cert/ Diploma, Professional Cert in Education
- Level 5 (e.g. Foundation degree, HND, DipHE)
- Level 4 (e.g Diploma, CertHE)
- Level 3 (e.g. A level, AS level, NVQ)
- Level 2 (e.g. GCSE, NVQ)
- Other (please specify)

  ____

Appendix G - Demographic Questionnaire (Employer/Board)

Demographic Information Form (Employer/Board Member)

Instructions: Please provide a response for each of the following questions

Name: ______________________________
Age: ______________________________

With what gender do you identify? (Please tick)

- **Female**
- **Male**
- **Other** (specify)______________________________

Occupation? ______________________________

Employment status
- Full time
- Part time
- Casual
- Other (specify)______________________________

How many hours <u>per week</u> do you work (on average)? ______________________________

How many days <u>per week</u> do you work (on average)? ______________________________

How many hours <u>per day</u> do you spend sitting at work (on average)? ________________

Is your work primarily desk based?

- **Yes**
- **No**

Appendix H - Ethical Approval (a)

UNIVERSITY OF ULSTER **RESEARCH GOVERNANCE**

RG3 Filter Committee Report Form

Project Title	Prolonged sitting time: Focus groups exploring barriers, facilitators and views of desk based office workers
Chief Investigator	Prof Marie Murphy
Filter Committee	School of Sport

This form should be completed by Filter Committees for all research project applications in categories A to D (*for categories A, B, and D the University's own application form – RG1a and RG1b – will have been submitted; for category C, the national, or ORECNI, application form will have been submitted).

Where substantial changes are required the Filter Committee should return an application to the Chief Investigator for clarification/amendment; the Filter Committee can reject an application if it is thought to be unethical, inappropriate, incomplete or not valid/viable.

Only when satisfied that its requirements have been met in full and any amendments are complete, the Filter Committee should make one of the following recommendations:

The research proposal is complete, of an appropriate standard and is in

- category A and the study may proceed* [X]
- category B and the study must be submitted to the University's Research Ethics Committee** Please indicate briefly the reason(s) for this categorisation [ ]
- category C and the study must be submitted to ORECNI along with the necessary supporting materials from the Research Governance Section*** [ ]
- category D and the study must be submitted to the University's Research Ethics Committee** [ ]

Signed: Gareth Davis
Chairperson/Administrator of Filter Committee

Date: 5/7/16

***The application form and this assessment should now be returned to the Chief Investigator. The Filter Committee should retain a copy of the complete set of forms.**

**** The application form and this assessment should now be returned to the Chief Investigator so that he/she can submit the application to the UUREC via the Research Governance section. The Filter Committee should retain a copy of the complete set of forms for their own records.**

***** The application form and this assessment should now be returned to the Chief Investigator so that he/she can prepare for application to a NRES/ORECNI committee. The Filter Committee should retain a copy of the complete set of forms for their own records.**

<u>For all categories, details of the application and review outcome should be minuted using the agreed format and forwarded to the Research Governance section</u>

Version 3 (10/07)

1

Appendix I - Employee Topic Guide mapped to TDF

Icebreaker: Could we please start with some introductions: your name, say what area you work in and how long you have worked in this company/organisation.

Opener:

1) I would now like to ask for your thoughts and beliefs on sitting at work

Prompts:

Question	TDF Domain
What impact – if any- do you think prolonged sitting at work has on employees in terms of physical and mental health and overall work life?	Knowledge, Beliefs about consequences
Are you aware of any guidelines for how much sitting employees should be doing at work? If so what are these?	Knowledge
Do you feel you sit too much at work, not enough or just the right amount?	Knowledge

2) How do you feel about reducing sitting at work?

Prompts:

Would you like to reduce your sitting at work?	Intentions, Goals, Beliefs about capabilities
Do you intend to reduce your sitting at work?	Intentions, Goals, Beliefs about capabilities
What advantages or disadvantages, do you think reducing sitting would have?	Knowledge, Beliefs about consequences
Within your workplace, are there, or have there been any processes or practices in place to reduce sitting time at work?	Behavioural regulation, Memory, Attention and Decision Processes, Reinforcement

3) What do you believe influences your sitting patterns during the work day and how this may be modified?

Prompts:

What aspects of the work environment e.g office structure, building and room layout, equipment etc. tend to increase your sitting at work?	Environmental Context and Resources
Do you think these aspects can be changed? If so, what could be done differently?	Beliefs about capabilities, Optimism
What aspects of the work environment helps decrease your sitting at work?	Environmental Context and Resources
What can be done to further promote this reduction in sitting?	Environmental Context and Resources

4) Please consider any social influences such as work team relationships, peer/manager views and opinions on reducing sitting at work.

Prompts:

How might the relationships within your work team influence your sitting patterns during the work day?	Social influences , Social/professional role and identity
How do the views/opinions of others (co-workers/management) influence your sitting behaviours?	Social influences , Social/professional role and identity
Would you feel uncomfortable standing at your desk, in meetings, whilst on the phone etc. if your colleagues were not to?	Emotion, Social influences, Social/professional role and identity

5) How do you think reducing your sitting would affect your workload/productivity?
6) Please discuss anything else that may influence your sitting patterns at work

As you may be aware technology is a tool being used to improve health and fitness. These include tools such as activity trackers, mobile phone apps, smartwatches, motivational websites, prompts on computers and phones are being widely used.

Use this time to show examples of these tools-

7) Do you use or have you used technology such as activity trackers, mobile apps, software prompts, websites to improve health and or fitness?

Questions 7 – 10 refers to TDF domains "Behavioural Regulation" and "Memory, Attention and Decision Process".

Was it aimed at reducing sitting time?

If yes….

Prompts

Please name and describe the tool and what you use/used it for	
How effective did/do you find it?	
Discuss aspects that work/worked well for you	
Discuss any difficulties you encounter/ed	
How long have you used/did you use it for?	

If yes, and aimed at sitting less

Prompts

How did/do you feel about using technology as a tool to reduce sitting at work	
How effective did/do you find it for reducing sitting?	
Discuss aspects that work/ed well in your work environment?	
Discuss any difficulties you encounter/ed	
Does/Did it impact on staff productivity or were there any other implications?	
Do/Did you use it to set goals? How did you find the process?	
Do/Did you use it to track sitting time? What did you think of this aspect/feature?	
Did you use it to prompt you to reduce sitting? What do you think of this aspect/feature?	
If none of the above, please describe how you used the tool	

If no…..

Prompts:

How would you feel about using technology as a tool to improve your health or become more active?	
How would you feel about using technology as a tool to reduce sitting at work?	
How effective do you think using technology as a tool (i.e. mobile apps/ activity trackers) would be to reduce sitting at work?	
What tools do you think would work well in your work environment?	
What difficulties would you anticipate in using these tools?	

How do you think these tools would impact staff productivity or can you foresee any other implications?	
How would you feel about using it to set goals? To self-monitor and track sitting time? To prompt you to reduce sitting?	

8) I would like you think about the design and use of technology as a tool to reduce sitting at your workplace and to please share your thoughts

Prompts:

What methods would you suggest to be the most effective for use at work e.g. websites, activity trackers, email/text message prompts, mobile apps	
Why do you think this would be most effective?	
Would you participate?	
What would encourage you to participate?	
What benefit do you think you would get from participating?	

9) Can you think of ways to encourage employees to start using these tools at work and how to keep them engaged in the long term?

Prompts:

Can you think of anything that would encourage you to take part?	
Are there any incentives that would increase the likelihood of you engaging in the intervention?	
Can you think of any ways that would encourage employees to engage with the tool more in the long term?	

10) Can you foresee any issues in the implementation of an intervention like this at work?

Prompts

How do you think your employer/management would feel about this being used at the workplace during office hours?	
How do you think using this tool may affect employee productivity?	
Would you have privacy concerns regarding your employer having access to your sitting/activity data?	

Close: Is there anything else that we didn't talk about today that you think is important for us to know? Is there anything you would like to add?

Summary: Summary of session and main points.

Thank you very much for your time and valuable contribution to the study.

Appendix J - Employer Topic Guide

Icebreaker: Could we please start with some introductions: your name, say what area you work in and role in line management of staff and how long you have worked in this company/organisation

Opener:

1. I would now like to ask for your thoughts and beliefs on employees sitting at work.

Prompts:

What impact, if any, do you think prolonged sitting at work has on employees in terms of physical and mental health and overall work life?
Are you aware of any guidelines for how much sitting employees should be doing at work? If so what are these?
How do you feel about your employee's current sitting levels at work? Do they sit too much at work, not enough or just the right amount?

2. How do you feel about reducing employee sitting at work?

Prompts:

Would you like to reduce employee sitting time at work?
Do you intend to help reduce employee sitting time at work?
How would you expect members of your team (other management and employees) to feel about being encouraged to reduce their sitting levels at work?
Could you tell me your thoughts on how important reducing employee sitting time is to your service/company?

How would you describe the role that management has in reducing sitting amongst employees?
What advantages or disadvantages, do you think reducing employee sitting would have?
Within your company/service, are there, or have there been any processes or practices in place to reduce employee sitting?

3. What do you believe influences employee sitting patterns during the work day and how these may be modified?

Prompts:

What aspects of the work environment e.g office structure, building and room layout, equipment etc. do you think tends to increase sitting time amongst employees?
Do you think any of these aspects can be changed? If so, what could be done differently?
What aspects of the physical work environment helps decrease employee sitting at work?
What can be done to further promote this reduction in sitting?

4. Please consider any social influences such as work team relationships, peer/ manager views and opinions on reducing sitting at work.

Prompts:

How might the relationships within the work team influence employee sitting patterns during the work day?
How do you think the views and opinions of management and peers influence employee sitting patterns during the work day?

5. How do you think reducing employee sitting time would affect staff workload/productivity at work?
6. Please discuss anything else that you feel may influence sitting patterns at work?

As you may be aware technology is being used as a tool to improve health and fitness. These include tools such as activity trackers, mobile phone apps, smartwatches, motivational websites, prompts on computers and phones

<u>*Use this time to show examples of these tools-*</u>

7. Have you or other managers ever advised your staff to use technology such as activity trackers, mobile apps, software prompts, websites to improve health and or fitness? Was it aimed at reducing employee sitting time?

If yes

Prompts:

Please name and describe the tool and what it was/is used for
How effective was/is it?
Discuss aspects that work/ed well
Discuss any difficulties encountered
How long have they used/did they use it for?

If yes, and aimed at sitting less

How did/do you feel about technology as a tool to reduce employee sitting?

How effective was/is it for reducing employee sitting?
Discuss aspects that work/ed well in your work environment
Discuss any difficulties encountered
Did/does it impact on staff productivity or were there any other implications for management?
Please describe how employees used/use the tool. Goal setting, tracking sitting time, prompts to get up from the chair?

If no,

Prompts:

How would you feel about employees using technology as a tool to improve their health and fitness?
How would you feel about employees using technology as a tool to reduce their sitting at work?
How effective do you think using technology as a tool (i.e. mobile apps/ activity trackers) would be to reduce employee sitting at work?
What tools do you think would work well in your work environment for your employees? Do you need to give examples again here? E.g. activity trackers, mobile phone apps, smart watches, motivational websites, prompts on computers and phones
What difficulties would you anticipate your employees to encounter in using these tools?
How do you think these tools would impact on staff productivity or can you foresee any other implications for management?
How would you feel about staff using it to set goals? To self-monitor and track sitting time? To prompt them to reduce sitting?

8. I would like you to think about the design and use of technology as a tool to reduce sitting employees at your workplace and to please share your thoughts.

Prompts:

What methods would you think to be the most effective for use at work amongst your employees E.g. websites, activity trackers, email/text message prompts, mobile apps
Why do you think this would be most effective?
Do you think your staff would participate?
What do you think would encourage staff to participate?
What benefits would they get from participating?

9. Can you think of ways to encourage employees to start using these tools at work and how to keep them engaged in the long term

Prompts:

Can you think of anything that would encourage your employees to take part?
Are there any incentives that may increase the likelihood of employees engaging in the intervention?
Can you think of any ways that would encourage employees to engage with the tool more in the long term?

10. Can you foresee any issues in the implementation of an intervention like this within your workplace?

Prompts:

How do you feel about this being used at the workplace during office hours?
How do you think using this tool may affect employee productivity?
Do you think your staff would have privacy concerns regarding the employer having access to their sitting/activity data?

Close: Is there anything else that we didn’t talk about today that you think is important for us to know? Is there anything you would like to add?
Summary: Summary of session and main points.

Thank you very much for your time and valuable contribution to the study.

Appendix K - Board Member Topic Guide

Icebreaker: Could we please start with some introductions: your name, say what area you work in

Is there any other management level over yours that you report to?

Opener:

1. What impact – if any- do you think prolonged sitting at work has on employees

Prompts:

In terms of physical and mental health and overall work life?
Are you aware of any guidelines for how much sitting employees should be doing at work? If so what are these?
How do you feel about your employee's current sitting levels at work? Do they sit too much at work, not enough or just the right amount?

Sedentary behaviour refers to any activity done while awake involving very low energy expenditure while sitting or lying. At work this would include seated computer use, reading, meetings, lunch time siting, phone use etc. Going for a walk or simply standing up while you work would help reduce sedentary behaviour.

2. How do you feel about reducing employee sitting at work?

Prompts:

Would you like to reduce employee sitting time at work? Why?
Do you have PLANS to help reduce employee sitting time at work?

If they were to break up sitting at work, what do you think they would do instead?
Thinking about the people that work here in X company, how do you think they would feel about being encouraged to reduce their sitting levels at work?
Do you think management would have a different view to lower level employees? Expand?
Could you tell me your thoughts on how important reducing employee sitting time is to your service/company?
How would you describe the role that your position in management (?) has in reducing sitting amongst employees?
How would you describe the role that your management team has in reducing sitting amongst employees?
What do you think you can do to help assist employees reduce sitting time? would this be possible/feasible?
What do you think your management team can do to help assist employees reduce sitting time? would this be possible/feasible?
What advantages or disadvantages, do you think reducing employee sitting would have?
Within your company/service, are there, or have there been any processes or practices in place to reduce employee sitting?

3. What do you believe influences employee sitting patterns during the work day and how these may be modified ?

Prompts:

What aspects of the work environment e.g office structure, building and room layout, equipment etc. do you think tends to increase sitting time amongst employees?

Do you think any of these aspects can be changed? If so, what could be done differently?
What aspects of the physical work environment helps decrease employee sitting at work?
What can be done to further promote this reduction in sitting?

4. Please consider any social influences such as work team relationships, peer/ manager views and opinions on reducing sitting at work.

Prompts:

How might the relationships within the work team influence employee sitting patterns during the work day?
How do you think the views and opinions of peers influence employee sitting patterns during the work day?
How do you think the views and opinions of the management teams influence employee sitting patterns during the work day?
How do you think YOUR views/opinions influence employee sitting patterns during the work day?. Do you think that you have a social influence on people that work for this company?

5. How do you think reducing employee sitting time would affect staff workload/productivity at work?

6. Please discuss anything else that you feel may influence sitting patterns at work?

As you may be aware technology is being used as a tool to improve health and fitness. These include tools such as activity trackers, mobile phone apps, smartwatches, motivational websites, prompts on computers and phones

7. Have you or other managers ever advised your staff to use technology such as activity trackers, mobile apps, software prompts, websites to improve health and or fitness? Was it aimed at reducing employee sitting time?

If yes

Prompts:

Please name and describe the tool and what it was/is used for
How effective was/is it?
Discuss aspects that work/ed well
Discuss any difficulties encountered
How often did/do they use it?

If yes, and aimed at sitting less

How did/do you feel about technology as a tool to reduce employee sitting?
How effective was/is it for reducing employee sitting?
Discuss aspects that work/ed well in your work environment
Discuss any difficulties encountered
Did/does it impact on staff productivity or were there any other implications for management?
Please describe how employees used/use the tool. Goal setting, tracking sitting time, prompts to get up from the chair?

If no,

Prompts:

How would you feel about employees using technology as a tool to improve their health and fitness?
How would you feel about employees using technology as a tool to reduce their sitting at work?
How effective do you think using technology as a tool (i.e. mobile apps/ activity trackers) would be to reduce employee sitting at work?
What tools do you think would work well in your work environment for your employees?
What difficulties would you anticipate your employees to encounter in using these tools?
How do you think these tools would impact on staff productivity or can you foresee any other implications for management?
How would you feel about staff using it to set goals? To self-monitor and track sitting time? To prompt them to reduce sitting?

8. From previous research and having spoken to employees and line managers from a range of workplaces, we have come up with suggestions for an intervention that we hope to develop to reduce sitting in office workers. I will run through some of the ideas generated and ask for your comments.

"This tool we hope to develop is a smartphone app. This app will be used during office hours. We plan for the company to roll out this initiative and encourage all staff to take part. Staff will monitor how much they sit during the workday over the course of a week using the app for a number of weeks. It will be designed to be really quick and easy to record their sitting and they will be asked to make a record every hour of the workday. They will then then set a personal sitting goal for the week ahead – for example a two hour reduction in daily office sitting, so staff continue to record their sitting every hour. The app will automatically calculate if they are reaching their goal and if not, it will send them reminders/prompts and educational tips to help them along”.

Please give your comments

What do you think about this intervention?
Do you think this would be possible to implement with your desk-based office staff?
Do you think this would be effective?
Can you suggest improvements?
What do you think would encourage staff to participate?
What benefits would they get from participating?
How would this be supported by senior and middle management - how could we ensure this?

9. Can you think of ways to encourage employees to start using these tools at work and how to keep them engaged in the long term

Prompts:

Can you think of anything that would encourage your employees to take part?
What incentives may increase the likelihood of employees engaging in the intervention?
Can you think of any ways that would encourage employees to engage with the tool more in the long term?

10. Can you foresee any issues in the implementation of an intervention like this within your workplace?

Prompts:

How do you feel about this being used at the workplace during office hours?
How do you think using this tool may affect employee productivity?

Do you think your staff would have privacy concerns regarding the employer having access to their sitting/activity data?

Close: Is there anything else that we didn't talk about today that you think is important for us to know? Is there anything you would like to add?

Summary: Summary of session and main points.

Thank you very much for your time and valuable contribution to the study.

Appendix L - TDF Domains and Constructs

(Source Atkins et al., 2017).

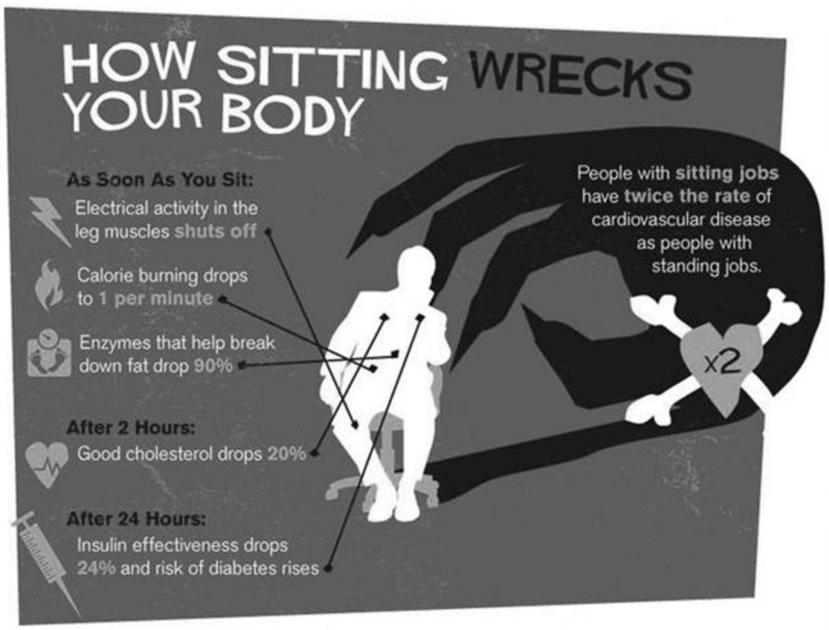
Domain (definition)	Constructs
1. Knowledge (An awareness of the existence of something)	Knowledge (including knowledge of condition/scientific rationale) Procedural knowledge Knowledge of task environment
2. Skills (An ability or proficiency acquired through practice)	Skills Skills development Competence Ability Interpersonal skills Practice Skill assessment
3. Social/professional role and identity (A coherent set of behaviours and displayed personal qualities of an individual in a social or work setting)	Professional identity Professional role Social identity Identity Professional boundaries Professional confidence Group identity Leadership Organisational commitment
4. Beliefs about capabilities (Acceptance of the truth, reality or validity about an ability, talent or facility that a person can put to constructive use)	Self-confidence Perceived competence Self-efficacy Perceived behavioural control Beliefs

	Self-esteem Empowerment Professional confidence
5. Optimism (The confidence that things will happen for the best or that desired goals will be attained)	Optimism Pessimism Unrealistic optimism Identity
6. Beliefs about Consequences (Acceptance of the truth, reality, or validity about outcomes of a behaviour in a given situation)	Beliefs Outcome expectancies Characteristics of outcome expectancies Anticipated regret Consequents
7. Reinforcement (Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus)	Rewards (proximal/distal, valued/not valued, probable/improbable) Incentives Punishment Consequents Reinforcement Contingencies Sanctions
8. Intentions (A conscious decision to perform a behaviour or a resolve to act in a certain way)	Stability of intentions Stages of change model Transtheoretical model and stages of change
9. Goals (Mental representations of outcomes or end states that an individual wants to achieve)	Goals (distal/proximal) Goal priority Goal/target setting Goals (autonomous/controlled)

	Action planning Implementation intention
10. Memory, attention and decision processes (The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives)	Memory Attention Attention control Decision making Cognitive overload/tiredness
11. Environmental context and resources (Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence and adaptive behaviour)	Environmental stressors Resources/material resources Organisational culture/climate Salient events/critical incidents Person × environment interaction Barriers and facilitators
12. Social influences (Those interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviours)	Social pressure Social norms Group conformity Social comparisons Group norms Social support Power Intergroup conflict Alienation Group identity Modelling
13. Emotion (A complex reaction pattern, involving experiential, behavioural, and physiological elements, by which the individual attempts to deal with a personally significant matter or event)	Fear Anxiety Affect Stress

	Depression Positive/negative affect Burn-out
14. Behavioural regulation (Anything aimed at managing or changing objectively observed or measured actions)	Self-monitoring Breaking habit Action planning

Appendix M - Infographic



Source: http://www.earthlymission.com/category/infographics/

Appendix N - Ethical Approval (b)

UNIVERSITY OF ULSTER RESEARCH GOVERNANCE

RG3 Filter Committee Report Form

Project Title	Mobile health (m-health) intervention to promote sitting time reductions in office workers: A feasibility 3-armed cluster randomised controlled trial with process evaluation
Chief Investigator	Prof Marie Murphy
Filter Committee	School of Sport

This form should be completed by Filter Committees for all research project applications in categories A to D (*for categories A, B, and D the University's own application form – RG1a and RG1b – will have been submitted; for category C, the national, or ORECNI, application form will have been submitted).

Where substantial changes are required the Filter Committee should return an application to the Chief Investigator for clarification/amendment; the Filter Committee can reject an application if it is thought to be unethical, inappropriate, incomplete or not valid/viable.

Only when satisfied that its requirements have been met in full and any amendments are complete, the Filter Committee should make one of the following recommendations:

The research proposal is complete, of an appropriate standard and is in

- category A and the study may proceed* [X]
- category B and the study must be submitted to the University's Research Ethics Committee** Please indicate briefly the reason(s) for this categorisation [ ]
- category C and the study must be submitted to ORECNI along with the necessary supporting materials from the Research Governance Section*** [ ]
- category D and the study must be submitted to the University's Research Ethics Committee** [ ]

Signed: Gerard Davies Date: 13/9/17.

Chairperson/Administrator of Filter Committee

***The application form and this assessment should now be returned to the Chief Investigator. The Filter Committee should retain a copy of the complete set of forms.**

**** The application form and this assessment should now be returned to the Chief Investigator so that he/she can submit the application to the UUREC via the Research Governance section. The Filter Committee should retain a copy of the complete set of forms for their own records.**

***** The application form and this assessment should now be returned to the Chief Investigator so that he/she can prepare for application to a NRES/ORECNI committee. The Filter Committee should retain a copy of the complete set of forms for their own records.**

For all categories, details of the application and review outcome should be minuted using the agreed format and forwarded to the Research Governance section

Version 3 (10/07) 1

<u>Participant information sheet “Think Aloud Study”.</u>

Title: “Mobile health (m-health) intervention to promote sitting time reductions in office workers; a think aloud study”

You are being invited to take part in a research study, which is part of a PhD project at Ulster University. Before you decide whether or not to take part, it is important that you understand what the research is for and what you will be asked to do. Please read the following information and do not hesitate to ask any questions about anything that might not be clear to you. Make sure that you are happy before you decide what to do. Thank you for taking the time to consider this invitation.

What is the purpose of the study?

As part of an on-going research project at Ulster University investigating prolonged sitting in office workers, this study aims to review a mobile app intervention developed to help reduce sedentary behaviour (sitting time) at work.

Who will be invited to take part in the study?

Desk-based office workers aged between 18 and 65 years.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part, you will be given this information sheet to keep. You will also be asked to sign a consent form. If you choose to take part, you can change your mind at any time and withdraw from the study without giving a reason.

What will the study involve?

You will be asked to use a mobile app designed to help office workers reduce their sitting time at work. You will be asked to “talk out loud” all of the thoughts that occur to you as you use the app. The goal is to think out loud. The researcher will stay silent until you have completed the questions. The interview will be recorded and then written out word for word by the researcher. This will be a one off session which will last approximately 20-30 minutes. Your thoughts will help us identify any problems with the app and how to make it better for the user.

What are the potential benefits/risks?
We cannot promise that taking part will benefit you. It is an opportunity to contribute towards the advancement of research in the area.

What if something goes wrong?
It is very unlikely that something should go wrong during this study. However, if any issues or problems arise, Ulster University has procedures in place for reporting, investigating, recording and handling adverse events. Any complaints will be taken seriously. If you have any further concerns please contact Prof. Marie Murphy, Chief Investigator for this study.

Will the information collected be kept confidential?
All the information that you provide us with will be treated in the strictest confidence. Only those conducting the research will have access to the data collected during this study. All data coded so that information is anonymous.

Who will carry out the research?
Prof. Marie Murphy (Chief Investigator), Miss Aoife Stephenson (PhD student), Dr. Jacqueline Mair, Prof. Suzanne McDonough, Prof. Chris Nugent, Dr. Mathias Garcia-Constantino. All members of the research team are based at Ulster University. This project is funded by a Vice Chancellors Research Scholarship (VCRS).

Who do I speak to if I have any questions?
If you have any questions or want more information, please contact Aoife Stephenson (details below).

What next?
If you wish to take part in this research, please complete the included consent forms and return to your workplace. The study will take place between September 2017 and August 2018.

Contact details:
Prof. Marie Murphy Office: (028) 90366669
Email: mh.murphy@ulster.ac.uk
Miss Aoife Stephenson
Email: stephenson-a@email.ulster.ac.uk

Thank you for taking the time to read this information.

Appendix P - Consent Form "Think-Aloud" Study

Appendix x CONSENT FORM FOR PARTICIPANTS
(Note: one copy for subject and one for researcher)

Title of study: M-health intervention to reduce sitting time in office workers; Think aloud study

Chief Investigator: Prof. Marie Murphy

Please initial each box

I confirm that I have been given and have read and understood the information sheet for the above study and have asked and received answers to any questions raised ☐

I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason and without my rights being affected in any way ☐

I understand that the researchers will hold all information and data collected securely and in confidence and that all efforts will be made to ensure that I cannot be identified as a participant in the study (except as might be required by law), and I give permission for the researchers to hold relevant personal data ☐

I agree to take part in the above study ☐

Name of participant (please print)	Signature	Date (dd/mm/yyyy)
Name of researcher (please print)	Signature	Date (dd/mm/yyyy)

Please retain this copy for your own records

Appendix Q - “Think-aloud” tasks questions

Think aloud’Tasks

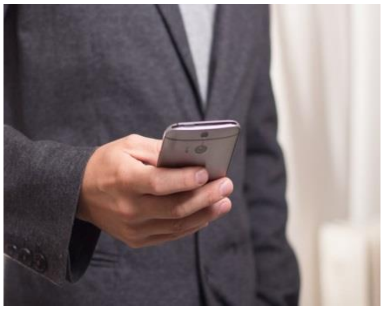
1. Set goal
2. Self-report SB
3. Receive educational fact/tip
4. View feedback
5. Browse the app

Questions

1. What are your overall views toward the app?
2. Was there anything you particularly disliked?
3. Was there anything you found particularly hard to use?
4. Was there anything you particularly liked?
5. Was there anything you found particularly easy to use?
6. Anything you wanted to see there/expected to see there but didn’t?
7. Do you have any suggestions for how the app could be improved?
8. Are there any other comments you would like to make?

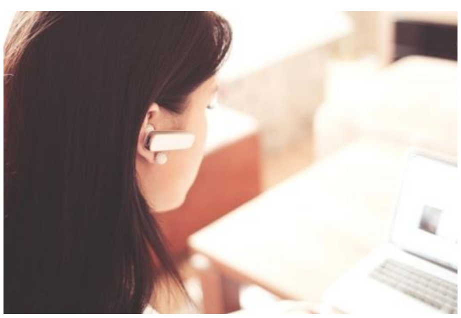
Appendix R - Educational Facts and Tips

1. Sitting for long periods can increase your chances of developing cancer, heart disease and diabetes. Why don't you stand or walk around while on the phone?



2. Sitting for long periods of time increases your risk of early death even if you are fit and exercise regularly. Try walking to a co-worker's desk instead of emailing.

3. Even if you exercise regularly, too much sitting can still be bad for you. Why don't you use a hands-free head piece and move around the office while taking calls?



4. Regardless of how active you are, too much sitting is bad for your heart and blood vessels. Try standing during your breaks.

5. Studies have linked high sitting levels with being overweight and obese. Arrange your next work meeting so that you're walking around the block with your meeting partner.

6. People who sit for long periods of time are more likely to gain excess weight. Try being more active by taking a longer, more roundabout way back to your desk.

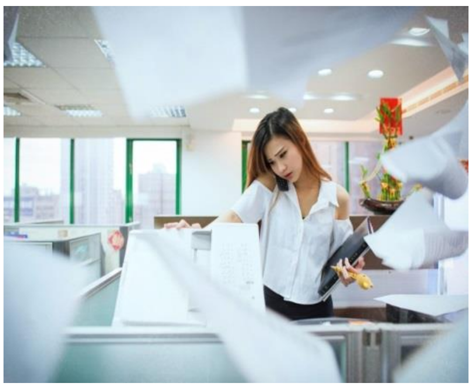
7. We are advised to exercise regularly – at least 150 minutes a week – and reduce sitting time. You could take your exercise shoes to work and walk or jog during your lunch break.

8. Sitting for long periods can slow your metabolism, which affects your body's ability to control blood sugar and burn fat. Why not stand while eating your unch?

9. Sitting requires very little energy expenditure and limits the calories burned. Send your printing to the printer down the hall, rather than to the closest.

10. Sitting uses less energy than standing or moving. This is why office workers burn fewer calories a day than manual workers. Walk with your colleagues rather than gathering in a meeting room.

11. When you sit, your blood flow slows and you burn less fat. Move your bin and printer or anything else you use throughout the day away from your desk. This way you have to get up each time you use them.



12. To reduce the risk of some cancers linked to excess sitting, introduce walking or standing meetings to the work schedule.

13. Too much sitting can lead to poor circulation and swelling in your ankles, so while at your desk, try standing on your tip toes and then gently dropping your heels back to the ground and repeating.

NO IMAGE

14. Weight bearing activities such as standing and walking lead to stronger bones. Use the farthest printer from your desk to ensure you get a break from sitting.

15. Sitting for too long may take its toll on your back especially if you're sitting poorly in front of a computer. Take a break, get up and stretch.

16. Prolonged sitting and poor posture can lead to back pain. Whenever talking on the telephone, stand up and if possible, walk.

17. Too much sitting can reduce your lifespan by promoting dozens of chronic diseases, even if you exercise regularly. Why not invite a colleague for a walk at lunch?

18. It is better for you to switch between standing and sitting at work. If you need a quick answer to a question, it's often as easy to walk to someone's office as it is to email or call.

19. Try standing during your coffee break instead of sitting. Use a high table or counter and encourage colleagues to use it too.

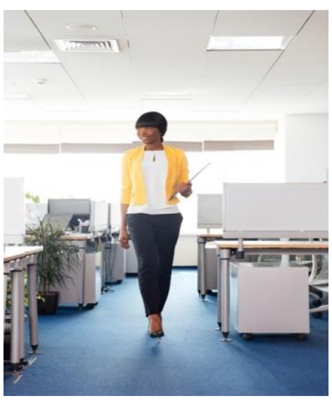
20. It’s up to you to make sure you get up and move at work. Why not use the farthest bathroom from your desk?

21. Think about your health and walk and talk instead of sitting and speaking while on the phone

22. Keep your water bottle half full at work. You’ll have to get up more often to fill it up and for bathroom breaks, which means more moving.

23. Drink lots of water at work, it is good for your body and it will force you to get up and use the bathroom frequently

24. Take business calls standing up. This burns more calories than sitting.

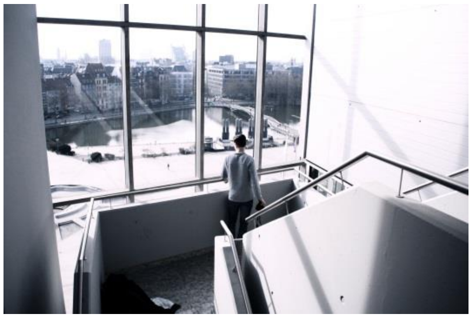


25. Reorganise the layout of your office space so you have to stand up to reach frequently used files, the phone, or your printer, rather than having everything within easy reach.

26. Ask to take your meetings out of the usual meeting room and go for a walk. This is helpful for brainstorming sessions or just catching up on progress and may be more time efficient.

27. Instead of emailing or calling colleagues, walk to their part of the building for some face time when you need to ask a question or solve a work issue.

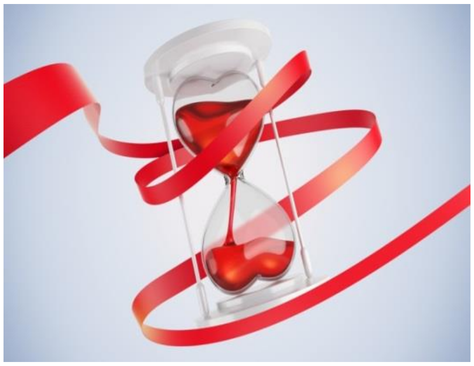
28. Those who reduce sitting and move more at work are more likely to have better mental well-being. Take the stairs instead of the lift where possible.



29. Try breaking up sitting with short periods of standing, walking and exercising in the office. This can boost your productivity.

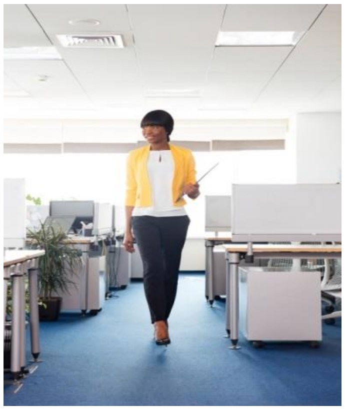
30. When sitting, your calorie burning drops. Try standing up and moving whenever you have a drink of water at work.

31. When sitting for too long, less fresh blood and oxygen flow through the body. Breaking up sitting can increase blood flow and protect blood vessel health.

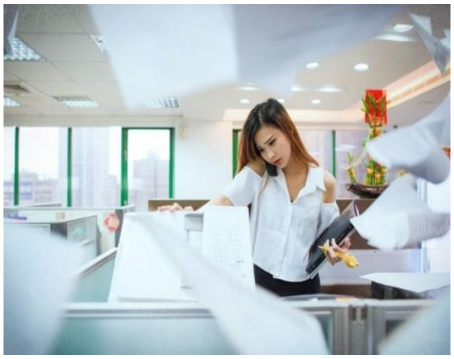


32. Sitting for long periods of time causes your metabolism to slow, you burn fewer calories and increase your chances that excess energy will be stored as fat.

33. When you are upright and active, even if it is only for a short period of time, you can improve your mood. Try taking the longer, more roundabout way to the bathroom.



34. When you are upright and active, even if it is only for a short period of time, you can reduce feelings of tiredness. Why not use the photocopiers furthest away from your workstation?



35. Mistakes are more likely to occur if you are feeling sleepy. Take a break from sitting, stand up and stretch.

36. Replacing sitting time with physical activity can suppress hunger. Why don't you take a brisk walk around the office?

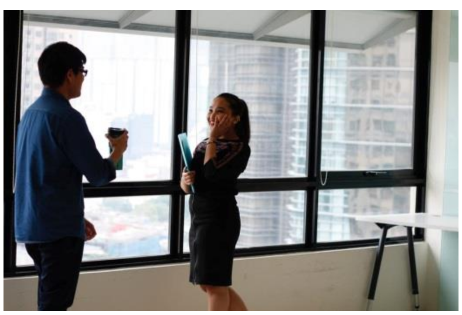
37. Bursts of activity during the work day can improve your energy levels. Take the stairs where possible.

38. Interrupting prolonged sitting with walking may be an effective way to fight fatigue. Do some leisurely walking with colleagues after you eat lunch together at work.

39. Regularly breaking up prolonged sitting may reduce blood pressure. Schedule a standing meeting, and if you need desk space, improvise with a high table or counter

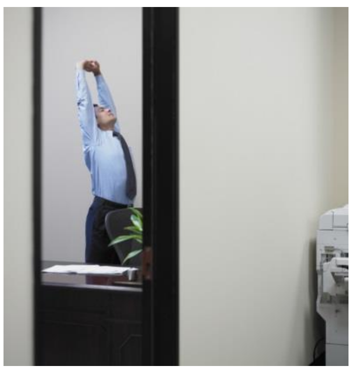
40. Sedentary office work can cause back discomfort. Regularly changing your posture from sitting to standing and moving can reduce discomfort without impacting productivity.

41. Use coffee break time to stand and communicate with colleagues; try not sit at your desk during breaks.



42. Long periods of sitting are linked with poor health outcomes. Try to take a walk break every time you take a coffee break.

43. Research suggests reducing your sitting lowers the risk of mental health issues such as depression. Take the opportunity to get out of your chair and do a few simple exercises by your desk.

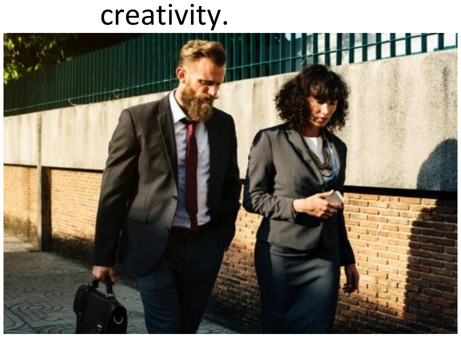


44. If you have to sit for certain work tasks, try to take a quick break to stand or walk every 20-30 minutes. Research suggests that this can reduce the negative health impact of sitting.

45. Sedentary behaviour is associated with poorer health outcomes, including an increased risk of type 2 diabetes. Try to stand at the back of the room during presentations.

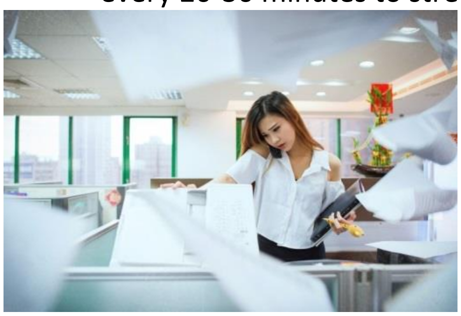
46. Reducing your sitting may increase your life expectancy. Take a look at your work day, and see what tasks could just as easily be done standing or walking.

47. Organising walking meetings is not only better for your health; it may also boost creativity.

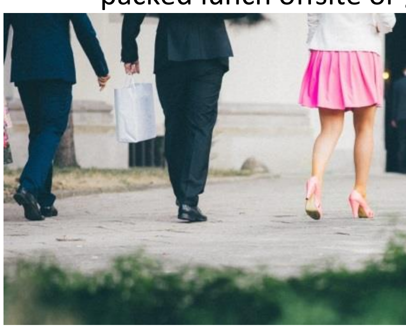


48. Drink from smaller cups. You will need to get up more frequently at the office if you use a small cup for coffee or water, which means more moving.

49. Research suggests that those who spend more time standing and moving have lower levels of bad cholesterol than those who sit. Stand up or leave your desk every 20-30 minutes to stretch, get a drink of water or use the printer.



50. Try to reduce sitting and move more by leaving your desk for lunch. Eat out, take packed lunch offsite or go to a different floor.



Images sourced from Shutterstock

Appendix S - Participant information sheet (Feasibility Cluster RCT)

Participant information sheet

Title: "Mobile health (m-health) intervention to promote sitting time reductions in office workers; A feasibility 3-armed cluster randomised controlled trial with process evaluation".

You are being invited to take part in a research study, which is part of a PhD project at Ulster University. Before you decide whether or not to take part, it is important that you understand what the research is for and what you will be asked to do. Please read the following information and do not hesitate to ask any questions about anything that might not be clear to you. Make sure that you are happy before you decide what to do. Thank you for taking the time to consider this invitation.

What is the purpose of the study?

An ongoing research project at Ulster University is investigating prolonged sitting in office workers. The aim of this project is to compare changes in workplace sitting time following an app based programme, with or without a height adjustable work desk, relative to a comparison condition who are advised to continue their normal workplace behaviours. Other aims are to determine how the programme impacts upon standing and moving at work and at home, as well as any effects on work productivity and mood. We also aim to conduct an evaluation of the programme to understand how exactly it affected participants sitting, activity, productivity and mood. This will help us understand how satisfied participants were with the programme, what elements worked well, what ones didn't, and to help inform and improve future programmes.

Who will be invited to take part in the study?

Full time employees who work five days per week and spend most of the work day sitting at a desk will be invited to be part of the study. Staff with a planned absence from work of more than five days over the full duration of the study, will not be eligible to participate. Employees will not be invited to participate in the study if they have a medical condition that limits standing or mobility or requires them to sit rather than stand at work. Pregnant employees will also not be invited to participate.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part, you will be given this information sheet to keep. You will also be asked to sign a consent form. If you choose to take part, you can change your mind at any time and withdraw from the study without giving a reason.

What will the study involve?

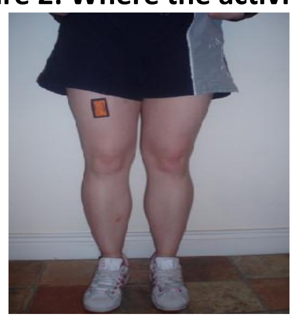
If you decide to take part, there are a number of steps you will follow:

Step 1: You will be asked a number of screening questions to make sure you are eligible for the study. If you agree to take part and are eligible, you will sign a consent form which will be collected from your workplace. There are approximately 20 places available for this programme which will be allocated on a first come, first served basis.

Step 2: Your height and weight will be measured and you will be asked to fill in questionnaires relating to your gender, age, post code, work schedule etc. This will occur in a private testing room at your workplace. You will be asked to fill in questionnaire about mood. These will take approximately 15 minutes to complete. You will be asked to respond to a text message regarding your self rated productivity for the next 5 work days. You will also be given an activPAL (see figure 1).

Figure 1: An activPAL

Figure 2: Where the activPAL is placed



This is a small matchbox-sized device that you attach to your thigh. It measures how much time you spend sitting down or lying, standing up and moving around. This device is small and comfortable and is worn underneath your usual daily clothes. As part of the study, you will be asked to wear the device for 24 hours per day for 7 days only taking it off when bathing or swimming. Figure 2 shows where the activPAL will be attached to the front of one of your legs and a skin friendly medical patch will be placed over it to stop it from falling off. We will tell you how to wear the device and when to take it off. You will also be given a diary to record when you wake and go to bed, when you're at work, reasons why you removed the monitor etc. Once you have completed 7 days of wearing the activPAL, you will be asked to return the activPAL to your workplace.

Step 3: You will be randomly allocated to one of three groups, either:

Group 1 - Mobile app, OR
Group 2 - Mobile app plus a height adjustable work desk, OR
Control - Normal routine for the duration of the study.

It is important to emphasise that whilst we hope the app and the height adjustable desk will be helpful in reducing office sitting we do not know this definitively. For this reason, participants in both the interventions and the control arm of this trial are equally important.

If allocated to group 1 or 2, you will receive an app created for this study. This app is the m-health component of the project. The app will allow you to self-report how much you are sitting at work and set your own goals to help reduce sitting, give you feedback on your sitting, prompt you to break your sitting, and provide some facts and tips around reducing sitting at work. You will be given a study specific phone and charger provided by researchers and the free app will already be downloaded. Based upon the goals set, and the amount of time that is reported as sitting, you may (or may not) receive a prompt to remind you not to sit too much, for example "time to get up!". The app will also provide a progress report and educational tips. Both groups 1 and 2 (not the control) will appoint an office champion to act as a role model and encourage participation in the study.

To provide further opportunities to reduce sitting at work group 2 participants will be provided with a height adjustable work desk which sits on your existing work desk, for the duration of the intervention. This work desk will allow you to easily and quietly alternate your working posture between sitting and standing. Those in the control group will be advised to maintain their normal workplace behaviour.

Step 4: To be able to assess the effect of the programme we need to repeat the productivity measures and mood questionnaires and activPAL measurements taken at your baseline assessment (described in Step 2 above). The questionnaire will take approximately 5 minutes to complete and will occur at your workplace. A member of the research team will contact you for follow-up 4 weeks after the intervention starts and again at 8 weeks. At these time points you will be asked to wear the activPAL again for 7 days. At the end of the project, intervention groups 1 and 2 will be asked to complete an additional range of questionnaires. These questionnaires will ask them for opinions on the programme, including how satisfied you were with the project, how easy you found it to use the app and/or height adjustable work desk, the strengths and weaknesses of the project, what changed for you as a result of participating etc. This will be conducted online and will take approximately 20-30 minutes.

What are the potential benefits/risks?

We cannot promise that taking part will benefit you, but the study will give you an opportunity to reduce your sitting at work. You may feel better as a result of spending less time sitting during the work day. It is an opportunity to contribute towards the advancement of research in the area.

There is a small risk that you may find the data collection procedures, in particular some aspects of the questionnaires that discuss mood, distressing. If this situation were to occur the researcher collecting the data will ask if you if you would like to take a break and if are happy to continue. At all points during the study you will be reminded that participation is voluntary and that you may withdraw at any point without this decision affecting your rights being affected in any way.

A small number of people are sensitive to the adhesive tape used for the activPAL, which is similar to that of a sticking plaster. If this happens to you, we will advise you to remove the tape and attach the activPAL to the other thigh or to stop wearing the activPAL.

What if something goes wrong?

It is very unlikely that something should go wrong during this study. However, if any issues or problems arise, Ulster University has procedures in place for reporting, investigating, recording and handling adverse events. Any complaints will be taken seriously. If you have any further concerns please contact Prof. Marie Murphy, Chief Investigator for this study.

Will the information collected be kept confidential?

All the information that you provide us with will be treated in the strictest confidence. Only those conducting the research will have access to the data collected during this study. All data coded so that information is anonymous. All research conducted will comply with the Data Protection Act (1998).

Who will carry out the research?

Prof. Marie Murphy (Chief Investigator), Miss Aoife Stephenson (PhD student), Dr. Jacqueline Mair, Prof. Suzanne McDonough, Prof. Chris Nugent, Dr. Mathias Garcia-Constantino. All members of the research team are based at Ulster University. This project is funded by a Vice Chancellors Research Scholarship (VCRS).

Who do I speak to if I have any questions?

If you have any questions or want more information, please contact Aoife Stephenson (details below).

What next?

If you wish to take part in this research, please complete the included consent forms and return to your workplace. The study will take place between September 2017 and August 2018.

Contact details:
Prof. Marie Murphy Office: (028) 90366669
Email: mh.murphy@ulster.ac.uk
Miss Aoife Stephenson
Email: stephenson-a@email.ulster.ac.uk

Thank you for taking the time to read this information.

Appendix T - Screening Form

Ulster University

1. **Age: (must be 18-65)**

___

2. **How many hours per week do you work (on average)?**

___

3. **How many days per week do you work (on average)? (must be 4 days per week)**

___

4. **How many hours per day do you work (on average)?**

___

5. **Is your work primarily desk-based? (must be yes)**

Yes/No/Unsure

6. **How many hours per day do you spend sitting at work (on average) (must be ≥ 75%)**

___

7. **Are you pregnant? (must answer no)**

Yes/No/Unsure

8. Are you non-ambulant or have an existing conditions which may restrict standing/moving (must answer no)

Yes/No/Unsure

9. Are you fluent in English? (must be yes)

Yes/No/Unsure

10. Do you plan to be absent from work for more than 5 days consecutively over the duration of the intervention? (must be no)

Yes/No/Unsure

11. Are you currently participating in an intervention study to reduce SB or increase PA? (must answer no)

Yes/No/Unsure

Appendix U - Consent Form Feasibility study

A CONSENT FORM FOR PARTICIPANTS
(Note: one copy for subject and one for researcher)

Title of study: "Mobile health (m-health) intervention to promote sitting time reductions in office workers; A feasibility 3-armed cluster randomised controlled trial with process evaluation".

Chief Investigator: Prof. Marie Murphy

Please initial each box

I confirm that I have been given and have read and understood the information sheet for the above study and have asked and received answers to any questions raised ☐

I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason and without my rights being affected in any way ☐

I understand that the researchers will hold all information and data collected securely and in confidence and that all efforts will be made to ensure that I cannot be identified as a participant in the study (except as might be required by law), and I give permission for the researchers to hold relevant personal data ☐

I give permission to be contacted by the researchers via text message/email ☐

I agree to take part in the above study ☐

Name of participant (please print)	Signature	Date (dd/mm/yyyy)
Name of researcher (please print)	Signature	Date (dd/mm/yyyy)

Please retain this copy for your own records

How to use “Worktivity”

Worktivity will be set up and ready to go for you. Your normal work hours will be programmed in to the device before you start.

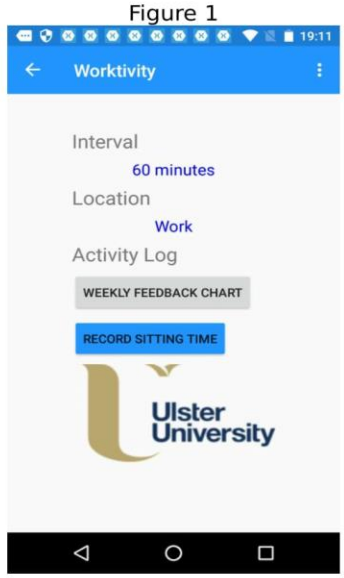
This app is designed to help you reduce your sitting at work. For the first 2 weeks it allows you to self-monitor or record your sitting time. After 2 weeks another aspect of the app will be rolled out.

Every morning at work you must remember to open the app first thing. This means locating the blue “worktivity” app icon and clicking on it. You must leave the app running in the background for the workday.

When you first open the app; **please check that the time and date are correct.** If not, please change it if possible, if not please contact me (see details below).

One hour in to your work day, you will be prompted to record your sitting in the last 60 minutes. Click the blue button “**RECORD SITTING TIME**”. Use the slider to select the number of minutes best representative of your sitting in the last hour. After 5 minutes, if you haven’t entered your sitting time, you will receive a reminder to log. (See figure 1 below)

Figure 1



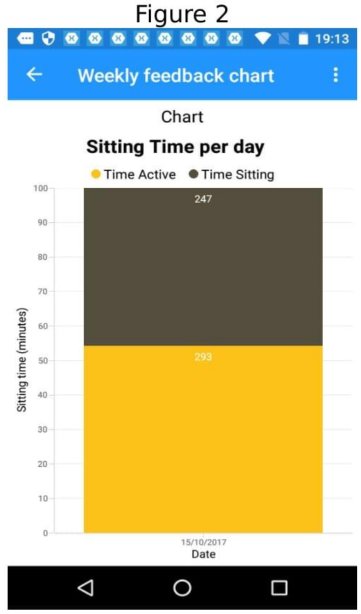
This prompt will occur every 60 minutes for the rest of your work day. Please remember to log your sitting every hour as close to the prompt to log as possible. Please log only once per hour.

If you will be away from your desk for more than 1 hour, please bring the device with you and log while you are away from the desk.

The prompts can be set to be visual screen prompts, vibrate and alarm. We recommend that you leave the vibrate function and/or the alarm active, so you don't forget to log sitting. To change the prompt delivery settings use the longer button on the right side of the phone.

The **Weekly feedback chart** allows you to review what you have logged. You can see your recorded sitting levels per day. On your device, time you have spent sitting (in minutes) is displayed in grey (the darker of the 2 colours in figure 2 below). Time active is represented in yellow on your device (lighter of the 2 colours in figure 2 below).

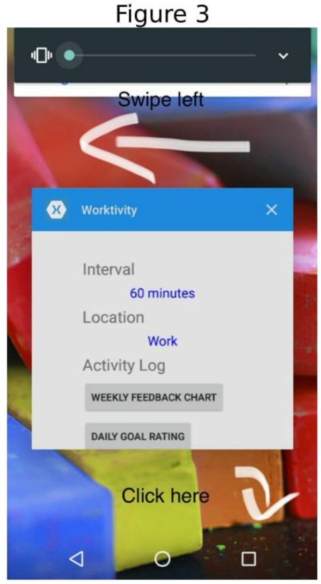
Figure 2



- Please remember to keep your device charged.
- Please do not uninstall the app from the device as we may lose your data.
- **Please remember to close the app as you leave work and re open it in the morning. On the phones you can close the app**

by pressing the box on the bottom right of the phone screen and swiping the open worktivity app to the left (See figure 3)

Figure 3



If you have any issues please don’t hesitate to contact me via email: stephenson-a@ulster.ac.uk

Appendix W - Goal Setting Procedure

1. Check that the phone is set to GMT. Settings, Date and time- automatic timer set to GMT.

2. Goal setting should be 'patient-led/patient-centred' so they should definitely choose the goal with support from us.

3. Review their summary graphs with them, ask them for their thoughts first (what do they think about the amount of sitting [too much/ok/too little], do they have an idea about how much in total they want to reduce by) and then tell them about the Buckley recommendations and then ask them what they think would be a good goal for them. You can guide them if you think their goal is unrealistic.

4. Buckley 2015 "The derived guidance is as follows: for those occupations which are predominantly desk-based, workers should aim to initially progress towards accumulating 2 h/day of standing and light activity (light walking) during working hours, eventually progressing to a total accumulation of 4 h/day (prorated to part-time hours)".
5. SMART

Specific

Make sure goals are precise and stated in performance terms. For instance, if you want to reduce sitting at work, your goal might be "to reduce sitting time at work by 2 hours in 6 weeks."

Measurable

A goal is measurable when it is easy to determine if it has been accomplished. This can be done by using the app.

Achievable

One of the biggest mistakes people make while setting goals is that they set unattainable goals. Goals should be set high, but they must also be realistic.

Relevant

Goals should be important to participant.

Time-Bound

Make sure each goal has a specific time frame for completion. This one is predetermined -6 weeks.

In the settings tab on the app select the goal from 1hr-8hrs. The password is 1234. Please tell the user that this goal setting feature will activate on Nov 2nd. Explain to them it will now include a goal setting feature – they are to look at this at the end of the day to see if they have met their 5 stars for that day. Also explain that in conjunction with self-monitoring their time sitting they will now be prompted to move based on these goals, in order to help them achieve their goals.

Appendix X - Demographics questionnaire

Demographics questionnaire

Date:

Participant ID number:

Please complete the following questions

- **How old are you:**

- **With what gender do you identify?** (Please tick)
    - o Female
    - o Male
    - o Other (specify)____

What is you highest grade or level of school/education have you completed?

- o Level 8 (e.g. PhD, Doctorate, Higher Doctorate)
- o Level 7 (e.g. Master's Degree, PGCE, PGDip PGCert)
- o Level 6 (e.g. Bachelor's Degree, Graduate Cert/ Diploma, Professional Cert in Education
- o Level 5 (e.g. Foundation degree, HND, DipHE)
- o Level 4 (e.g Diploma, CertHE)
- o Level 3 (e.g. A level, AS level, NVQ)
- o Level 2 (e.g. GCSE, NVQ)
- o Other (specify) ____

Please choose the category that best describes your main job. If none of the categories fits you exactly, please respond with the closest category to your experience. (Select only one.)

- Executive, administrator, or senior manager (e.g., CEO, sales VP, plant manager)
- Professional (e.g., engineer, accountant, systems analyst)
- Technical support (e.g., lab technician, legal assistant, computer programmer)
- Sales (e.g., sales representative, stockbroker, retail sales)
- Clerical and administrative support (e.g., secretary, billing clerk, office supervisor)
- Service occupation (e.g., security officer, food service worker, janitor)
- Precision production and crafts worker (e.g., mechanic, carpenter, machinist)
- Chemical/Production Operator (e.g., shift supervisors and hourly employees)
- Laborer (e.g., truck driver, construction worker)

What is your annual income from your job, before taxes?

- < 4,999
- 5,000-9,999
- 10,000-14,999
- 15,000-19,999
- 20,000-24,999
- 25,000-29,999
- 30,000-34,999
- 35,000-39,999
- 40,000-44,999
- 45,000-49,999
- 50,000-54,999
- 55,000-59,999

- 60,000-64,999
- 65,000-69,999
- 70,000-74,999
- 75,000+

What days of the week do you usually work?

____

What time do you usually begin work? Please specify AM/PM

____

What time do you usually end work? Please specify AM/PM

____

Is your work schedule best described as a regular schedule (roughly the same hours every day), a rotating schedule (e.g., working a day shift some days and a night shift other days), or an irregular schedule (e.g., unpredictable hours controlled by situations or workload)?

- Regular schedule
- Rotating schedule
- Irregular schedule

What is your postcode?

How would you prefer us to contact you during the trial in relation to productivity?

- **Text message**
- **Email**

Please provide your phone number or email address

Appendix Y - Logic Model

Inputs
Knowledge of evidence base
Establish Team • Researchers • App Developers • End Users • Stakeholders • Employers • Board Members
Equipment • Mobile Phones • Chargers • SSWD • ActivPAL device and adhesive patches • Consumables

Outputs: Activities	Outputs: Participation
Focus groups/ interviews	Implement app intervention +/- SSWD
Design intervention	Self-monitor SB
Obtain Ethics	Personal "sit-less" goal
Recruit companies	Deliver educational fact/tip
Recruit participants	Deliver sit less nudges
	Measure SB using activPAL
	Measure mood and productivity (BRUMS/EMA)

Outcomes- Impact: Short	Outcomes- Impact: Medium-Long
Decrease SB at work	Decrease SB in the workplace
Improve productivity	Sustained SB reduction
Improve mood	Change in office culture
	Sustained productivity improvement
	Sustained mood improvement
	Improved cardio-metabolic health

Appendix Z - Satisfaction Surveys

ID:____

Satisfaction Survey MA+SSWD group only

We would be grateful if you would complete this questionnaire about your experiences of being involved in this study. Feedback from this survey will enable us to identify areas that may need improvement. Your opinions are therefore very valuable. Please answer the questions below by ticking the circle beside the answer most relevant to you. We also welcome your comments and suggestions. Thank you.

Section 1: Overall programme.

In this section we are going to ask you about your opinions on the overall programme. Please consider **<u>the programme as a whole</u>** when answering the questions in Section 1.

1. **The programme was helpful in reducing my sitting time**

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?

____

____

2. **I am likely to recommend the programme to a colleague**

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?

____

____

3. The programme is suitable for a workplace setting?

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?

____

____

4. Which aspects of the programme did you like best?

- o App self-monitoring
- o App movement/stand prompts
- o Educational tips

Other (please specify)

____

____

Why did you like this aspect best?

____

____

5. Which aspects of the programme did you like least?

- o App self-monitoring
- o App movement/stand prompts
- o Educational tips

Other (please specify):

____

____

Why did you like this aspect least?

____

____

6. **What did you think about the length of the intervention?**

- Too short
- Too long
- Appropriate length

Why did you answer this way?

____

____

7. **I feel this intervention will have a lasting effect on reducing my sitting?**

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

8. **I am satisfied with the overall intervention?**

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

9. **Did you encounter anything that made participating in the programme more difficult?**

____

____

10. Did you encounter anything that made participating in the programme easier?

____

____

11. **If you participated for the entire intervention period, what kept you participating in the program?**

____

____

12. If you didn't participate for the entire intervention period, what was the reason for not participating or dropping out?

____

Section 2: Mobile/Tablet application (app).

In this section we will ask you to for your opinions **on the mobile/tablet app** that was used as part of the programme. Please consider the reminders you received to log your sitting and the summary graphs

1. The app helped me reduce my sitting

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?

____

____

2. I am comfortable with using app technology

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree

- Strongly disagree

Why did you answer this way?
____
____

3. The app is suitable for use in the workplace to self-report/log sitting

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?
____
____

4. It was easy to use the app

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?
____
____

5. There were many technical issues with the app

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

6. I am likely to recommend the app to a colleague

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

7. Being able to set my own sitting goal was helpful

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

8. The reminders to self-report/log sitting time were too frequent

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

9. The reminders to self-report/log sitting were annoying

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

10. I responded to all of the reminders to self-report/log your sitting?

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

11. The prompts to stand and move were helpful

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

12. The prompts to stand and move were annoying

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?

____

____

13. After receiving a prompt to move/stand, I usually did stand/move.

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?

____

____

14. I am satisfied with how the app presented feedback and information

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?

____

____

15. I would like to continue using the app after the study

- o Strongly agree
- o Agree

- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

16. I am satisfied with the app

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

17. What parts of the app did you like and why?

____

____

18. What parts did you not like and why?

____

____

19. Did you encounter anything that made using the app more difficult?

____

____

20. Did you encounter anything that made using the app easier?

____

____

21. Please suggest ways how the app section can be improved? E.g. Was there any thing missing, was there enough detail, was information displayed appropriately? What parts did you not like and why?

____

____

Section 3: Education.

In this section we are going to ask for your opinions on the **education component** as part of the programme. Please consider the educational facts and tips you received at the end of each day while answering this section.

1. **The educational facts and tips were helpful**

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?

____

____

2. **The educational facts and tips were repetitive**

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?

____

____

3. **The educational facts and tips were annoying**

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?

____

____

4. **I understood the information provided in the educational facts and tips**

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

5. **After reading the educational facts and tips, I actually applied them as well.**

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

6. **Do you have any comments regarding the educational facts and tips component of the programme? E.g. Was there any thing missing, was there enough detail, were the educational tips displayed appropriately?**

____

____

7. **What did you think about the amount of educational facts and tips you received?**

- Too few
- Too many
- Appropriate amount

Why did you answer this way?

____

____

8. I am satisfied with the daily educational facts and tips?

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

Section 4: Height adjustable desk

In this section we are going to ask you about your opinions on the **height adjustable desk** as part of the programme. Please consider the height adjustable desk while answering questions for section 4.

1. I am satisfied with the height adjustable desk

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

2. The height adjustable desk helped me reduce my sitting

- Strongly agree
- Agree
- Neither agree nor disagree

- Disagree
- Strongly disagree

Why did you answer this way?

____

____

3. I am comfortable with using a height adjustable desk at work

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

4. The height adjustable desk is suitable to be used in the workplace

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

5. It was easy to use the height adjustable desk

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

6. There were many practical issues with using the height adjustable desk

- ○ Strongly agree
- ○ Agree
- ○ Neither agree nor disagree
- ○ Disagree
- ○ Strongly disagree

Please specify the issues :

____

____

Why did you answer this way?

____

____

7. I am likely to recommend the desk to a colleague

- ○ Strongly agree
- ○ Agree
- ○ Neither agree nor disagree
- ○ Disagree
- ○ Strongly disagree

Why did you answer this way?

____

____

8. I would like to continue using the desk after the study

- ○ Strongly agree
- ○ Agree
- ○ Neither agree nor disagree
- ○ Disagree
- ○ Strongly disagree

Why did you answer this way?

____

____

9. **Did you encounter anything that made the height adjustable desk difficult to use?**

____

____

10. **Did you encounter anything that made using the height adjustable desk easier?**

____

____

11. **Any further comments regarding the height adjustable desk**

____

____

Section 5: Productivity

In this section we are going to ask you about your opinions on work productivity while taking part in the various aspects of the programme.

1. For this question please consider the intervention as a whole

My productivity at work was affected negatively by participating in the programme

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?

____

____

2. For this question please consider then reminders you received to log you sitting

My productivity was affected negatively <u>by receiving</u> the reminders to log sitting throughout the day

- o Strongly agree

- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

3. For this question please consider then reminders you received to log you sitting

My productivity was affected negatively <u>by responding</u> to the reminders to log sitting throughout the day

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

4. For this question please consider the height adjustable desk

My productivity at work was affected negatively by using the height adjustable desk

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

Any other comments:

____

ID:____

Satisfaction Survey MA group only

We would be grateful if you would complete this questionnaire about your experiences of being involved in this study. Feedback from this survey will enable us to identify areas that may need improvement. Your opinions are therefore very valuable. Please answer the questions below by ticking the circle beside the answer most relevant to you. We also welcome your comments and suggestions. Thank you.

Section 1: Overall programme.

In this section we are going to ask you about your opinions on the overall programme. Please consider **<u>the programme as a whole</u>** when answering the questions in Section 1.

13. The programme was helpful in reducing my sitting time

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?

____

____

14. I am likely to recommend the programme to a colleague

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?

____

____

15. The programme is suitable for a workplace setting?

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?

____

____

16. Which aspects of the programme did you like best?

- o App self-monitoring
- o App movement/stand prompts
- o Educational tips

Other (please specify)

____

____

Why did you like this aspect best?

____

____

17. Which aspects of the programme did you like least?

- o App self-monitoring
- o App movement/stand prompts
- o Educational tips

Other (please specify):

____

____

Why did you like this aspect least?

____

____

18. What did you think about the length of the intervention?

- o Too short
- o Too long
- o Appropriate length

Why did you answer this way?

____

____

19. **I feel this intervention will have a lasting effect on reducing my sitting?**

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?

____

____

20. I am satisfied with the overall intervention?

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?

____

____

21. **Did you encounter anything that made participating in the programme more difficult?**

____
____

22. Did you encounter anything that made participating in the programme easier?

____
____

23. **If you participated for the entire intervention period, what kept you participating in the program?**

____
____

24. If you didn't participate for the entire intervention period, what was the reason for not participating or dropping out?

____
____

Section 2: Mobile/Tablet application (app).

In this section we will ask you to for your opinions **<u>on the mobile/tablet app</u>** that was used as part of the programme. Please consider the reminders you received to log your sitting and the summary graphs

22. The app helped me reduce my sitting

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____
____

23. I am comfortable with using app technology

- Strongly agree
- Agree
- Neither agree nor disagree

- Disagree
- Strongly disagree

Why did you answer this way?

____

____

24. The app is suitable for use in the workplace to self-report/log sitting

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

25. It was easy to use the app

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

26. There were many technical issues with the app

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

27. I am likely to recommend the app to a colleague

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

28. Being able to set my own sitting goal was helpful

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

29. The reminders to self-report/log sitting time were too frequent

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

30. The reminders to self-report/log sitting were annoying

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

31. I responded to all of the reminders to self-report/log your sitting?

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

32. The prompts to stand and move were helpful

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

33. The prompts to stand and move were annoying

- Strongly agree
- Agree
- Neither agree nor disagree

- Disagree
- Strongly disagree

Why did you answer this way?

____

____

34. After receiving a prompt to move/stand, I usually did stand/move.

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

35. I am satisfied with how the app presented feedback and information

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

36. I would like to continue using the app after the study

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____
____

37. I am satisfied with the app

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____
____

38. What parts of the app did you like and why?

____
____

39. What parts did you not like and why?

____
____

40. Did you encounter anything that made using the app more difficult?

____
____

41. Did you encounter anything that made using the app easier?

____
____

42. Please suggest ways how the app section can be improved? E.g. Was there any thing missing, was there enough detail, was information displayed appropriately? What parts did you not like and why?

____
____

Section 3: Education.

In this section we are going to ask for your opinions on the **education component** as part of the programme. Please consider the educational facts and tips you received at the end of each day while answering this section.

9. The educational facts and tips were helpful

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?
____
____

10. The educational facts and tips were repetitive

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?
____
____

11. The educational facts and tips were annoying

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?

____
____

12. I understood the information provided in the educational facts and tips

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?

____
____

13. After reading the educational facts and tips, I actually applied them as well.

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?

____
____

14. Do you have any comments regarding the educational facts and tips component of the programme? E.g. Was there any thing missing, was there enough detail, were the educational tips displayed appropriately?

____
____

15. What did you think about the amount of educational facts and tips you received?

- o Too few
- o Too many
- o Appropriate amount

Why did you answer this way?
____
____

16. I am satisfied with the daily educational facts and tips?

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?
____
____

Section 4: Productivity

In this section we are going to ask you about your opinions on work productivity while taking part in the various aspects of the programme.

5. For this question please consider the intervention as a whole

My productivity at work was affected negatively by participating in the programme

- o Strongly agree
- o Agree
- o Neither agree nor disagree
- o Disagree
- o Strongly disagree

Why did you answer this way?
____
____

6. For this question please consider then reminders you received to log you sitting

My productivity was affected negatively <u>by receiving</u> the reminders to log sitting throughout the day

- o Strongly agree

- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

7. For this question please consider then reminders you received to log you sitting

My productivity was affected negatively by responding to the reminders to log sitting throughout the day

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Why did you answer this way?

____

____

Any other comments:

____

____

Appendix AA - Office Audit (blank)

Is the office open plan?
Are the desks communal?
Are the desks booth-like?
Do staff have their own offices?
Are the offices centralised to one area?
Describe the desks available to staff
Is there the opportunity to stand in the office? Access to tall tables, shelves, ledges?
Do staff have their own desktop PC?
Do staff have access to a work laptop?
Do staff have access to their own laptop?
Do staff have access to mobile devices such as I pads/tablets?
Do staff have a work mobile phone?
Are staff permitted to use their own mobile phone at work?
Do staff have a work landline on their desks?
Do staff have access to a cordless landline?
Do staff have access to a headset for phone calls?
Do staff have their own printer at their desk?
Does the office have communal printers?
Where is this/ are these located?
Does the office have communal photocopiers?
Where is this/are these located?
Do staff have their own bin at their desk?
Does the office have communal bins?
Where is this/ are these located?

Do staff have their own filing/storage space at their desk?
Does the office have communal filing/storage space?
Where is this/ are these located?
How many floors are in the building?
What floor are the offices in question located?
Is there/ are there elevators in the building?
Can the offices be accessed by elevator?
Are there stairs in the building?
Can the offices be accessed by stairs?
Is there a central canteen/kitchen in the building?
Is there a kitchen or break room for staff?
Where and on what floor is this located?
How is this accessed?
Are the tables and chairs in the kitchen/break room?
Is there the opportunity to stand in kitchen/break room? Tall tables, shelves, ledges etc.?
Where are the toilets in the building?
Where are the meeting rooms in the building?
How is this accessed?
Are there tables and chairs in the meeting room?
Describe the room layout:
Is there the opportunity to stand in the meeting rooms? Tall tables, shelves, ledges etc.?
Is the office is a rural or urban setting?
Describe the availability of outdoor spaces for PA at lunch:
Are there shower and/or changing facilities in the workplace
Describe the noise level in the office

Describe the natural light exposure
Are the lights controlled by movement sensors?
Is office temperature regulated to maintain a constant temperature?
Do staff have flexible working/lunch hours?
How long do staff usually have for lunch?
How long do staff usually have for coffee breaks?

Appendix BB - Instructions and Frequently Asked Questions for wearing ActivPAL^{TM}

Instructions and Frequently Asked Questions for wearing the ActivPAL^{TM}

What is an activPAL^{TM}?
An activPAL^{TM} is an inclinometer which is a small, electronic device which will measure the amount of time you spend sitting, lying, standing and stepping during your normal day. Figure 1 (below) shows an example of an activPAL^{TM} which will be used in the study. As part of the study, you will be asked to wear the device for 24 hours per day for 7 days only taking it off at when bathing or swimming, it can be worn during sleep. Figure 2 (below) shows where the activPAL^{TM} will be attached to the front of one of your legs.

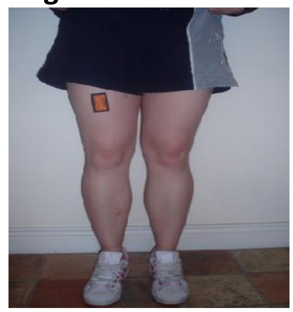
What do I do on Day 1?
On the day you receive your activPAL^{TM}, you will attach the activPAL^{TM} to the front of your thigh using a patch over it to stop it from falling off. You will be given patches to put on each day to replace any removed for bathing or swimming. We will tell you how to wear the device and when to take it off. You should return any unused patches when you return your activPAL^{TM}.

How do I apply the activPAL^{TM} and patch?
Position the monitor on your thigh in the same area as depicted in Figure 2, ensuring the stick man is standing up (head facing upwards). To hold the monitor in place put the patch over the top.

What else do I have to do?
It is important to fill in the daily sitting log every day for the 7 days you are wearing the monitor. This will help us look specifically at the data from when you were awake and wearing the monitor.

Figure 1: An activPAL™

Figure 2: Where the activPAL™ is placed



Do I replace the patch each day?
No, you don't have to. If you are taking a bath or going swimming, you can take the patch off but remember to put the activPAL™ back on and secure with another patch. The patch should be renewed after showering. If the thigh is showing signs of slight irritation you can attach the monitor to the other leg.

What do I do once I have worn the activPAL™ for seven days?
Once you have completed 7 days of wearing the activPAL, you will be asked to return the activPAL™ to the research team at your workplace

What are the possible side effects of taking part?
When you wear the activPAL™, it is attached to your leg using a skin friendly patch. The patch is an ordinary medical type dressing plaster. The skin over which the activPAL is placed should be clean and free from creams or oils and the activPAL™ should not be placed over broken skin. Please note that in the unlikely event that a skin rash occurs under the activPAL™ or patch, then remove both, seek advice and do not put on another one. If the patch becomes loose, replace it with another one.
Note: The thigh monitor will emit a green flash every 6 seconds to indicate that it is working and recording data. If it is not, please contact Aoife: stephenson-a@email.ulster.ac.uk

Do I replace the patch each day?
No, you don't have to. If you are taking a bath or going swimming, you can take the patch off but remember to put the activPAL™ back on and secure with another patch. The patch should be renewed after showering.

What do I do once I have worn the activPAL™ for seven days?
Once you have completed 7 days of wearing the activPAL, you will be asked to return the activPAL to the research team at your workplace

Do I have to do anything extra when wearing the activPAL™?
You simply have to carry on with your daily activities as normal. You do not have to do anything extra.

What are the possible side effects of taking part?
When you wear the activPAL™, it is attached to your leg using a skin friendly patch. The patch is an ordinary medical type dressing plaster. The skin over which the activPAL™ is placed should be clean and free from creams or oils and the activPAL™ should not be placed over broken skin.

Please note that in the unlikely event that a skin rash occurs under the activPAL™ or patch, then remove both, seek advice and do not put on another one. If the patch becomes loose, replace it with another one

Appendix CC - Daily Diary

Over the next 8 days please use this sheet daily to record a) the time you woke up, b) the time you got out of bed, c) the time you started work (if it is a work day), d) any times that you took off the activPAL monitor (thigh monitor) and why, e) the time you finished work (if it is a work day), d) the time you got in to bed, f) the time you fell asleep (fill this in the following morning).

Day and date	Wake up	Get up	Start work	Finished work	Times I took off monitor and why	Got in to bed	Went to sleep	Comments
Mon 17th Dec	*07.00*	*07.15*	*09.00*	*17.00*	*18.00 for 45 mins swimming*	*23.00*	*23.30*	*Slight irritation on right leg so moved to left*

How to fill in the log

- The log is divided in to 7 days. Please complete each question for all 7 days (on non-work days no need to fill out the times you started and finished work). Please try and be as accurate as possible- record exact times if you can, or at least to the nearest 5 minutes if your estimated times.
- Start by writing the date in the top row
- Then record the time that you woke up and the time that you actually got out of bed (these may be the same for some days). We ask these as some people may spend time in bed before getting up/going to sleep
- Please write AM or PM next to your times
- Then record the time you start work (on work days only)
- Then record the time you finish work (on work days only)
- If you remove your monitor for more than 10 minutes during the day please note down the time you removed the device, the length of time it was removed and the reason why it was removed.
- Then record what time you got in to bed to go to sleep and the time that you actually fell asleep (i.e. the estimated time that you fell asleep not the time you got in to bed)
- Please record your sleep time first thing in the morning when you wake up along with recording your wake time and the time that you got out of bed
- There is also space for comments. It is useful for us to know if you had skin irritations, accidentally wore the monitor upside down or any other information you think we should know
- Being as accurate and thorough as possible when completing the log enables us to look at your data more accurately
- If you have any questions please email Aoife on: stephenson-a@email.ulster.ac.uk

Appendix DD - **Brunel Mood Scale**

Brunel Mood Scale

ID:____

Below is a list of words that describe feelings. Please read each one carefully. Then select the option that best describes how you have felt during the past week including today.

Make sure you answer every question.

1. Panicky

   Not At All   A Little   Moderately   Quite A Lot   Extremely

2. Lively

   Not At All   A Little   Moderately   Quite A Lot   Extremely

3. Confused

   Not At All   A Little   Moderately   Quite A Lot   Extremely

4. Worn Out

   Not At All   A Little   Moderately   Quite A Lot   Extremely

5. Depressed

   Not At All   A Little   Moderately   Quite A Lot   Extremely

6. Downhearted

   Not At All   A Little   Moderately   Quite A Lot   Extremely

7. Annoyed

   Not At All   A Little   Moderately   Quite A Lot   Extremely

8. Exhausted

   Not At All   A Little   Moderately   Quite A Lot   Extremely

9. Mixed-Up

   Not At All   A Little   Moderately   Quite A Lot   Extremely

10. Sleepy

Not At All A Little Moderately Quite A Lot Extremely

11. Bitter

Not At All A Little Moderately Quite A Lot Extremely

12. Unhappy

Not At All A Little Moderately Quite A Lot Extremely

13. Anxious

Not At All A Little Moderately Quite A Lot Extremely

14. Worried

Not At All A Little Moderately Quite A Lot Extremely

15. Energetic

Not At All A Little Moderately Quite A Lot Extremely

16. Miserable

Not At All A Little Moderately Quite A Lot Extremely

17. Muddled

Not At All A Little Moderately Quite A Lot Extremely

18. Nervous

Not At All A Little Moderately Quite A Lot Extremely

19. Angry

Not At All A Little Moderately Quite A Lot Extremely

20. Active

Not At All A Little Moderately Quite A Lot Extremely

21. Tired

Not At All A Little Moderately Quite A Lot Extremely

22. Bad Tempered

Not At All A Little Moderately Quite A Lot Extremely

23. Alert

Not At All	A Little	Moderately	Quite A Lot	Extremely

24. Uncertain

Not At All	A Little	Moderately	Quite A Lot	Extremely

Appendix EE - Primary themes, subthemes, and selected extracts from the satisfaction survey open responses

Theme	MA Subthemes		MA+SSWD Subthemes	
Intervention benefits	Awareness	"It made you aware of the amount of time you spent sitting down"	Awareness	"it was interesting to see how much sitting I did during the day, and the difference when using the standing desks" "while I was still using the sit/stand desk I didn't still need reminding to stand after 4 weeks"
	Productivity	"the programme encouraged me to take breaks but this was not counterproductive if anything it helped my productivity"	Productivity	"it wasn't too disruptive and probably helped concentration" (prompts to break sitting) "At work we often collaborate in small groups in an ad hoc manner. The standing desks were an excellent point to meet together

				without kneeling at others desks or blocking pathways in the office”
	Simplicity	“Easy slide bar for time. Easy to see daily results”	Simplicity	“The UI (user interface) was basic and easy to understand”
			Choice of posture	“I enjoyed having the option to stand”
Intervention barriers				
	Time priorities at work	“could be a distraction at times” (app) “wasn’t always possible to drop what I was currently doing at work” (to interact with the app)	Time priorities at work	“not possible to stop work every hour” (to interact with app)” “The constant prompts from the phone can be distracting within the office environment”
	Inaccuracies with self-report and technology	“manually recording data was inaccurate” “sometimes notifications didn’t happen”	Inaccuracies with self-report and technology	“I found it to be too intrusive to have to interact hourly and it was then inaccurate if you messed a marker” “Crashed occasionally, reminders were sporadic, going off too often, not going off at all”

	Environment	"I tried at the start (to reduce SB) however in the absence of a proper standing desk I was improvising and it was uncomfortable."	Novelty	"I think after the novelty wore off, I wasn't fussed (with the intervention)"
	Frustration/guilt	"The need of hourly swiping annoyed me. Especially that I realised how little I stand when at work but still was not able to make change as the whole office life is sitting orientated" "without use of a standing desk it was frustrating as I knew I needed to stand more but was busy with work"	Space/Cabling	"I didn't particularly like the desk - possibly better if bigger- i.e. the same size as your normal desk" "cable management tricky with shorter cables, some problem with cables, but not too bad"
			Preference to sit	"I feel in the job I do and my personal preference. I concentrate better when I'm sitting"
Suggestions				
	Fix technical bugs with app	"The odd issue with prompts when charging the device"	Fix technical bugs with app	"In the beginning the devices were glitchy and many needed changed"
	More automation of app	"If there was some way of being able to see the activPAL™ data on the app"	More automation of app	"Hook it up to a fitness tracker to monitor standing, sleeping etc. to

		“Having to log sitting time manually, felt very inaccurate”		automate the process if you didn’t have to input the data - if this could be automatically done by a sensor? If not, its inaccurate”
	Context specific app	“Found it difficult at time with the app when I was out at meetings”	Context specific app	“The app had to be filled in each hour which wasn’t always possible e.g. going home early or in a meeting”
			Larger surface area for desk worktop	“The desk slowed me down as less space- I use a lot of paper work and the desk got in the way at times” “Bulky and takes up a lot of room/work space”

Appendix FF - Office Audit Full Results

	C (pre)	C (post)	MA (pre)	MA (post)	MA+SSWD (pre)	MA+SSWD (post)
Is the office open plan?	Y	Y	Y	Y	Y	Y
Are the desks communal?	N	N	N	N	N	N
Are the desks booth-like?	N	N	N	N	N	N
Do staff have their own offices?	N	N	Some	Some	N	N
Are the offices centralised to one area?	Y	Y	Y	Y	Y	Y
Describe the desks available to staff						
C (pre and post): Large rectangular desks where workers sit facing one another, small partition in front, but none to the side						
MA (pre and post): Most people have standard rectangular desk. Two desks are joined together and sit facing another 2 desks joined together, there is no partitioning						
MA+SSWD (pre and post): Large rectangular desks where workers sit facing one another, there is no partitioning. There are 6 desks to a pod.						
Is there the opportunity to stand in the office? Access to tall tables, shelves, ledges?	N	N	N	N	N	N
Do staff have their own desktop PC?	N	N	Y	Y	Y	Y
Do staff have access to a work laptop?	Y	Y	Y	Y	Y	Y
Do staff have access to their own laptop?	N	N	N	N	N	N
Do staff have access to mobile devices such as I pads/tablets?	N	N	N	N	N	N
Do staff have a work mobile phone?	Some	Some	Some	Some	Some	Some
Are staff permitted to use their own mobile phone at work?	Y	Y	Y	Y	Y	Y
Do staff have a work landline on their desks?	Y	Y	Y	Y	Some	Some
Do staff have access to a cordless landline?	Y	Y	Some	Some	N	N
Do staff have access to a headset for phone calls?	Y	Y	Some	Some	Some	Some
Do staff have their own printer at their desk?	N	N	N	N	N	N
Does the office have communal printers?	Y	Y	Y	Y	Y	Y

Where is this/ are these located?						
C (pre and post): Located in the centre of the office						
MA (pre and post): One on each floor, located in the centre of the office						
MA+SSWD (pre and post): Located at one end of the office, near the kitchen						
Does the office have communal photocopiers?	Y	Y	Y	Y	Y	Y
Where is this/are these located?						
C (pre and post): Located in the centre of the office						
MA (pre and post): One on each floor, located in the centre of the office						
MA+SSWD (pre and post): Located at one end of the office, near the kitchen						
Do staff have their own bin at their desk?	N	N	N	N	Y	Y
Does the office have communal bins?	Y	Y	Y	Y	Y	Y
Where is this/ are these located?						
C (pre and post): A small number of bins at either end of the office and in the centre						
MA (pre and post): In the kitchen areas and one centralised bin area on each floor						
MA+SSWD (pre and post): Located at one end of the office, near the kitchen						
Do staff have their own filing/storage space at their desk?	Y	Y	Y	Y	Y	Y
Does the office have communal filing/storage space?	Y	Y	For some	For some	Y	Y
Where is this/ are these located?						
C (pre and post): Storage room to the side of the main office floor						
MA (pre and post): Only on one of the two floors (4^{th})						
MA+SSWD (pre and post): Storage room to the side of the main office floor						
How many floors are in the building?						
C (pre and post): 4 floors						
MA (pre and post): 5 floors						
MA+SSWD (pre and post): 2 floors						

What floor are the offices in question located?						
C (pre and post): Third floor						
MA (pre and post): Third floor						
MA+SSWD (pre and post): First floor						
Is there/ are there elevators in the building?	Y	Y	Y	Y	Y	Y
Can the offices be accessed by elevator?	Y	Y	Y	Y	Y	Y
Are there stairs in the building?	Y	Y	Y	Y	Y	Y
Can the offices be accessed by stairs?	Y	Y	Y	Y	Y	Y
Is there a central canteen/kitchen in the building?	N	N	N	N	N	N
Is there a kitchen or break room for staff?	Y	Y	Y	Y	Y	Y
Where and on what floor is this located?						
C (pre and post): Same floor as office						
MA (pre and post): One located to the side of each floor of the offices						
MA+SSWD (pre and post): Same floor as office						
How is this accessed?						
C (pre and post): As per office (stairs, lift or walk)						
MA (pre and post): As per office (stairs, lift or walk)						
MA+SSWD (pre and post): As per office (stairs, lift or walk)						
Are the tables and chairs in the kitchen/break room?	Y	Y	Y	Y	Y	Y
Is there the opportunity to stand in kitchen/break room? Tall tables, shelves, ledges etc.?	N	N	N	N	N	N
Where are the toilets in the building?						
C (pre and post): 1st floor of building (2 floors down from office)						
MA (pre and post): Toilets on both floors- towards the back of each floor, lobbies of both floors						
MA+SSWD (pre and post): On same floor as office, in entrance hallway						

Where are the meeting rooms in the building?						
C (pre and post): On a mezzanine level above the main office floor.						
MA (pre and post): Spaced out on the perimeter of the office floor						
MA+SSWD (pre and post): Spaced out on the perimeter of the office floor						
How is this accessed?						
C (pre and post): Stairs						
MA (pre and post): As per office (stairs, lift, walk)						
MA+SSWD (pre and post): As per office (stairs, lift, walk)						
Are there tables and chairs in the meeting room?	Y	Y	Y	Y	Y	Y
Describe the room layout:						
C (pre and post): Large centralised table with chairs surrounding it						
MA (pre and post): Large centralised table with chairs surrounding it, facing a whiteboard						
MA+SSWD (pre and post): Large centralised table with chairs surrounding it						
Is there the opportunity to stand in the meeting rooms? Tall tables, shelves, ledges etc.?	N	N	N	N	N	N
Is the office is a rural or urban setting?						
C (pre and post): Urban						
MA (pre and post): Urban						
MA+SSWD (pre and post): Urban						
Describe the availability of outdoor spaces for PA at lunch:						
C (pre and post): Footpaths to walk on outside the building along a busy road and a waterway						
MA (pre and post): Not a vast selection. Footpaths to walk on outside the building along a quiet road						
MA+SSWD (pre and post): Not a vast selection. Footpaths to walk on outside the building along a quiet road						
Are there shower and/or changing facilities in the workplace	N	N	Y	Y	Y	Y
Describe the noise level in the office						

C (pre and post): Quiet						
MA (pre and post): Quiet						
MA+SSWD (pre and post): Quiet						
Describe the natural light exposure						
C (pre and post): Good, surrounded by windows						
MA (pre and post): Good, surrounded by windows						
MA+SSWD (pre and post): Good, surrounded by windows						
Are the lights controlled by movement sensors?	N	N	Y	Y	Some	Some
Is office temperature regulated to maintain a constant temperature?	N	N	N	N	Y	Y
Do staff have flexible working/lunch hours?	Y	Y	Y	Y	Y	Y
How long do staff usually have for lunch?						
C (pre and post): 1 hour						
MA (pre and post): 30 mins to 1 hour						
MA+SSWD (pre and post): 1 hour						
How long do staff usually have for coffee breaks?						
C (pre and post): 2x 15 mins						
MA (pre and post): No limits						
MA+SSWD (pre and post): 2x 20 mins						