Sedentary behaviour in office workers: correlates and interventions

A Doctoral Thesis

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By

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Abstract

Background: The concept of sedentary behaviour has emerged since the turn of the millennium and research into this area is rapidly developing. Sedentary behaviours are activities that require very little energy expenditure whilst in a sitting or reclining posture thus are distinct from physical inactivity. Previous observational studies have demonstrated that high amounts of sedentary behaviour are associated with an increased risk of obesity, type 2 diabetes, metabolic syndrome, cardiovascular disease, cancer, depression and all-cause, cardiovascular and cancer mortality. Experimental studies suggest that prolonged sedentary time causes metabolic dysregulation and could be the explanation for the associated negative health effects. Breaks in prolonged sedentary time where standing or stepping occurs have shown beneficial effects on metabolic risk markers but the threshold for these effects is ambivalent and may depend on the population. The increasing prevalence of sedentary behaviours due to advances in technology are concerning but there is a lack of large-scale studies from the UK identifying the extent of sedentary behaviour prevalence and where the majority of sedentary time is accumulated in working-aged adults. A number of correlates are associated with sedentary behaviour including individual, social and environmental factors but the extent to which multiple other health behaviours correlate with specific sedentary behaviours is unknown. Interventions to reduce sedentary time have focused on the workplace where office workers spend large amounts of time sedentary. Multicomponent workplace interventions have reported reductions in sedentary time but there is limited research in the UK investigating the long-term effects of these interventions on working and non-working hours sedentary time. Additionally, the use of persuasive technology in the form of a wearable device to reduce sedentary time has rarely been explored as an intervention strategy.

Aims: *Study One* aimed to assess the prevalence of domain-specific sedentary behaviour in a large sample of office workers from the UK and links with multiple other health behaviours. *Study Two* aimed to investigate the effectiveness of a pilot multicomponent workplace intervention to reduce sedentary time over the short (3 months) and long-term (12 months). *Study Three* aimed to explore the feasibility of a self-monitoring and prompting device to reduce sedentary time in a sample of office workers who have sit-stand desks.

Methods: *Study One* performed a secondary data analysis on a large sample of office workers (n=7,170) who self-reported their domain-specific sitting time, physical activity level, smoking status, alcohol consumption, and fruit and vegetable intake in a 2012 and/or 2014 survey. Multiple logistic regression models explored the association between sedentary behaviours and multiple other health behaviours. A separate analysis was performed to investigate how these associations tracked over time (n=806). *Study Two* implemented a multicomponent workplace intervention in a sample of office workers (baseline n=30) and measured the effects 3 and 12-months post-baseline compared to a control group (baseline n=30). activPAL sedentary time was the primary outcome with accelerometer-determined physical activity and markers of health measured as secondary outcomes. *Study Three* provided a sample of office workers who had sit-stand desks (n=19 baseline, n=17 follow-up) with a wearable device to self-monitor their sedentary time through an application and prompt reductions in prolonged sedentary time through haptic feedback (LUMO). Feasibility and acceptability of the 4-week intervention were measured through wear time, engagement with application, questionnaire and interview feedback. The effect on sedentary time was measured with the LUMO and activPAL in addition to health and work-related measures.

Results: *Study One* found that 643±160 minutes on a workday and 491±210 minutes on a non-workday were spent sitting. The majority of workday sitting took place at work (383±95 minutes/day) and whilst TV viewing on a non-workday (173±101 minutes/day). ≥7 hours sitting at work and ≥2 hours TV viewing on a workday both more than doubled the odds of partaking in ≥3 unhealthy behaviours [Odds ratio, OR=2.03, 95% CI, (1.59-2.61); OR=2.19 (1.71-2.80)] and ≥3 hours of TV viewing on a non-workday nearly tripled the odds [OR= 2.96 (2.32-3.77)]. No associations between domain-specific sitting time at baseline and change in unhealthy behaviour score were found over two years with the majority of participants maintaining baseline levels of all behaviours. *Study Two* found a trend towards reduced sedentary time at work by -7.9±25.1% and -18.4±12.4% per day at 3- (n=25 intervention, n=18 control group) and 12-months (n=11 intervention, n=7 control group) post-baseline in addition to overall workday by -4.6±13.8% and -8.0±8.3%. The intervention group showed an increase in sedentary time outside of work on a workday (4.2±9.5%) and overall on a non-workday (3.5±10.8%) after 12 months compared to baseline. However, the results found at the 3-month follow-up were not statistically significant and no significant differences in physical activity or health measures between groups were observed. Furthermore, due to the reduced sample size at the 12-month follow-up, no statistical testing was performed. *Study Three* found that the LUMO was a feasible intervention device in the short-term demonstrating high wear time (mean=60.6% of measurement days) and application engagement (mean=26.2±33.2 sessions, 30.3±26.5 minutes per week) with sedentary time being the most engaged with aspect of the application. The acceptability of the LUMO depended on the task undertaken, experience of problems with the device and preference towards the application or the prompt but overall, it increased awareness of behaviour. A trend towards reductions in sedentary time (-4%) and prolonged bouts of sedentary time >60 mins (-3%) on a workday were observed. Improvements were found in fat percentage and mass, blood pressure, job performance, work engagement, need for recovery and job satisfaction. Non-workday sedentary time >60 min bouts increased (4.8%) and increases in non-working hours sedentary time were apparent in weeks 3 and 4.

Conclusions: Office workers are highly sedentary at work and whilst TV viewing which is associated with partaking in other multiple unhealthy behaviours. Multicomponent workplace interventions result in a trend towards reductions in occupational sedentary behaviour over the short and long-term. However, compensation during non-working hours could attenuate overall sedentary behaviour reductions resulting from workplace interventions. Wearable technology as an intervention strategy to reduce sedentary time shows promise and further research is needed in fully-powered studies. Future interventions should target multiple unhealthy behaviours in addition to sedentary time during work and non-working hours.

Keywords: sedentary behaviour, office workers, workplace, interventions, wearable technology, correlates, persuasive technology.

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Dedication

I dedicate my thesis to my husband and parents who have made me who I am today. Nick, thank you for your endless love and support over the last 12 years. I could not have done this without you. Thanks for your patience and understanding, I will be sure to repay this debt of gratitude, with interest.

Mum and Dad, words cannot express my appreciation, love and admiration for you both. You have always inspired me, and I am truly forever in your debt.

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Study Two

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List of Abbreviations

ANOVA, Analysis of Variance

AusDiab, Australian Diabetes, Obesity and Lifestyle Study

BCW, Behaviour Change Wheel

BLE, Bluetooth Low Energy

BMI, Body Mass Index

CI, confidence interval

cm, Centimetres

cpm, Counts per minute

CVD, cardiovascular disease

DSSTQ, Domain Specific Sitting Time Questionnaire

EE, energy expenditure

EMA, Ecological Momentary Assessment

g, Grams

h, hour

HDL, high-density lipoprotein

Hz, Hertz

ICC, Intra-Class Correlations

IPAQ, International Physical Activity Questionnaire

k, kappa

kg, kilograms

kg/m^2, kilograms per metre squared

kJ, kilojoules

LDL, Low Density Lipoprotein

LPL, lipoprotein lipase

LUMO, LUMOBack

METs, metabolic equivalents

min, minute

mm, millimetres

Mmol/L, millimoles per litre

mmHg, millimetre of mercury

MVPA, moderate-vigorous physical activity n, sample size

NHANES, National Health and Nutritional Examination Surveys

NHS, National Health Service

NICS, Northern Ireland Civil Service

OR, odds ratio

OSPAQ, Occupational Sitting and Physical Activity Questionnaire

p, p-value

PA, physical activity

r, correlation coefficient

RCT, Randomised Control Trial

mRNA, messenger ribonucleic acid

RR, risk ratio

SBRN, Sedentary Behaviour Research Network

SD, standard deviation

SE, standard error

SPSS, Statistical Package for Social Sciences

TASST, Taxonomy of Self-report Sedentary behaviour Tools

TV, Television

UK, United Kingdom

TRI, technology readiness index

US(A), United States (of America)

WHO, World Health Organisation

WSQ, Workforce Sitting Questionnaire

Contributions

Under the supervision of Dr Stacy Clemes and Dr Lauren Sherar, the work comprising this thesis was carried out by the author. *Study One:* The Stormont Study funded by a grant from the Doughty Fund of the Faculty of Occupational Medicine, Royal College of Physicians of Ireland, was designed and carried out by a team of researchers from Loughborough University and Northern Ireland in 2012 and 2014. With their permission, the author cleaned the raw survey data and conducted the secondary data analysis. *Study Two:* Dr Veronica Varela Mato led the study design, protocol, recruitment and data collection up to 3 months. The 12-month follow-up protocol and data collection was led by the author. The author processed and analysed all the measurement data from baseline, 3-month and 12-month follow-ups. *Study Three:* The author led all aspects of this study including the idea inception, design, protocol, recruitment, data collection, processing, analysis and formulation of the chapter.

Chapter 1: Introduction and literature review

Overview

This chapter introduces the topic of sedentary behaviour and evaluates the current research in this area. The introduction provides an overview of the area with the aims and objectives of the thesis. Subsequently, the literature review critically evaluates the current research concerning sedentary behaviour in working-aged adults and begins by defining sedentary behaviour, discussing measurement tools, overall prevalence rates and associated health consequences. Occupational sedentary behaviour is then focused on including previous workplace interventions aimed at reducing sedentary time in office workers. Finally, the rationale for this thesis is detailed in relation to gaps identified in the literature.

1.1 Introduction

The health benefits of physical activity are widely acknowledged[1] with physical inactivity being the fourth leading cause of global mortality[2] and costing the NHS an estimated £940 million per year.[3] Conversely, the concept of sedentary behaviour derived from the Latin word *sedere*, meaning *to sit*,[4] has emerged over the last twenty years which is distinct from physical inactivity.[5] Sedentary behaviours are predominantly sitting behaviours requiring very little energy expenditure and can occur in all domains including transportation, occupation, leisure-time, and domestic.[6] Whereas, physical inactivity is classified as not meeting the current physical activity guidelines.[7]

The potential harmful effects of sedentary behaviour on health was first recognised by Professor Jerry Morris and colleagues[8] in the 1950s after discovering that bus drivers and postal mail sorters with sedentary occupations had a higher incidence of cardiovascular events compared to active ticket collectors and postal workers. Research over the last twenty years has highlighted sedentary behaviour as an independent risk factor for numerous morbidities and premature mortality, independent of physical activity.[9–14] High amounts of sedentary time are associated with an increased risk of cardiovascular disease (CVD), obesity, metabolic syndrome, some forms of site-specific cancer, type 2 diabetes, depression, and all-cause, cardiovascular and cancer mortality.[9–33] Breaks in sedentary time where light physical activity or standing take place have been shown to have beneficial effects on metabolic risk markers when compared to prolonged sedentary time.[34–43] 'Sedentary physiology' is a proposed explanation for the link between sedentary behaviour and negative health outcomes where high amounts of sedentary time result in metabolic dysregulation.[44] This concept was originally developed by Hamilton and colleagues[44] ('inactivity physiology') who found that lipoprotein lipase was reduced in the skeletal muscles of immobilised rats and has since been observed in bed rest studies.

Worryingly, sedentary behaviours are increasingly prevalent with one study reporting a 46.6% increase in sedentary time between 1961 and 2005 in the UK. This is predominantly due to advances in technology over recent decades resulting in a shift towards sedentary work and commuting in particular.[45] In the UK, one study found that on average, adults are sedentary for over 10 hours on a workday and over 7.5 hours on a non-workday.[46] However, there are a limited number of large-scale studies in the UK exploring the prevalence of sedentary behaviours in different domains.[46] Additionally, various intrapersonal correlates have been identified for different domains of sedentary time including age, educational attainment and employment but the extent to which sedentary behaviour is associated with multiple other health behaviours including physical activity, fruit and vegetable consumption, alcohol consumption and smoking status is ambiguous.[46]

The workplace has been recognised as a potential domain where high amounts of sedentary time can occur especially due to the increase in desk-based occupations.[47] Office environments are generally sitting-conducive due to traditional fixed-height seated desks and meeting tables with a UK study finding that office workers spent 6.5 hours sedentary per day at work.[47] Therefore, office workers are generally ‘compulsory sitters’ who could be at high risk of the negative health outcomes associated with sedentary behaviour.[48] Furthermore, cross-sectional studies have found that high occupational sedentary time is associated with high non-occupational sedentary time.[49] New workplace recommendations have recognised the importance of reducing sedentary time at work and promote reductions in occupational sitting using adjustable-height desks allowing office workers to sit or stand whilst working.[50] The guidelines recommend initially aiming to accumulate 2 hours per day of standing and light activity at work eventually progressing to 4 hours per day. Similarly, various national physical activity guidelines have incorporated sedentary behaviour guidelines into recent updated policies but the recommendations are equivocal.[51] The current UK guidelines state that “all adults should minimise the amount of time spent being sedentary for extended periods” but does not explain what an extended period is classified as nor does it suggest what to do in order to minimise sedentary behaviour.[52]

Interventions have been developed to reduce occupational sedentary time[53] with initial research focused on promoting physical activity in the workplace, such as using pedometers and coaching, but overall these interventions have had no effect on reducing sedentary time.[54–60] Later studies replaced conventional seated-height workstations with activity permissive workstations including treadmill, cycle ergometer and sit-stand desks.[61,62] Sit-stand desk implementation has been found to reduce occupational sedentary behaviour in most intervention studies but without additional elements improvements were limited.[63–71] Recent studies focus on implementing multiple strategies to address deficits in the three essential aspects of behaviour change proposed by the behaviour change wheel framework.[72] This theory states that Capability, Opportunity and Motivation are essential to behaviour change and interventions that have adopted this framework have reported significant reductions in sedentary behaviour.[73] However, very few studies have explored the long-term effects of multicomponent interventions and research in the UK is limited. Furthermore, the majority of workplace intervention studies have measured occupational sedentary time only thus, the effect on non-working hours sedentary time is rarely explored. Wearable technology is increasingly prevalent in daily life but the feasibility of these devices as intervention tools to reduce sedentary time is unclear.[74,75] Few studies have explored this, and those that have produced limited improvements due to a lack of opportunity where office workers were not provided with sit-stand desks.[76]

1.1.1 Thesis aims

This thesis aimed to provide a significant contribution to the growing body of sedentary behaviour research in office workers by investigating the gaps in the literature summarised in this chapter. The research study described in Chapter 2 explored the prevalence of domain-specific sedentary behaviour in a large sample of office workers from the UK and links with multiple other health behaviours. Subsequently, the second study (Chapter 3) investigated the effectiveness of a pilot multicomponent workplace intervention to reduce sedentary time over the short (3 months) and long-term (12 months). Finally, Chapter 4 describes a study that explored the feasibility of a self-monitoring and prompting device to reduce sedentary time in a sample of office workers who have sit-stand desks.

1.1.2 Objectives

Study One

1. To assess the prevalence of sedentary behaviour in a large sample from the UK and highlight important domains of sedentary behaviour.
2. To explore the associations between domain-specific sedentary time and multiple other health behaviours.
3. To examine if any associations between sedentary time and other health behaviours track over time.

Study Two

4. To investigate whether a multicomponent, workplace intervention adopting individual and environmental strategies was an effective way to reduce sedentary time in office workers over the short-term and long-term.

5. To investigate whether there was any effect of the multicomponent intervention on health markers and physical activity.

Study Three

6. To assess the feasibility of a sedentary behaviour self-monitoring and prompting device (LUMO) to reduce sedentary time in a sample of office workers who already have sit-stand desks.

7. To gather preliminary data on the impact of the above intervention on sedentary time, physical activity, desk use, health- and work-related outcomes.

The remainder of this chapter provides a critical overview of the literature surrounding sedentary behaviour in working aged-adults and highlights some gaps in the literature that this thesis aimed to address.

1.2 Literature Review

1.2.1 Definition of sedentary behaviour

Over the past 15 years, there has been an increased interest in sedentary behaviour as an independent risk factor for multiple deleterious health outcomes.[9] Due to the influx of research studies in this area, the definition of sedentary behaviour has evolved over time. Initially, definitions were based purely on the energy expenditure (EE) of an activity generally measured using metabolic equivalents (METs).[77] One MET is defined as, 'the amount of oxygen consumed while sitting at rest and is equal to 3.5 ml Oxygen per kg body weight x min.'[78] Thus, sedentary behaviours were categorised as activities with a low EE,[79] a MET value between 1 and 1.5,[80] ≤1.5[44] or less than 2.[81] Other definitions categorised sedentary behaviour by the activity undertaken including 'time spent sitting or lying'[82] and 'non-upright activities'.[83] However, these definitions could be interpreted to include sleep and/or light physical activities which are known to be beneficial for health.[84] Therefore, subsequent definitions combined the use of EE and activity type.[5,6,9,85–87]

The results of a recent project by the Sedentary Behaviour Research Network (SBRN) to standardise the definitions used in the area produced a conceptual model illustrating movement-based terminology across 24-hours (Figure 1.1).[77] One of the main reasons for standardisation of terminology was due to the use of the term 'sedentary behaviour' to describe the absence of moderate-vigorous physical activity (MVPA) in exercise research.[87] Thus, the definition of sedentary behaviour was concluded as, "any waking behaviour characterised by an energy expenditure ≤1.5 metabolic equivalents (METs) while in a sitting or reclining posture."[87] Additionally, sedentary time was defined as 'the time spent for any duration (e.g. minutes per day) in any context (e.g. at school or work) in sedentary behaviours' and a sedentary bout is 'a period of uninterrupted sedentary time.'[88] Sitting was defined as, 'a position in which one's weight is supported by one's buttocks rather than one's feet, and in which one's back is upright.'[89] Whereas, stationary behaviour 'refers to any waking behaviour done while lying, reclining, sitting or standing with no ambulation, irrespective of energy expenditure.[77] Finally, physical inactivity was defined as 'an insufficient physical activity level to meet present physical activity recommendations.'[90] Thus, adults who are not achieving 150 minutes of MVPA or 75 minutes of vigorous-intensity physical activity or an equivalent combination of moderate- and vigorous-intensity activity per week are classified as physically inactive.[7] These definitions put forward by the SBRN are used throughout this thesis.

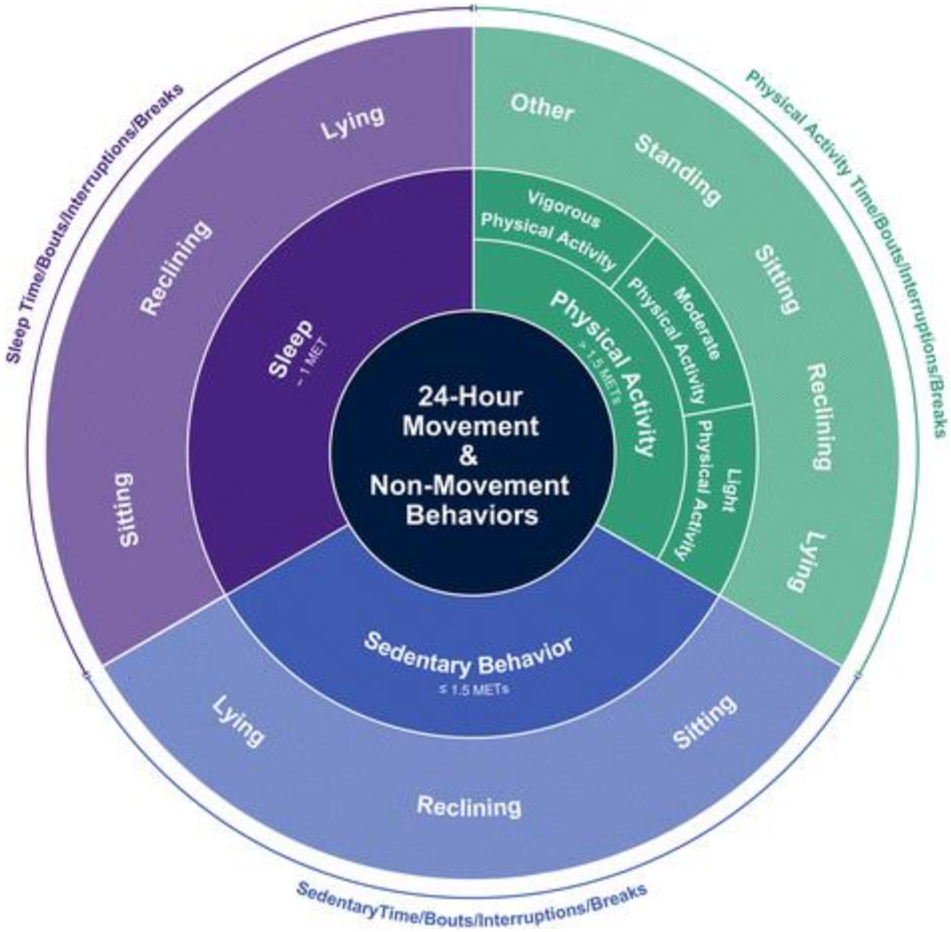


Figure 1.1 The 'conceptual model of movement-based terminology arranged around a 24-h period' taken from 'Sedentary Behavior Research Network (SBRN) – Terminology Consensus Project process and outcome' Mark S. Tremblay et al. International Journal of Behavioral Nutrition and Physical Activity 2017 14:75. © The Authors. 2017. 77

1.2.2 Measurement of sedentary behaviour

Sedentary behaviour can be measured in numerous ways and varies widely across the literature. The adoption of a measure depends greatly on the study design and population. Measures of sedentary behaviour can be both subjective and objective with both methods having advantages and limitations.

Objective measures of sedentary behaviour

Due to the classification of sedentary behaviours as activities ≤1.5 METS, the use of gold-standard EE measures typical of physical activity research could be adopted (e.g. calorimetry and doubly labelled water).[91] However, these methods cannot be used in free-living environments and/or only measure total EE rather than specific behaviours. Thus, in order to measure sedentary time in free-living environments monitors and sensors can be used.

Accelerometers

Accelerometers are devices that measure body movement via piezoelectric sensors that detect accelerations in one to three orthogonal planes (anteroposterior, mediolateral and vertical).[92] The frequency and amplitude of these accelerations is measured in the form of movement 'counts' which can be used to determine the total volume and breaks in stationary time.[93] The ActiGraph GT3X monitor (ActiGraph LLC, Pensacola, FL, USA) has been shown to be a valid measure of MVPA[94] and is widely used in sedentary behaviour research and is small (38 x 37 x 18 mm) and light (28g).[95] The GT3X is a triaxial accelerometer that is traditionally hip-mounted thus worn on a belt or clipped onto clothing. Stationary time is generally defined as <100 counts per minute (cpm) and can be determined at the point of initialisation via the proprietary software (ActiLife).[96] However, the <100 cpm cut-off point was not empirically derived and when compared to direct observation, was found to underestimate sedentary time by 4.9%.[95] This is potentially due to the ActiGraph measuring stationary time thus the posture of the wearer cannot be determined and some standing activities have been found to be below 100 cpm.[97] An inclinometer function was added to the ActiGraph monitors and behaviour can be classified as sitting, standing, lying and device removed.[93] However, a study by Carr et al.[98] found that the monitor only accurately identified anatomical positioning during 70% of all activities under controlled conditions. Conversely, Edwardson and colleagues[99] found that deployment of the thigh-mounted ActiGraph was more accurate than the waist-worn ActiGraph at determining sitting, lying and upright time.

An additional limitation of the ActiGraph monitors are that they are not water-proof so cannot be worn during water-based activities. This can result in non-wear time and a less valid measurement of sedentary time.[100] The GENEActiv (Activinsights Ltd., Cambridgeshire, UK) is a waterproof, triaxial accelerometer worn on the wrist that is small (36 x 30 x 12 mm) and light (16g).[101] Using the 'Sedentary Sphere Method' which calculates the most likely posture for each epoch from the wrist worn-device, sedentary behaviour can be calculated. However, when this method was tested by Rowlands and colleagues,[102] sitting time was underestimated by the GENEActiv by 30 minutes over the 7 hour controlled measurement period. Due to the inaccuracy of accelerometers to detect sedentary time, monitors focused on identifying posture were developed.

Posture monitors

The activPAL3 (PAL Technologies Ltd, Glasgow, UK) monitor is small (55 x 35 x 7 mm) and light (15g).[103] It is attached to the midline on the anterior aspect of the thigh directly on the skin by an adhesive and measures thigh inclination.[104] From the accelerometer signal, posture is inferred as sitting/lying, standing or walking from the position of the thigh using algorithms (Intelligent Activity Classification) in the proprietary software (activPAL Professional Research).[93] The activPAL is considered the gold standard for measuring sedentary time in the field[105] and had a mean percentage difference of 0.19% (limits of agreement -0.68% to 1.06%) for sedentary time compared to direct observation.[104] Additionally, when the validity of the activPAL for detecting reductions in sedentary time was investigated, the monitor was highly correlated with direct observation (r^2=0.94).[95]

The activPAL3 can be waterproofed using a nitrile sleeve allowing for continuous measurement of sedentary time. It can be used to measure time spent sitting/lying, standing and stepping with additional information on the number of sit-stand transitions. Additionally, the recent development of the Processing PAL application allows for additional outcomes to be measured including: sleep, non-wear, number of sitting, standing and stepping bouts, time spent in sitting, standing and stepping bouts and time spent light and MVPA stepping.[106] This application applies an algorithm to activPAL 'event' files obtained from the proprietary software and can be checked visually by creating heatmaps.[107] Therefore, the classification of non-wear times is based on the activity data and can be checked against participant diaries. This automated method has shown a high level of agreement with diary reported wear times during waking hours (k=0.94)[106] and reduces the processing time dramatically compared to manual methods.

One of the limitations of the activPAL3 device is that studies have reported skin reactions to the adhesive used to attach the monitor.[108] The SitFIT was developed by PAL Technologies which is underpinned by the same concept as the activPAL monitor but is worn in the front trouser pocket.[109] The small, triaxial accelerometer uses static and dynamic accelerations in the three orthogonal axes to calculate wear (and non-wear) time, postural allocation (upright or sedentary), transportation, and stepping. This device was developed to enable long-term wear during waking hours and improve device accessibility as the SitFIT provides real-time visual feedback. Feedback on stepping and sedentary/upright behaviours are displayed on the device and haptic feedback of time spent sitting through a vibrotactile actuator can be customised. The SitFIT links to smart devices through Bluetooth and the activity data can be processed using the proprietary software (PAL Technologies Ltd.) The potential for movement and changes in orientation which could occur in the pocket was addressed using an algorithm. The SitFIT has been shown to be a valid measure of sedentary time (r=0.84) and step counts (r=0.98) compared to the activPAL in a sample of men (n=21, aged 30-65 years) under free-living conditions.[109] However, the main limitation of this device is that it is only feasible for adults who usually wear trousers with front pockets.

The VitaBit (VitaBit Software International B.V., Eindhoven, The Netherlands) is a cuboid tri-axial accelerometer (3.9 x 1.4 x 0.85 cm, 4.8g) with a battery life of >30 days.[110] The device is thigh-worn and attached via a magnetic clip to clothing or worn in the pocket. VitaBit detects accelerations between an amplitude of -16 to 16 g with a sampling rate of 33 Hz and the output data rate is 30 seconds. The proprietary algorithm classifies accelerations as sitting, standing or walking and stores ≥30 days of data which is synchronised via Bluetooth to a smartphone application. Additionally, VitaBit has the function to prompt the user via e-mails or push messages on the associated smart phone application. Compared to the thigh-worn ActiGraph, VitaBit showed sensitivity rates of 81.5%, 68.7% and 66.0% for sitting, standing and walking respectively in free-living conditions (n=14). Furthermore, specificity rates of 84.0%, 83.9% and 93.5% were found for sitting, standing and walking. The feasibility of this device as an intervention tools is currently unknown as it is yet to be researched.

The LUMOback (LUMO) (Lumo Bodytech Inc., Mountain View, CA, USA) is a consumer posture monitor (41.5 x 100 x 8 mm, 25g) that is attached to a belt in a similar way to the ActiGraph. The device measures the angle of the pelvis with a resolution of 1° and consists of a microcontroller, accelerometer, flash memory, Bluetooth chip and haptic motor.[111] The device can be calibrated to the individual user and detects sitting, standing, lying down, walking, running and driving. Real-time feedback of behaviour is available via low energy Bluetooth to an Apple smart device with the LUMO application installed. A prompting feature can be selected which notifies the user via a message on their smart device when they have been sedentary for a period of time (user-defined). Another prompt in the form of a vibration through the device can be selected to notify the wearer that their posture is not optimal. Sanders and colleagues[112] repurposed the LUMO to vibrate after a defined period of sedentary time through a change to the firmware. The device has been shown to be a valid measure of sedentary time compared to the activPAL over a 24-hour period (mean error = 18±52.1 minutes).[113] However, there is no download feature on the device or the application, so data can only be obtained by contacting the manufacturer and the LUMOBack has been discontinued by the manufacturer.

Pressure sensors

Pressure sensors placed on seats have been used to measure sitting time in the workplace. The ‘sitting pad’ is a cushion containing a medical grade pressure sensor (43 x 32 x 2 cm) which detects transitions of greater than 3 seconds to and from the seat in addition to a microcontroller (11.5 x 5 x 3 cm) that records the time of each transition.[114] The data are downloaded using proprietary software producing sitting time and number of transitions in a Microsoft Excel spreadsheet. The sitting pad showed excellent levels of agreement with camera measured sitting (r=0.999) in free-living conditions.[114] The DARMA PRO (Darma Inc., Mountain View, CA) is similar in the fact that it measures sitting habits but has additional features. The consumer sensor also monitors posture, stress level and provides feedback via a smart device application and vibration through the cushion.[115] However, this sensor has not been validated as a measure of sedentary time. Additionally, pressure sensors can only measure sitting time thus cannot distinguish between active (>1.5 METs) and passive sitting (≤1.5 METs) therefore limiting the validity of the devices to measure sedentary time.[77] On the other hand, these devices do not have to be worn so reduce the burden on the participant but sitting time can only be measured within the environment that the sensor is placed.

Strengths and limitations of objective measures

Objective measures of sedentary behaviour have high validity and reliability. Additionally, objective measures are not subject to biases and allow the collection of intermittent and incidental behaviours down to 1 second in duration.[116] This includes the measurement of how sedentary time is accumulated i.e. in short or prolonged bouts. Furthermore, wearable sensors have relatively low participant burden and can be used in a wide range of populations including children.[93] Conversely, some studies have reported skin reactions[108] and the devices can place a moderate burden on the researcher. This is due to the time needed to initialise, download and process the data. Thus, the use of objective measures is often unfeasible for large-scale epidemiological studies with the addition of cost per device. Additionally, there is evidence that wearable monitors are subject to reactivity bias resulting in inaccurate measures.[117] Furthermore, the context of sedentary time cannot be assessed via the devices. The addition of participant diaries can provide some context however, this places additional burden on the participant and diaries can be subject to recall bias.

<u>Subjective measures</u>

Self-report measures of sedentary behaviour can be self-administered, completed in-person or over the telephone. Questionnaires are the most common subjective measure and often used in large samples.[118] Other measures including diaries, are used less frequently but are also considered in this section.

Questionnaires

Early studies measured TV viewing time using questionnaires as a proxy measure for sedentary behaviour. A review by Clark and colleagues[118] found that test-retest reliabilities of measures of TV viewing were predominantly acceptable (r=0.32 to 0.93) but validity studies show large differences in correlations with referent measures (r= -0.19 to 0.80). Other proxy measures for sedentary behaviour include leisure-time sitting, media use (screen-time) with very few reporting the reliability or validity of the measures.[93] Using a proxy measure tends to under-report sedentary behaviour due to the measurement of only one sedentary behaviour domain.[119]

Other questionnaires have measured total sedentary behaviour either via single-item questions or multiple questions. The International Physical Activity Questionnaire (IPAQ) asks participants to report the amount of time usually spent sitting during the last 7 days on a weekday and a weekend day (long-version only).[120] When the IPAQ was compared to accelerometery, the criterion validity was low to moderate (long form r=0.24, short form r=0.24) but the test-retest reliability was high for the long (r=0.82) and short (r=0.81) versions.[121] In order to measure the context of daily sedentary time, the Domain Specific Sitting Time Questionnaire (DSSTQ) can be used.[122] The DSSTQ asks participants how long they spend sitting on a week day and weekend day whilst travelling, at work, watching TV, using a computer at home and in leisure time activities not including TV. When total sitting time was calculated from the DSSTQ, it did not significantly differ from accelerometer determined stationary time on a week day (mean difference= -14±28 minutes/day) or weekend day (mean difference= -4±45 minutes/day). However the limits of agreement were large and it was recommended that this tool is sufficient for providing population-level estimates of sedentary time, however it would likely not be suitable for detecting changes in sitting in intervention research.[123] The Workforce sitting questionnaire (WSQ) is an adapted version of the DSSTQ which measured the last 7 days and included a measure of the number of days spent at work.[124] Total sitting time form the WSQ showed average reliability (ICC=0.46-0.90) and sufficient criterion validity compared to accelerometer stationary time (r=0.22-0.46 in women, r=0.18-0.29 in men). Sitting time on a workday was also valid (r=0.45) and reliable (r=0.63).

Other questionnaires have been used to measure the work domain of sedentary behaviour as a large amount of sedentary time can be accumulated within the workplace. One study asked participants to estimate the total amount of sitting time during the last week whilst at work or working from home and how many breaks from sitting during 1 hour of sitting at work are normally taken.[125] The results were significantly correlated to accelerometer-determined stationary time (r=0.39) with the questionnaire over reporting sitting time on average by 0.45 hours/day. Additionally, self-reported breaks were significantly correlated (r=0.26) to accelerometery but it was concluded that further development was needed. The Occupational Sitting and Physical Activity Questionnaire (OSPAQ) developed by Chau and colleagues,[126] asks participants to report the amount of time spent sitting, standing, walking and doing heavy labour at work in the last 7 days. OSPAQ-determined sitting time was significantly correlated to ActiGraph-determined sedentary time (r=0.65) and a high ICC was found (0.89, 95% CI: 0.83-0.92) demonstrating high test-retest reliability and moderate validity. In a recent systematic comparative validation study by Chastin and colleagues,[127] 18 self-report measures of sedentary time based on the Taxonomy of Self-report Sedentary behaviour Tools (TASST) framework were compared to activPAL sedentary time. The study found that self-report measures showed poor accuracy compared to objective measures with most tools under-reporting sedentary time.

Diaries

One of the limitations of questionnaires is the influence of recall bias particularly due to the sporadic nature of sedentary behaviour.[93] Single-item measures of sedentary time have been used in daily diaries which ask participants to report how long they had spent sitting on that day. However, these have been found to significantly underestimate sedentary time compared to accelerometer stationary time on a weekday (-173±18 minutes/day) and weekend day (-219±23 minutes/day).[123] Ecological momentary assessment (EMA) methods record participants' current behaviours in real time and in the natural environment.[128] EMA has been utilised in samples of adolescents via paper diaries and adults via mobile phone surveys.[129] Biddle and colleagues[130] piloted EMA diaries in adolescents and found that ICC with minute-by-minute diaries were high suggesting 15-minute momentary time samples provided accurate estimates of behaviour.

Strengths and limitations of subjective measures

The main strengths of self-report measures are that they are cost-effective and feasible in large samples.[131] Questionnaires have relatively low participant and researcher burden and can measure the context of sedentary time.[132] Additionally, self-report measures generally show high test-retest reliability facilitating comparisons over time and between populations.[133] Conversely, subjective measures consistently demonstrate poor validity and are vulnerable to social desirability and recall biases.[127] Furthermore, sedentary behaviours are sporadic and often concurrent thus increasing the recall difficulty.[93] However, the use of a self-report measure alongside an objective measure where possible can strengthen the measurement of sedentary behaviour.

For example EMA via mobile phones have been used to add context to objective measures of sedentary time in adults successfully over a short-period of time (4 days).[134]

1.2.3 Sedentary behaviour prevalence

The prevalence of sedentary behaviour has increased dramatically over the last thirty years due to advances in technology including mechanisation and motorisation.[135] A study by Borodulin et al.[135] showed that the prevalence of Finnish men employed in physically demanding work decreased from 60% in 1972 to 38% in 2002 and from 47% to 25% in women. Additionally, there was a significant decrease from 30% of men undertaking thirty minutes of active commuting daily in 1972 to 10% in 2002. A decrease was also observed in women from 34% to 22% but this was not significant. Conversely, the prevalence of leisure-time physical activity increased by 11% in men and 27% in women over the same time period. This study shows that there has been a transition from physically active work and commuting to more sedentary practises over the last thirty years.

The National Health and Nutrition Examination Survey (NHANES) in the United States found that participants spent 54.9% of their monitored time stationary (7.7 hours/day) in 2003/2004 using accelerometery.[136] Additionally, females spent more time stationary compared to men before age 30 but this was reversed after age 60 with adults aged ≥60 years spending the most time stationary. In Australia, results from the Australian Diabetes, Obesity and Lifestyle Study (AusDiab) found that adults spent 57% of accelerometer time stationary.[137] A Canadian survey in 2007-2009 found that adults were stationary for 9.5 hours per day (69% of waking hours) when measured via accelerometery.[138] As mentioned previously, accelerometery is a measure of stationary time thus does not accurately distinguish between sitting and standing and could have resulted in over-reported values for sedentary time in these studies. Thus, in a paper analysing data from the Maastricht study, activPAL sedentary time was found to account for 60.1% of total daily waking time.[139] However, only adults aged 40-75 years were included in this sample.

Studies utilising self-report measures of sedentary time have reported lower prevalence rates. In a 20-country comparison, median reported sitting time was 300 minutes/day when measured using the IPAQ.[45] The lowest reported sitting time was found in Portugal, Brazil and Columbia whereas the highest sitting times were reported by adults in Taiwan, Norway, Hong Kong, Saudi Arabia and Japan. In another study comparing IPAQ-derived sitting time between countries, a median of 360 minutes/day was reported in samples of adults from the UK, Germany, Italy, Switzerland and Austria.[24] Additionally, adults from the USA sample reported significantly higher median sitting times (420 minutes/day) and lower sitting times were found in adults from Spain, France and Portugal (300 minutes/day). Similar results were found when Eurobarometer data was investigated with a mean sitting time of 309 minutes/day in a sample of 27,637 adults from 32 countries with the IPAQ.[140] The study reported a broad geographical pattern where lower sitting times were generally reported by southern European countries whereas higher amounts were found in northern countries and this pattern was confirmed 8 years later in the Special Eurobarometer study.[141]

Compared to the accelerometery stationary behaviour prevalence rates presented, the IPAQ measured daily sitting time is considerably less. In a UK study utilising data from the DSSTQ, a median of 680±290 minutes per day were spent sitting with males reporting significantly higher sitting times compared to females.[47] An Australian study utilising the DSSTQ in a sample of desk-based workers found a smaller median amount of sitting time was reported (540 minutes/day) and that insufficiently active and younger adults (18-29 years) reported higher daily sitting times.[142] Another UK study found that higher sitting times were reported on workdays (625±168 minutes/day) compared to non-workdays (469±210 minutes/day) in a large sample of office workers.[46]

As demonstrated here and concluded by a 2016 review of prevalence studies, reported sedentary times vary widely between studies thus, population levels of sedentary behaviour are unclear.[143] This is predominantly due to the use of various measures of sedentary behaviour. Very limited evidence is available for the UK prevalence rates specifically and which domain the largest proportion of sedentary time takes place in. Additionally the trend in sedentary behaviour is unclear with some evidence of a decrease in prolonged sitting time measured between 2002 and 2013 via the Eurobarometer.[144] Conversely, Ng and colleagues[145] found that between 1961 and 2005 UK sedentary behaviour had increased by 46.6% and forecast that by 2030, over 51 hours per week could be spent sedentary during leisure time.

1.2.4 Sedentary behaviour and health

The health consequences associated with sedentary behaviour were first explored by Prof Jerry Morris and colleagues[146] in the 1950s. This pioneering research found that London bus drivers and mail sorters (seated workers) had a higher incidence of cardiovascular events compared to ticket collectors and postal workers.[8] However, the conclusions drawn from this study related to physical inactivity and it was not until the year 2000 that sedentary behaviour was considered as a distinct behaviour with health implications.[80] Since this time, numerous research has been undertaken to help understand the link between sedentary behaviour and health.

Observational studies

Research has shown that sedentary behaviour independent of physical activity, is associated with an increased risk of cardiovascular disease (CVD),[11,12,26,28] obesity,[23–25] metabolic syndrome,[22,29] some forms of site-specific cancer,[11,13,21] type 2 diabetes,[10–12,16,20] depression,[14,19] and all-cause,[9–11,15–18,30,32,33] cardiovascular [9–12,30–33] and cancer mortality.[11–13,27,30,33] A review of longitudinal studies was conducted by Thorp et al.[9] who found a convincing level of evidence for a relationship between sedentary behaviour and all-cause and CVD-related mortality risk in men and women. Conversely, limited evidence was found for an association between sedentary behaviour and diabetes, cancer incidence, CVD, mental disorders, systematic gallstone disease, obesity, markers of cardiometabolic health and metabolic conditions. This was due to mixed findings and a lack of high-quality prospective studies. In contrast to this review, Proper and colleagues[16] concluded that there was moderate evidence for a positive relationship between type 2 diabetes and sitting time. Strong evidence was found for the relationship between sitting time and all-cause and CVD mortality but no evidence for mortality from cancer. Additionally, insufficient evidence was found for a link between sedentary behaviour and body weight-related measures, CVD risk and endometrial cancer with more high-quality research needed to clarify causal relationships.

Wilmot et al.[12] conducted a meta-analysis and found that participants with the greatest sedentary time were associated with an increased risk of diabetes (RR 2.12, 95% CI: 1.61, 2.78), CVD events (RR 2.47, 95% CI: 1.44, 4.24), CVD mortality (HR 1.90, 95% CI: 1.36, 2.66) and all-cause mortality (HR 1.49, 95% CI: 1.14, 2.03) compared to the lowest. Biswas and colleagues[11] confirmed these results and found that sedentary time was also associated with an increased risk of cancer mortality and cancer incidence (HR 1.130, 95% CI: 1.053, 1.213). The association between sedentary behaviour and cancer has been reported in a further systematic review which showed evidence of an increased risk of colorectal, endometrial, ovarian and prostate cancer associated with high volumes of sedentary time.[13] Furthermore, a meta-analysis by Zhai and colleagues[14] found that high sedentary behaviour was associated with an increased risk of depression (RR 1.25, 95% CI: 1.16, 1.35). Patterson and colleagues[10] stated a threshold of 6-8 hours/day of total sedentary and 3-4 hours per day of TV viewing above which the risk of all-cause and CVD mortality increased. Whereas, Pandey et al.[28] found that CVD risk was not increased until a threshold of over 10 hours of sedentary time.

Occupational sedentary behaviour contributes significantly to total sedentary time and the associated health outcomes but has also been found to have specific health consequences as an individual domain. Hu et al.[20] found that with each 2 hours per day increase in occupational sitting, there was an associated 5% increased risk of obesity and 7% increased risk of diabetes in a sample of 50,000 nurses. This was supported by a later study which also observed an association between occupational sitting and having a Body Mass Index (BMI) of ≥25 kg/m^2 in men only.[147] A recent study of over 10,000 British workers found that sitting occupations had a higher associated risk of all-cause and cancer mortality compared to standing/walking occupations, in women only.[148] Whereas, a review in 2010 found that there is only limited evidence for a relationship between occupational sitting and health risks which was likely, partly due to heterogeneity of study measures, designs and findings.[48] There was some evidence that occupational sitting time was associated with obesity and cancer. However, this was purely cross-sectional, and no prospective studies had confirmed the relationships over time. There was some prospective evidence for an associated increased risk of diabetes and mortality with occupational sedentary time. Further prospective research is needed to investigate the links between occupational sedentary time and negative health outcomes using objective measures of sedentary time.

The relationship between sedentary behaviour and cardiometabolic risk markers have been explored by Dunstan and colleagues[22] using data from the AusDiab study 2004-2005. Sitting time was detrimentally associated with waist circumference, BMI, systolic blood pressure, fasting triglycerides, HDL cholesterol, 2-h post load plasma glucose and fasting insulin. Conversely, no association was found between sitting time and fasting plasma glucose and diastolic blood pressure. The negative consequences of prolonged sitting were also found in the 2004 to 2005 AusDiab Study where uninterrupted sedentary time was deleteriously associated with BMI, waist circumference, triglycerides and 2-h plasma glucose compared to breaks in sedentary time, independent of MVPA time and total sedentary time.[149] A similar study utilising data from the 2003/04 and 2005/06 NHANES, found that accelerometer-determined stationary time was detrimentally associated with waist circumference, HDL cholesterol, C-reactive protein, triglycerides, insulin, β-cell function and insulin sensitivity.[150] Furthermore, breaks in sedentary time were beneficially associated with waist circumference and C-reactive protein.

A review by Brocklebank et al.[151] concluded that accelerometer-determined stationary time was unfavourably associated with insulin sensitivity, fasting insulin, insulin resistance and triglycerides. It was also found that breaks in stationary time were favourably associated with triglycerides. Edwardson and colleagues[152] performed isotemporal substitution regression modelling and found that reallocation of activPAL prolonged sedentary time to short sedentary time, standing or stepping was associated with improved 2-hour glucose, fasting and 2-hour insulin and insulin sensitivity. Interestingly, in this sample of adults at high risk of impaired glucose regulation or type 2 diabetes (n=435), reallocation of short sedentary time with stepping was also associated with improved glucose and insulin outcomes over the 7-day measurement period.

Therefore, observational studies have shown that sedentary time is associated with negative health outcomes, but the general findings are mixed. Caution is needed when interpreting these results due to the problems with epidemiological data including the possibility of reverse causality where sedentary behaviour could be caused by health outcomes or vice versa. Additionally, the use of multiple measures of sedentary time including self-report and accelerometery have validity issues in addition to limiting the generalisability of the results. Experimental studies address these issues by prescribing routines of activity and closely monitoring the responses.

Experimental studies

Observational studies have found that sedentary behaviour is negatively associated with a number of health outcomes independent of MVPA and that prolonged sedentary time may be the cause. Therefore, breaking-up prolonged bouts of sedentary time could improve health, and this has been explored in experimental studies. Dunstan et al.[36] explored the effects of breaks in sedentary time every 20 minutes in overweight and obese adults aged 45-65 years after 2 hours of prolonged sitting. A 2-minute break of light- or moderate-intensity walking resulted in a lower area under the curve for glucose and insulin after a standardised test drink was consumed. Additionally, significant beneficial effects were observed in systolic and diastolic blood pressure with light and moderate-intensity activity breaks compared to uninterrupted sedentary time.[37] Blankenship and colleagues[153] compared the effects of frequent long and short sedentary time breaks every 20 minutes at work with prolonged sedentary time but walking for 30 minutes at lunch time. The obese adults in this study had no difference in glucose and insulin responses after a meal tolerance test between any conditions but glycaemic variability was lower in the frequent long sedentary breaks condition compared to the other two conditions. The long sedentary breaks lasted for 7.9 minutes on average compared to 3.8 minutes in the short breaks condition and the frequent long breaks condition included twice as much standing as the other conditions but there was no difference in EE.

Conversely, Bailey and Locke[41] found no difference between uninterrupted sedentary time and standing breaks of 2 minutes in duration every 20 minutes for the glucose area under the curve, blood pressure area under the curve or lipid measures (total cholesterol, HDL cholesterol and triglycerides) in 10 non-obese adults. However, this study found that breaks of light-intensity walking for 2 minutes every 20 minutes resulted in a lower glucose area under the curve (18.5 mmol/L/5-h) compared to the other two conditions. In a study by the same authors,[154] 2-minutes of light or moderate intensity walking every 20 minutes as breaks in sedentary time, had no effect on appetite and gut hormone concentrations after a test meal over 5 hours compared to uninterrupted sitting. However, moderate-intensity breaks significantly reduced glucose area under the curve compared to the other two conditions and both breaks in sitting time showed lower relative energy intake compared to uninterrupted sedentary time. However, this was a younger sample (mean age 26.6±8.5 years) of healthy adults (mean body fat 24.4±8.2%).

Swartz and colleagues[155] investigated different durations of walking interruptions after 30 minute bouts of sedentary time. Significantly more energy was expended when sedentary time was broken-up with walking with a net increase of 3.0, 7.4 and 16.5 kilocalories during 1, 2 and 5 minutes of walking respectively compared to prolonged sedentary time. However, this study only included adults aged 18-39 years old. Similarly, in a sample of normoglycemic overweight/obese men (mean age 33±13 years), daily EE was higher after standing for 15 minutes every 30 minutes and after standing for 1.5 minutes 10 times every 30 minutes compared to sedentary time.[156] However, no significant differences were observed between conditions for postprandial glucose, insulin or triglyceride responses. Conversely, Thorp and colleagues[40] found significant beneficial effects for postprandial glucose when overweight and obese office workers alternated between sitting and standing using a sit-stand desk every 30 minutes compared to prolonged sitting. However, no significant effect was observed for serum insulin or plasma triglycerides. Peddie et al.[43] found that regular walking breaks of 1 minute 40 seconds every 30 minutes (regular activity breaks condition) were more effective at decreasing postprandial glycemia and insulinemia than 30 minutes of walking (physical activity condition) in a sample of healthy, normal weight adults (n=70). Conversely, the physical activity condition significantly reduced plasma triglyceride concentrations compared to the regular activity breaks and uninterrupted sedentary time conditions.

In type 2 diabetic samples, 3 minute breaks in sitting every 30 minutes consisting of walking or resistance exercises showed significantly attenuated glucose, insulin and C-peptide after a standardised meal compared to uninterrupted sedentary time.[38] Additionally, significantly attenuated triglycerides post-meal were observed in the resistance exercise break condition compared to uninterrupted sedentary time. The benefits of breaking up sedentary time continued after the laboratory conditions ended with reduced 22-hour glucose and nocturnal glucose concentrations for both break conditions compared to uninterrupted sedentary time.[157] These results are supported by Duvivier and colleagues[158] who found that replacing sitting with intermittent standing equal to 2.5 hours/day for 4 days, reduced mean 24-hour glucose levels, glucose excursions and duration of hyperglycaemia compared to uninterrupted sedentary time (14-hours/day). Furthermore, the magnitude of improvement was more pronounced for the intermittent standing condition compared to the exercise condition where 1.1 hour of MVPA was undertaken.

Therefore, more consistent benefits have been observed in type 2 diabetic samples with a 2016 review concluding that there is consistent experimental evidence that breaking up prolonged sedentary time with light ambulation is effective for improving glucose regulation.[35] Furthermore, there is encouraging evidence that standing instead of sitting improves glucose regulation particularly when undertaken in an office environment in overweight and obese adults. However, healthy adults may need higher doses of activity during sedentary breaks to observe benefits. A review by Benatti and colleagues[34] concluded that prospective experimental studies show that breaking-up sedentary time with light-intensity physical activity and standing may induce acute favourable changes in the postprandial metabolic parameters in physically inactive and type 2 diabetic participants. However, higher intensities or volumes of physical activity are needed to elicit positive results on young, active adults. These conclusions are generally based on laboratory conditions with strict routines so the real-world generalisability is limited. Interventions are needed in free-living conditions to confirm the association between prolonged sedentary time and negative health consequences.

<u>Sedentary behaviour physiology</u>

In 2004, Hamilton and colleagues, proposed the concept of ‘inactivity physiology’ which states that too much sedentary time is different to a lack of exercise and has its own unique metabolic consequences.[159] In a series of studies, a dramatic reduction in lipoprotein lipase (LPL) was observed during sedentary time in the blood vessels of the skeletal muscle in the legs of rats.[160] LPL is a protein that has an important role in controlling HDL cholesterol, plasma triglyceride catabolism and other markers of metabolic risk.[161] Thus, due to the reduction in LPL, there is a rapid decrease in HDL cholesterol observed[162] which transports excess cholesterol from the peripheral tissues to the liver for storage or excretion preventing circulatory problems that can lead to arteriosclerosis and chronic disease.[161] Bey and Hamilton[163] found that it took 4-hours of light-intensity walking and normal cage activity for LPL in the skeletal muscles to return to baseline levels and concluded that the observed changes appeared to be due to transcriptional changes rather than LPL messenger (m)RNA levels. However, these results were observed by suspending rats by their tail and cannot be generalised to humans.

Tremblay and colleagues[44] reviewed the concept of 'inactivity physiology' and introduced the term 'sedentary physiology' to fully distinguish the field from exercise physiology. Especially as the mechanisms linking sedentary behaviour and LPL activity are apparently distinct from those linking physical activity to LPL activity.[44] For example, LPL activity changes due to sedentary behaviour are generally found in the oxidative muscle fibres whereas LPL responses to physical activity are found in glycolytic fibres with the effects of sedentary behaviour 4-fold larger than the benefits of vigorous exercise in rat studies.[160,163,164] Furthermore, the effects of sedentary behaviour on LPL activities appears to be through transcriptional mechanisms as opposed to the increase in LPL mRNA levels observed as a result of exercise. Research from participants in bed rest have shown that 5 days of 23.5 hours/day spent sedentary result in significant increases in insulin response (67% increase), total cholesterol, plasma triglycerides and glucose without a change in body weight.[165] Similar findings were observed in participants after 20 days bed rest with significant increases in plasma triglycerides and reduced HDL cholesterol levels.[166] Additionally, an 18% decrease in LPL activity was observed in young adults after 11 days of bed rest with significant reductions in HDL cholesterol and increases in plasma triglycerides.[166]

Sedentary behaviour has also been reported to influence carbohydrate metabolism with rapid reductions in muscle GLUT-4 content (muscle glucose transporter), insulin stimulated glucose uptake and glucose transporter protein concentration due to denervation of skeletal muscles.[167,168] Furthermore, reductions in bone mineral density have been observed with high sedentary behaviour from long-term bed rest studies.[169] The mechanism behind this has been proposed as a rapid increase in bone reabsorption that is not matched by bone formation resulting in reduced bone mass.[44] Sedentary behaviour may also effect vascular function with 5 days of bed rest showing reductions in peripheral vascular function, increased blood pressure and reduced brachial artery diameter.[165]

The biological pathways in which sedentary behaviour influences cancer risk were reviewed by Lynch and colleagues.[13] It was proposed that adiposity may facilitate carcinogenesis through increasing sex hormone levels, insulin resistance, chronic inflammation and altered adipokine secretion but mixed findings have been reported for the relationship between adiposity and sedentary behaviour. Additionally, modest evidence was found between sedentary behaviour and metabolic dysfunction which can promote the development of cancer through insulin resistance. However, insufficient evidence was found for the association between sedentary behaviour and sex hormones, inflammation and vitamin D. Furthermore, this review was predominantly based on observation evidence thus is limited in terms of causality. Therefore, more research is needed into the mechanisms behind the association between sedentary behaviour and negative health outcomes. Additionally, long-term interventions aimed at reducing uninterrupted sedentary time should be a priority in order to measure the effect on health markers.

1.2.5 Correlates of sedentary behaviour

In order to develop appropriate interventions, the correlates of sedentary behaviour must be identified and understood.[170] Subsequently, the modifiable correlates can be targeted during interventions.[133] A review by Rhodes et al.,[171] focused on intrapersonal factors relating to sedentary behaviour and found that TV viewing was associated with increasing age, lower educational attainment, unemployment/retirement, having children in the home, depressive symptoms, lower psychological well-being and a higher BMI. Additionally, age was negatively associated with computer use whereas education was positively associated with computer use. No conclusive evidence was found for a relationship between sedentary behaviour and ethnicity, marital status, income or gender with the exception of video games where men are more sedentary compared to women. However, the majority of studies included in this review measured TV viewing or single domains of sedentary time by questionnaire and 76% were cross-sectional limiting the generalisability to other domains and causality.

Although it is important to identify intrapersonal correlates of sedentary behaviour in order to focus interventions on at risk groups, these correlates are unmodifiable. Other health behaviours have been explored in relation to sedentary behaviour and found mixed results.[171] A review by O'Donoghue and colleagues[172] found that smoking status was positively related to sedentary behaviour measured by TV viewing, time spent driving and total sitting time in six out of seven studies but half of these were in women only. Alcohol consumption was positively associated with transport sitting time and total sitting time in women only with no association to leisure screen time. Conversely, more consistent associations have been found between sedentary time and diet with positive correlations for food cravings and high calorie snacking. This finding is supported by a review by Pearson et al.[173] who found that sedentary behaviour was clearly correlated with elements of a less healthy diet including lower fruit and vegetable consumption, higher consumption of energy-dense snacks, drinks and fast foods, and greater total energy intake. Additionally, an update of this review found three further studies had found negative correlations between a healthy diet and TV viewing.[174]

Negative associations have generally been found between physical activity and sedentary time.[171,172] A systematic review by Mansoubi and colleagues[175] found consistent weak to moderate associations between physical activity and all measures of sedentary behaviour. Furthermore, studies utilising objective measures found stronger inverse associations between sedentary behaviour and physical activity. The review suggested that there is some evidence that sedentary behaviour displaces light intensity activity. Additionally, physical inactivity has been shown to cluster with the other lifestyle behaviours. In a study of English adults who completed the 2003 Health Survey for England,[176] the clustering of physical inactivity, smoking, heavy drinking and lack of fruit and vegetable consumption was evident particularly among men, lower social class households and singles. These lifestyle factors are known as SNAP (Smoking, Nutrition, Alcohol and Physical activity) and are the 'big four' modifiable causes of morbidity and mortality.[176–178] However, the relationship between sedentary behaviour and the clustering of SNAP behaviours has rarely been explored.[179] Therefore, research is needed to investigate the link between sedentary behaviour and other modifiable health behaviours to inform future multicomponent interventions.

In addition to health behaviours, other environmental sedentary behaviour correlates were identified in a review by Prince and colleagues.[180] An ecological approach was adopted which assumes there are multiple levels of influence including individual, social, community, environmental and policy.[181] Physical environmental factors that were negatively correlated with leisure-time sedentary behaviour included availability of green space, public transit, public facilities, bike facilities, shorter distance to physical activity facilities, natural sights and summer season. Whereas, ownership of TV/media, and litter and decay showed positive associations. Social environment correlates associated with lower sedentary behaviour included high personal safety, satisfaction with neighbourhood and contact with neighbours. For occupational sedentary behaviour, the availability of active workstations, office physical activity opportunities and/or promotions were negatively correlated but closer proximity to and greater visibility of co-workers were positively associated.

Occupational sedentary behaviour is an important domain as adults spend the majority of their sedentary time at work.[182] Hadgraft et al.[183] reviewed the interpersonal correlates of occupational sedentary time specifically and found that age in women only, and technical/vocational education, blue collar, worked hours per week and leisure-time physical activity in men only showed a negative association. Conversely, being separated/divorced/widowed (women only), having a high annual household income and being a non-smoker increased the odds of being in the high occupational sitting time category. Therefore, correlates differ depending on the domain of sedentary behaviour with the reviews in this area finding mixed results. Further research is needed into domain-specific sedentary behaviour correlates.

1.2.6 Occupational Sedentary Behaviour Prevalence

The workplace domain has been illustrated as an opportunity to accumulate large amounts of sedentary time due to a preponderance of office-based, thus desk-based, seated occupations. The decrease in occupational energy expenditure between 1960 and 2008 was analysed in detail by Church et al.[184] using data from the U.S. Bureau of Labour Statistics. This study showed that both goods producing and agriculture occupations had declined in the US and service occupations which were all classed as either sedentary or involving light activity only, had become more prevalent.

Therefore, moderate physical activity occupations (e.g. farming & mining) had decreased from 48% in 1960 to 20% in 2008 with an associated decline in daily EE of 140 calories for men and 124 calories for women.

As a consequence of the transition to less active jobs, occupational sedentary behaviour is more prevalent. A review by Bauman et al.[185] concluded that median self-reported occupational sitting time was 4.2 hours/day (range 3.0-6.3 hours/day) based on eight large population-based studies conducted between 2012 and 2016. Data from the Special Eurobarometer[141] showed that adults in white collar occupations were five times more likely to sit for over 7.5 hours per day compared to manual workers. Additionally, an average of 6.5 hours per day were spent sedentary at work out of a total 11 hours per day reported sitting in a UK sample (n=504) of employees, with males reporting significantly higher amounts of occupational sedentary time than females.[47] Similarly, a sample of Australian office workers spent 82% of their work hours sedentary compared to only 69% of their leisure-time.[182] Additionally, occupational sedentary behaviour contributed to nearly half (49%) of all weekly sedentary time.

Objectively measured occupational sedentary time prevalence rates are limited due to the difficulty in separating domains of sedentary behaviour when using these measurement techniques. However, the few large studies available support the high prevalence rates found by self-report measures but highlight the large individual variation in these rates.[186] The Stand Up Australia program of research (n=496) found that activPAL-determined sitting time accounted for 76±10.6% of total worktime with some workers sitting for less than 25% of the workday and others for over 90%.[187–190] Furthermore, Ryan and colleagues[191] found that in a sample of Scottish office workers (n=83), the majority of occupational activPAL-determined sitting time was accumulated in long, uninterrupted bouts of at least 30 minutes. On average, office workers were seated for 5.3±1.0 hours/day at work and 25-67% of sitting time was accrued in bouts of 30 minutes or longer. These results are supported by an English study of NHS employees (n=146) which found that on average, 72.6% (5.94±1.47 hours/workday) of the workday was spent sitting (measured via activPAL) and 47.1% (2.80±1.60 hours/workday) of this sitting time was accumulated in prolonged bouts of ≥30 minutes.

Substantially lower amounts of sedentary time were observed in a sample of Dutch workers, with an average of 3 hours of occupational sedentary behaviour reported out of a total of 7 hours per day spent sedentary, however, occupational sedentary behaviour still contributed to nearly half of total sedentary time.[85] Interestingly, participants with an occupational sedentary time above average also reported a significantly higher amount of leisure (i.e. outside of work) sedentary time compared to participants who reported lower than average amounts of occupational sedentary time. This was also found in a UK sample where adults in the high occupational sedentary time category (>80% of work hours sedentary) reported significantly higher amounts of sedentary time after work compared to the lowest occupational sedentary time group (<58% of work hours sedentary).[49] Additionally, the participants in the high workplace sedentary time group were also sedentary for 94 minutes per day longer on non-workdays compared to the low workplace sedentary time group. Consequently, sedentary workers appear to be more sedentary during leisure-time and do not compensate for the lack of occupational activity as once thought. Therefore, workplace interventions need to occur in order to reduce occupational sedentary time and the effect on leisure-time sedentary behaviour needs to be analysed.

1.2.7 Current public health guidelines

The inclusion of sedentary behaviour in public health guidelines is rare but emerging.[51] The World Health Organisation do not mention sedentary behaviour in the latest (2011) global recommendations on physical activity for health[7] and focus solely on MVPA and muscle-strengthening. Whereas, Canadian 24-hour movement guidelines[192] integrate physical activity, sedentary behaviour and sleep for children (0-17 years) only. Similarly, Finish national recommendations[51] state that 7-18 year olds should avoid sitting for more than 2 hours at a time but do not recommend this for adults. The 2nd edition of the USA guidelines[193] recommended that adults should move more and sit less whereas the Russian Federation simply recommend avoiding sedentary behaviour.[51] Additionally, a general decrease in non-active time spent on TV, games consoles and surfing the internet is included in Maltase guidelines.[51] Conversely, the Australian Government's 2014 physical activity and sedentary behaviour guidelines[194] state specific sedentary behaviour guidelines that recommend minimising the amount of time spent in prolonged sitting and to break up long periods of sitting as often as possible. New Zealand guidelines[195] also mention prolonged sitting and the first activity statement is: ‘sit less, move more! Break up long periods of sitting’. Dutch guidelines[196] have recently been updated to include ‘avoid long periods sitting down’. Current UK physical activity guidelines[52] highlight the importance of interrupting prolonged sedentary time by stating that, “all adults should minimise the amount of time spent being sedentary for extended periods” and describes taking regular breaks at work as an example of how to meet this guideline. Furthermore, Switzerland national guidelines[197] recommend activity breaks when sitting for more than 120 minutes and a two-hour limit on non-work screen time is stated in the Iceland guidelines.[51]

Therefore, national guidelines on sedentary behaviour are emerging but there is a range of recommendations including a general reduction, breaking up prolonged bouts and stating breaks are needed after two-hours of sedentary time. Additionally, workplace guidelines to reduce prolonged periods of sedentary work have been published. Comcare is a statutory authority of the Australian Government and has published a sedentary work practices toolkit[198] which provides information on implementing a program to reduce sedentary work practices, strategies, posters and tips. Additionally, an expert statement by an international group of experts was published in the British Journal of Sports Medicine in 2015.[50] The guidance recommend that predominantly desk-based workers should progress towards accumulating at least 2 hours per day of standing and light activity at work and aim to eventually increase this to 4 hours per day. Furthermore, the guidelines recommend seated-work should be regularly broken up with standing-based work and vice versa (adjustable desks are highly recommended) but the frequency and duration of breaks was not specified. Additionally, the recommendations state that prolonged static standing postures should be avoided and that movement should be checked and corrected on a regular basis especially in the presence of musculoskeletal symptoms. However, the response to the expert statement was generally negative as found in a study by Garner and colleagues[199] who analysed public comments posted within the first month of the statement release on UK news media websites. The thematical analysis found that there was confusion, misunderstanding and misapprehension among responders. The likely reasons for this are that the guidelines are vague and do not state how much sedentary time classifies as an ‘extended period’ or how often breaks in sedentary behaviour should occur. The lack of quantifiable thresholds is due to the limited and ambiguous research.[200] Therefore, further research is needed to further inform occupational sedentary behaviour guidelines.

1.2.8 Behaviour change

Physical activity interventions that are theory-based have been found to be more effective than those that are not.[201] The Behaviour Change Wheel (BCW) framework[202] was developed by expert consensus and a validated process which integrates behaviour change theory and is a synthesis of 19 frameworks of behaviour change. The behaviour change wheel has 3 layers (Figure 1.2) and at the centre are the sources of behaviour: ‘Capability’, ‘Opportunity’ and ‘Motivation’ (COM-B model). These three essential conditions for behaviour can be further split into physical and psychological capability, physical and social opportunity, and automatic and reflective motivation. The second layer consists of nine intervention functions that can be used to address deficits in one or more of the COM-B elements and the outer layer describes seven policy types that can be used to deliver the intervention functions.

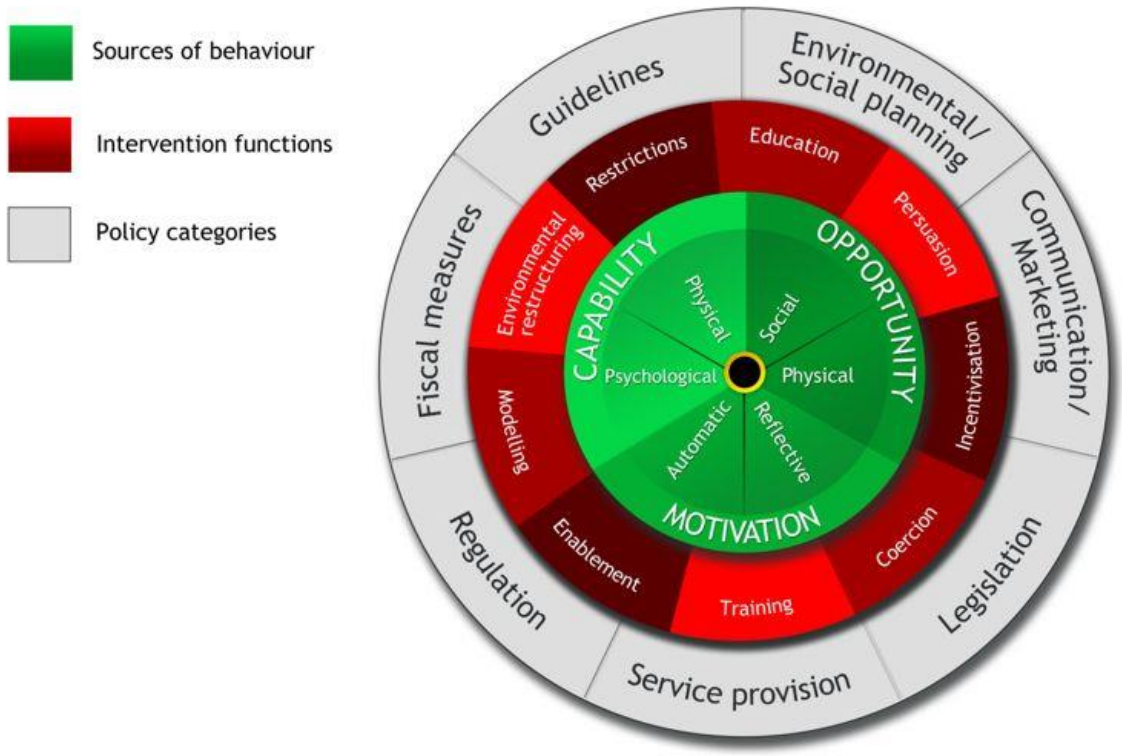


Figure 1.2 The Behaviour Change Wheel. Reproduced from: The behaviour change wheel: A new method for characterising and designing behaviour change interventions. Susan Michie, Maartje M van Stralen and Robert West. Implementation Science 2011, 6:42. © Michie et al; licensee BioMed Central Ltd. 2011

When designing an intervention using the BCW, there are three stages.[72] Firstly, the behaviour must be understood by defining the problem, selecting the target area, specifying the target behaviour and identifying what needs to change. Secondly, the intervention options must be identified and subsequently, the content and implementation options must be identified. A taxonomy of 93 distinct Behaviour Change Techniques (BCT) exists[203] and a review by Gardner et al.[204] found that sedentary behaviour interventions based on environmental restructuring, persuasion, or education were the most promising according to observed behaviour changes. Furthermore, self-monitoring, problem solving and restructuring the social or physical environment showed promise with interventions focusing on sedentary behaviour rather than physical activity being more effective at changing behaviour. The literature specific to workplace interventions aimed at reducing sedentary time will be reviewed imminently.

1.2.9 Workplace interventions to reduce sedentary time

Numerous interventions have been implemented in the workplace but most have focused on reducing musculoskeletal symptoms, injuries and absenteeism associated with manual handling and computer tasks.[205] Additionally, a large number of interventions have focused on increasing MVPA in the workplace and it is only recently that studies have focused primarily on specifically reducing sedentary time. Workplace intervention studies focusing on reducing sedentary time have implemented strategies based around physical activity and sedentary behaviour education and counselling (employee and employer level), prompts to break up prolonged sedentary time, self-monitoring of physical activity and sedentary time, active workstations, large-scale active office environments and combinations of these strategies (multicomponent). These intervention strategies will be discussed in more detail below.

Education and counselling interventions

The first intervention studies to measure sedentary behaviour provided education and counselling in the workplace but primarily aimed to increase physical activity. Large sample sizes were recruited of predominantly desk-based office workers with the majority of studies adopting a randomised control trial (RCT) design and have taken place in a range of countries. The intervention durations varied, and most studies adopted self-report measures of sedentary behaviour. A variety of sedentary behaviour domains have been assessed with mixed results.

A study by Verweji and colleagues[60] counselled both the employee on how to live a healthy lifestyle including reducing sedentary behaviour and the employer on how to improve the working environment to improve occupational health. After 6 months, self-reported sitting at work measured via an unvalidated questionnaire was reduced by 28 minutes per day in the intervention group compared to the control group who received usual care. This RCT (n=523) observed no changes in total sitting, leisure-time sitting, waist circumference, weight or snack intake after the intervention but the intervention group showed a significant increase in fruit intake compared to the control group. This study is partly supported by Marshall and colleagues[55] who compared active living print brochures and the same information but web-based in 512 university staff over 8 weeks. This Australian RCT study found that the web-based group significantly reduced their self-reported weekday sitting compared to baseline but no differences were observed compared to the print group. Similarly, a study involving Belgium university staff (n=66),[59] implemented individual physical activity programmes and educational brochures for all participants and then compared face-to-face and telephone coaching both consisting of goal evaluation, adherence and adaption if required. This RCT ran for 3 months and found that both groups significantly reduced their self-reported sitting time measure via the IPAQ (long) compared to pre-intervention but no between group differences were found. Aittasalo and colleagues[58] also utilised the IPAQ long version to measured self-reported sitting time in an RCT and found a significant reduction in non-workday but not workday sitting after 12 months in the intervention group who received physical activity counselling including planning, a diary and fitness testing at 8 weeks and 6 months (n=155). This reduction was significant compared to the other intervention group who received counselling without fitness testing but neither group showed a significant reduction in sitting compared to the controls.

Interventions that have observed no significant results implemented educational sessions on sedentary behaviour,[206] motivational emails,[56,207] physical activity counselling including planning and barrier identification[208] and mindfulness training with subsequent e-coaching.[57] The main limitations of the studies implementing information strategies discussed here are a lack of power to detect meaningful reductions in sitting time after 46% drop-out,[207] no control group,[208] measuring stationary time via accelerometer which cannot distinguish between sitting and standing,[207] short intervention duration,[55,56,59,206,207] no specific measure of work sedentary time,[55,56,58,59,206–208] education and counselling based on increasing physical activity and not on reducing sedentary behaviour specifically,[55–59,208] and self-reported measures of sedentary/sitting time.[55–60,208] Therefore, workplace interventions implementing education and counselling have predominantly shown no significant reductions in sedentary behaviour, this may be partly explained by targeting the employee only without also educating the employer, not focusing strategies primarily on reducing sedentary time and mostly self-report measures of sedentary time.

Interventions using persuasive technology

The term ‘persuasive technology’ refers to technology designed to change the users’ attitude and behaviour.[209] Few studies have implemented persuasive technology in workplace interventions to reduce sedentary time but some research into the effectiveness of self-monitoring device and prompts has been undertaken.[75] The majority of interventions implementing self-monitoring technology have used pedometers. Gilson and colleagues[210] compared a route-based walking group who were encouraged to increase step counts (measured via pedometer) during work breaks through brisk, sustained walking, an incidental walking group who were encouraged to increase step counts (measured via pedometer) during work tasks (e.g. walk and talk to colleagues rather than email), and a control group who maintained their normal behaviour. The large sample (n=179) from a combination of countries (UK, Australia & Spain) self-reported sitting time during the workday at baseline and after the 10 week intervention in a logbook after lunch and at the end of the workday for 5 days at both measurement points. The RCT found no difference in work sitting time after the intervention in either group compared to baseline or compared to the control group.

Parry et al.[207] also gave a sample of office workers (n=14) a pedometer and encouraged them to increase their steps in an RCT. Additionally, the participants were sent motivational emails every 2-3 weeks during the 12-week intervention and wore an ActiGraph GT3X for 7 consecutive days. No change was observed during work hours or for total workday, sustained (≥30 minutes) stationary time, or breaks in stationary time. The main limitation of these interventions is that they predominantly focused on increasing steps as opposed to reducing sedentary time thus no significant reductions in sedentary time were observed. Additionally, sedentary time was measured via self-reported sitting time or accelerometery-determined stationary time thus these are not gold standard measures limiting the validity of the results.

Wrist-worn activity monitors typically provide the user with more detailed activity feedback via an associated smart device application and are increasingly available.[211] Guitar et al.[212] provided call centre workers (n=22) who had access to a Fitbit One™ (Fitbit Inc., San Francisco, CA) with the goal of standing every 30 minutes during an 8-hour workday. Participants monitored their sitting time for 8-weeks using the associated Fitbit application and the results showed that on average workers stood 12 times per workday out of a maximum of 16 stands. The main limitations of this study are that no baseline measures were taken, it was uncontrolled and sedentary time was not explicitly measured thus the effectiveness of the intervention cannot be evaluated.

Compared to self-monitoring of activity, interventions using prompts to reduce sedentary behaviour have shown some significant effects. Evans and colleagues[206] educated all employees (n=28) on the importance of reducing sedentary time and additionally, installed prompting software (MyRestBreak 1.0) on the computers of intervention participants which prompted participants to stand every 30 minutes. The intervention group significantly reduced the number and duration of prolonged sedentary events (≥30 minutes) measure via activPAL after 5 days and increased the number of breaks in sedentary time compared to the education only group (controls). However, total workday sedentary time was not reduced in the intervention group. This is most likely due to the prompts only encouraging breaks in sedentary time of 1 minute in duration which is unlikely to reduce overall daily sedentary time, and participants were only prompted if they were at their computer and it was turned on. Furthermore, this RCT study had a small sample size thus potentially lacked the power to detect significant reductions in total sedentary time and limiting the generalisability of the results.

Conversely, Swarts and colleagues[213] recruited a larger sample (n=60) and provided prompts to break up sedentary time every hour on a wrist-worn device in addition to on participants' computers for 3 days during working hours. Participants were randomised into two intervention arms, the 'stand' group who were prompted to stand only and the 'step' group who were prompted to walk at least 100 steps using their pedometer to self-monitor this. Both groups significantly reduced activPAL-determined sedentary bout duration and the number of prolonged sedentary bouts ≥60 minutes at work. However, only the 'stand' group also significantly reduced overall work sedentary time, number of prolonged sedentary bouts ≥30 minutes and increased the number of breaks in sedentary time compared to baseline. Additionally, no significant between group differences were found and there was no control group limiting the conclusions of the study.

Júdice and colleagues[214] implemented computer prompts and pedometers in a pilot pre-post study (n=10 overweight and obese adults) for 1 week and found a non-significant reduction in activPAL-determined sedentary time of 1.85 hours per day (95% CI:0.96–2.75) post-baseline. Increases in standing of 0.77 hours per day (95% CI:0.06–1.48) and stepping of 1.09 hours per day (95% CI: 0.79– 1.38) were observed but there was no change in the number of sit-stand transitions. Due to the design of this study, it is unclear how effective the prompts or self-monitoring intervention elements were individually and in which domain the improvements occurred due to the pooling of work and non-workdays.

Interventions using prompts based on time rather than behaviour are limited because the participant could be non-sedentary when prompted or have just been active. Therefore, prompts based on behaviour could have higher feasibility to reduce sedentary time. Gilson and colleagues[215] provided office workers (n=24) with a sitting pad which measured the user's sitting time at their desk and real time prompts were displayed on the user's computer to interrupt desk sitting through a traffic light system (green to amber=30 minutes sitting, amber to red=60 minutes of sitting). This RCT found that GENEActiv-determined sedentary time after 5 months was significantly reduced by 8% of workday wear time and light physical activity was increased by 8% in the intervention group compared to baseline. However, the only significant difference between the comparison group who only received strategies for 'sitting less and moving more' and the sitting pad group who also received the same strategies, was a reduction in the longest sitting bout per workday.

Lynch and colleagues[216] conducted an RCT (n=83) which deployed Garmin Vivofit 2 ® (Garmin, Olathe, KS, USA) wrist-worn activity monitors to the intervention arm for 12 weeks in addition to behavioural feedback and goal setting. Participants could self-monitor their activity via the associated smart device application and received inactivity prompts in the form of an audible beep and a red bar on the device which built up every 15 minutes but could be reset by walking for a few minutes. ActivPAL determined sedentary time was significantly decreased by 37 min/d in the intervention compared to the control group.[217] However, these results are only generalisable to postmenopausal breast cancer survivors and workplace studies utilising the Vivofit have not measured sedentary time.[218] Furthermore, wrist-worn devices are restricted as sedentary behaviour intervention tools as they provide inactivity prompts which can occur whilst standing thus are not specific to reducing sedentary time.[219]

Providing participants with an additional device to use has limitations including increased participant burden and expense. Utilising smart devices such as mobile phones can be an effective way of delivering interventions with a review by Matthews and colleagues[220] concluding that the majority of persuasive technology in mobile applications implemented self-monitoring and aimed at increasing physical activity rather than reducing sedentary behaviours. Bond et al[221] measured the effect of a smartphone application based on a 'fuel gauge' (B-MOBILE) which displayed the number of sedentary minutes remining until the next activity break measured via the onboard accelerometer. The application prompted the user via an on-screen message and audible prompt which could be responded to by performing activity, silenced or delayed for 30 minutes. Sedentary time measured by the SenseWear Mini Armband monitor (BodyMedia, Inc., Pittsburgh, PA) was significantly reduced in a sample of overweight/obese working-aged adults (n=30) after 3 weeks compared to baseline with the 3-minute break after 30 minutes of sedentary time showing superior results compared to the 12-minute break after 120 minutes of sedentary time. However, this pre-post intervention study was not aimed at reducing workplace sedentary time thus may not be feasible in office workers.

Geleijnse and colleagues[222] developed a mobile application aimed at reducing sedentary time in office workers (SitCoach). The iPhone application measures physical activity every minute using the built-in accelerometer and allows the user to set maximum sitting time and active minute goals per day. SitCoach prompts the user via visual, acoustic and tactile messages when it is time to break up their sitting time. A feasibility study reported that office workers (n=8) who used the application during one workday were generally positive about their interactions with SitCoach but had low perceived control over their sitting behaviours and limited awareness of the adverse health effects of prolonged sitting. Following this study, a 6-week intervention was conducted using text messages containing hyperlinks to messages persuading them to be more active as prompts rather than an application due to the large battery use reported from the feasibility study.[223] In this RCT office workers (n=86) were prompted every 30 minutes of nearly uninterrupted computer activity was recorded and overall computer activity was reduced by 10 minutes after receiving the text message compared to before in the intervention group. The reduction in computer activity was significantly higher compared to the control group who received no prompt and opening the hyperlink to the persuasive message did not significantly impact the reduction in computer activity. The main limitation of this study is that computer activity was used as proxy measure for sedentary time thus not all workplace sedentary behaviours were measured. A recent review by Wang and colleagues[75] concluded that persuasive technology alone has not been shown to reduce sedentary time. For example, office workers need to be in an environment conducive to reducing sedentary time in order to respond to the prompts.

Interventions using active workstations

Workplace interventions have implemented various types of active workstations to make the physical working environment less sedentary/activity restrictive. A recent review by Ojo and colleagues[224] found that active workstations do not appear to decrease workplace performance thus have the potential to be effective sedentary behaviour intervention tools.

Treadmill desks

Treadmill desks have been shown to significantly reduce sedentary behaviour in office workers with one US pre-post study (n=12) observing significant reductions after 3 (-182 minutes/day) and 9 (88 minutes/day) months measured via activPAL.[225] Furthermore, positive significant effects were reported for waist and hip circumference (at 9 months), LDL and total cholesterol (at 3 and 9 months) and glycosylated haemoglobin (at 3 months). Koepp and colleagues[226] support these findings and observed significant reductions in accelerometery determined stationary time at both 6 (-91 minutes/day) and 12 (-43 minutes/day) month follow-up points of this pre-post study (n=36). Significant beneficial changes in weight, waist circumference, systolic blood pressure (all at 6 and 12 months), fat-free mass, haemoglobin A1c (both at 6 months) and HDL cholesterol (at 12 months) were also reported. The treadmill desk also had no significant impact on self- and supervisor-rated work performance and participants reported high acceptability of the desks. However, without a control group the contribution of the intervention to the reductions in sedentary time is unclear and the small sample sizes, likely due to the expense of the workstations ($3000-4000), limit generalisability.

'Hot desks'

To reduce costs, some studies have implemented a fewer number of active workstations to an occupational setting and employees were given the opportunity to share them ('hot desks'). For example, a sample of 19 office workers were provided with a limited number of treadmill and cycle ergometer hot desks to use for 12 weeks in an RCT.[207] No change in ActiGraph assessed stationary time (total workday, working hours, prolonged ≥30 minutes & breaks) was observed post-intervention. This was also the case for an Australian pre-post study where 4 fully-adjustable sit-stand hot desks were implemented in a sample of 11 office workers for 1 week and no change in sedentary time at work was found.[227] The observed lack of change in sedentary time in both studies could be due to the small samples thus a lack of power to detect changes but is more likely due to participants not using the hot desks enough to reduce sedentary time. One study did measure desk use via a self-report logbook on each hot desk[227] and found that the desks were only used in the standing position but were rarely used with one employee not using the desk at all and only 3 using it daily.

Pedal exercise machines (under existing desk)

Pedal exercise machines under existing seated desks can be used to reduce occupational sedentary time whilst seated and were given to 18 office workers for 4 weeks in one RCT.[228] A 4-week RCT reported that the devices were highly acceptable and feasible and did not negatively affect self-reported productivity; but no change was observed in self-reported sitting time at work. This result could be due to participants only using the pedal machines for, on average 23 minutes per day which may not produce a detectable reduction in sitting time with the small sample size. Furthermore, the self-reported questionnaire measures of sitting time may have impacted the results as participants may not have distinguished between active and inactive sitting. Thus, the use of the pedal machines whilst sitting may have been included in sitting time potentially limiting the measure as a proxy for sedentary time.

Sit-stand desks

Some sit-stand desks can be attached to existing seated-height desks (retro-fit) and have been implemented in several intervention studies. Alkhajah et al.[67] provided 18 participants with a retro-fit sit-stand desk for 3 months and compared the effects to a control group (n=14) who received no intervention. This pilot, non-randomised, quasi-experimental trial observed significant reductions in work (-144 & -95 minutes/8 hour workday) and total daily (-97 & -78 minutes/16 hour day) sedentary time and increased number of breaks in sedentary time at work (5 & 3/hour of sedentary time) and over the whole day (+1/hour of sedentary time & no change) measured via activPAL monitors (results compared to the control group at 1 week and 3 months respectively) post intervention. Additionally, a significant increase in HDL cholesterol was reported after the 3-month intervention compared to the control group and the desks had high acceptability and feasibility. However, the sample recruited were sedentary behaviour researchers limiting the generalisability of the results. These findings are supported by other studies with an Australian, pilot RCT retro-fit sit-stand desk intervention observing significant reductions in workplace activPAL-determined sedentary time (-73 minutes/day at work), self-reported TV viewing on a workday (-26 minutes/day) and non-workday (-46 mins/day) and total workday sitting time (-80 minutes/day) (measured via the WSQ) after 4 weeks in health agency employees (n=42).[64]

Conversely, Neuhaus and colleagues[188] found that activPAL-determined sedentary time during working hours was significantly reduced in the intervention group but not compared to the control group after retro-fit desks were installed for 3 months in a sample of office workers (n=27) with a quasi-RCT design. This could be due to the desks not being used because of reported problems associated with the retro-fit desks including a lack of hand and wrist support, not enough space and one participant withdrew due to overall body pain, although it was stated this participant wore high-heeled shoes for the duration of their participation. The retro-fit workstation design was also reported as a negative aspect in an RCT by Graves and colleagues[71] where 26 office workers received retro-fit desks for 8 weeks. EMA-determined sitting time at work was significantly reduced compared to the control group (n=21) by 80 minutes/8-hour workday (95% CI=−129.0, −31.4) with an associated increase in standing of 73 minutes/8-h workday (95% CI: 21.2, 124.6) and a decrease in total cholesterol of 0.4 mmol/L (95% CI: −0.79, −0.003).

Pronk et al.[65] gave retro-fit and fully-adjustable sit-stand desks to 24 office workers for 4 weeks and found a significant reduction in work sitting time measured via self-report (-66 minutes/day) and EMA (-224%). The fully-adjustable sit-stand desks replaced existing seated-desks and allowed the user to lift/lower the full surface of the desk. Positive effects on self-reported upper neck and back pain, vigour, fatigue, tension, confusion, depression, total mood disturbance, comfort, energy, happiness, focus and productivity were also observed. However, this non-randomised control trial is limited by the sedentary time measures which required participants to reply to 3 text messages a day with their current status (sitting, standing or walking) and the survey asked participants to retrospectively report their sitting time over the past 4 weeks thus reducing the validity of the results. Chau and colleagues[70] implemented fully-adjustable sit-stand desks in pilot crossover RCT with a sample of call centre workers (n=16) and found a significant reduction in activPAL-determined sedentary time after 1-week (−64, 95% CI: −125, −2), 4-weeks (−76, 95% CI: −142, −11) and 19-weeks (−100 min/workday, 95% CI: −172, −29) post-baseline compared to the control group. Additionally, no differences were observed in company-specific objective metric or subjective measures of productivity. Dutta and colleagues[66] also observed significant reductions in workplace and total daily sedentary time measured via questionnaires and accelerometery after 4-weeks of sit-stand desk use. In this randomised cross-over trial office workers (n=28) were given a variety of sit-stand desks including retro-fit models but the provision of the sit-stand desk type was based on the individual participants' needs. Participants also felt more relaxed, calm, less sluggish, had more energy and improved general wellness but no significant change was reported for self-reported productivity, tiredness and hunger.

These results are supported by Hedge and Ray[68] who observed a significant reduction in self-reported work sitting time (16.5% per day) with an average of 1.7 desk adjustments per day in a sample of computer workers (n=33) who were provided with fully-adjustable sit-stand desks for a 4-6 week period. This cross-over RCT found that participants also reported reduced discomfort and musculoskeletal symptoms, increased mouse, keyboard, chair and workstation comfort and 37.5% higher productivity ratings compared to control participants. A significant reduction in workplace sitting was also found in a qualitative based pre-post study[69] (-23%, -1.7 hours/day) measured by subjective measures (OSPAQ & WSQ respectively) after implementing fully-adjustable sit-to-stand desks in a sample of office workers (n=11) for 4 months. Furthermore, 8 out of 11 participants reported using the desks daily and they had high acceptability and usability. Gao and colleagues[229] also observed significant improvements in self-reported occupational sitting (-6.7%), work ability and perceived musculoskeletal comfort in the neck and shoulders as a result of sit-stand desk implementation (n=24) compared to the control group (n=21) after a 6-month RCT. However, these results are still limited due to the self-report measures.

In summary, treadmill desks have been shown to be effective in reducing workplace sedentary time and improving some health outcomes without a negative influence on work performance over long periods of time (9-12 months) but are very costly. Conversely, the limited evaluation of 'hot desks' of any kind (sit-stand, treadmill or cycle ergometer desks) have shown no reduction in sedentary time during periods of 1-12 weeks. This was also found when office workers were provided with pedal exercise machines for a short duration. Retro-fit sit-stand desks have shown significant reductions in sedentary time and increased HDL cholesterol without any adverse effect on work performance, presenteeism or absenteeism. However, the desks have been reported to be limited in terms of space and hand/wrist support. Providing a fully-adjustable or individually tailored variety of sit-stand desks have produced significant reductions in sedentary time, improved mood and comfort, reduced musculoskeletal discomfort and increased productivity (self-reported). However, the short duration and rare use of gold-standard sedentary time measures limits the results. Furthermore, the majority of studies have had small samples that have lacked power to detect changes in health and work outcomes and few studies have measured desk use or looked at the effects on sedentary time.

Large-scale workplace environment change

Natural experiments provide an ecologically valid perspective of the impact of workplace environment change.[230] These studies have shown that relocating from a conventional workplace to a movement-orientated working environment may not change behaviour significantly. Office workers from an academic physical activity research centre (n=24) did not significantly change activPAL-determined sedentary time after 4 months of relocating to a new environment which included electric sit-stand desks for faculty staff (n=4), an internal glass enclosed staircase, standing options in meeting rooms and common areas, centralised printing and supplies, and the office layout promoted vertical integration with key destinations on different floors.[230] However, the sample could potentially bias the results due to having an interest in the area thus could already be less sedentary limiting the generalisability of the results. Conversely, Clark and colleagues[231,232] observed significant reductions of 17% in self-reported workplace sitting time with a 15% increase in standing time in a sample of office workers (n=78) who experienced a change in the workplace environment including the installation of sit-stand desks after 3 months. However, these studies are limited by the study design which cannot take into account any external variables which could have influenced the results.

Multicomponent interventions

Recent workplace interventions have implemented a combination of the strategies previously mentioned (multicomponent) and measured the effects on sedentary behaviour, health and work-related outcomes. Brakenridge and colleagues,[190] undertook a pilot cluster-randomised trial comparing two interventions in office workers (n=153) over 12 months. Both groups received organisational-level strategies which included visible management support and emails from a workplace champion; however, one group also received a waist-worn activity tracker (LUMO). This device enabled the user to self-monitor sedentary time via a smart device application and a prompt could be set to alert the user when prolonged sitting had occurred via a notification on their smart device. Significant reductions in occupational sedentary time were observed for both groups (-41 minutes/10 hours with tracker, -36 minutes/10 hours without tracker) after 12 months compared to baseline.[76] Both groups also significantly improved overall sedentary time, prolonged sedentary time and standing time but the only significant difference between groups was for daily stepping (+21 minutes/16 hours & +847 steps/16 hours for tracker vs no tracker group).[233] A potential reason for the lack of significant difference in reduction of sedentary time between groups is that there was no provision of sit-stand desks. Therefore, participants' opportunities to act on the prolonged sedentary time prompts were limited.

Donath et al.[234] conducted a 12-week RCT in a sample of office workers who were already provided with fully-adjustable sit-stand desks but did not use them yet (n=31). Office workers in the intervention arm had software installed on their computers which prompted them to stand three times a day via pop-up messages at 10:00, 13:00 and 15:00 whereas the control participants received no intervention. Post-intervention, thigh-worn ActiGraph-determined sitting time was not significantly reduced during the working week in the intervention group compared to baseline or compared to the control group. The study concluded that the non-significant results could be due to the point of choice prompts not reflecting the individuals needs, background and specific working environment. Additionally, the prompts were not based on behaviour thus office workers may have already been standing at their desk prior or during the prompt.

Conversely, a US RCT (n=40) provided office workers with portable pedal exercise machines, access to a motivational website that contained tips on ways to reduce sedentary behaviour and a pedometer.[235] After 12 weeks, daily accelerometer-determined sedentary time (-59 minutes/day, -3.7% daily time) and waist circumference were significantly reduced compared to the control group with the pedal desks used on average for 31 minutes/day on 38% of all days. Barbieri and colleagues[236] randomly allocated office workers with a non-automated sit-stand desk (n=12) or a sit-stand desk which generated a computer prompt every 50 minutes the desk was in the seated position (semi-automated n=12). Participants in the semi-automated condition could choose whether to accept the prompt (desk would raise to standing position for 10 minutes), postpone (prompt would appear again after 2 minutes) or ignore (prompt would reset and count down from 50 minutes). During the 2-month intervention, the sit-stand desks were in the sit position for 85% of the workday in both groups which did not significantly change post-baseline but switches in sit-stand desk position were significantly more frequent in the semi-automated group. Conclusions from this study are limited due to the lack of sedentary time measurement.

The use of environmental and individual elements is supported by an Ellegast and colleagues[237] who found that in an RCT office workers who were given sit-stand desks, pedometers, face-to-face motivation for lunch walks and an incentive system for active commuting or sports activities significantly reduced daily self-reported sitting time (measured via activity logs) and BMI compared to the control group after 12 weeks (n=25). Intervention participants also reported significantly improved mood, reported feeling more awake and calmer compared to control participants. Maylor and colleagues[238] implemented a work-based multicomponent intervention in a sample of UK office workers (n=48) which incorporated organisational (educational session, step challenges), individual (health check and meeting, prompts, telephone support) and environmental elements (work environment changes) from a corporate wellness programme provided by Beat the Seat (Beat the Seat Ltd.).[239] This cluster-RCT found no difference in activPAL-determined sedentary time at work in the intervention group after 8-weeks compared to the control group (n=41). Significant improvements were observed for prolonged sedentary time at work, sit-stand transitions and stepping time in favour of the intervention group. Thus, the provision of active workstations may be necessary to reduce sedentary behaviour in multicomponent workplace interventions.

Danquah and colleagues[240] implemented a multicomponent intervention involving the appointment of local ambassadors, management support, environmental changes, a lecture and a workshop in a sample of Danish workers (n=317) who already had sit-stand desks. In this cluster-RCT ActiGraph-determined sedentary time (worn on the thigh) was significantly reduced in the intervention compared the control group after 1 month (-71 minutes/8-hour workday) and 3 months (-48 minutes/8-hour workday). Additionally, significant improvements were observed in prolonged sitting periods and fat percentage.

The Stand Up Australia program of research implemented intervention strategies which were based around the concept of 'Stand Up, Sit Less, Move More'.[188,189,241] The RCT intervention included organisational elements where the management suggested specific strategies for their workplace, participants were educated about the risks of sedentary behaviour, and a representative from the organisation sent weekly emails with a standing tip using templates provided by the research team. The environmental element was the provision of retro-fit sit-stand desks with instructions on how to use and set up the desks using ergonomic guidelines from the manufacturer (Ergotron) for all intervention participants. Finally, individual intervention elements included one face-to-face consultation where feedback was given on participants' baseline measures and goals were set, and weekly telephone calls to participants encouraging goal evaluation and self-monitoring. Control participants were advised to maintain their usual behaviour and sedentary time was measured using activPAL monitors worn 24 hours-a-day for 7 days at baseline and post intervention.

Healy and colleagues[187] followed-up participants after 4 weeks and saw a significant reduction in workplace sedentary time (-125 minutes/8 hour workday), prolonged (≥30 minutes) sedentary bouts (-74 minutes/8 hour workday) and increased sedentary breaks (+1.9/hour of workplace sitting) for intervention (n=18) compared to control (n=18) participants. The intervention group also significantly reduced their fasting blood glucose levels compared to baseline. Neuhaus et al.[65] followed-up participants (n=44) after 3 months and also found a significant reduction in workplace sedentary time in the multicomponent intervention group compared to the controls (-89 minutes/8-hour workday) and compared to the sit-stand desk only intervention group (-56 minutes/8-hour workday). The multicomponent intervention was also rated by participants as highly acceptable.

The Stand Up Victoria cluster RCT followed-up participants (n=231) 12 months from baseline who had received the intervention described above for 3 months.[189] Significant improvements were observed in the intervention group for workplace activPAL-derived sedentary time (-45 minutes/8-hour workday), standing time, prolonged sedentary time, overall sedentary time and standing time, fasting glucose and overall cardiometabolic risk score compared to control group.[242,243] Furthermore, the intervention was found not to have negatively impacted productivity, was well received by the organisation involved, and was cost-effective.[244,245]

The Stand More AT Work two-arm cluster RCT was designed to examine the long-term (12 month) effects of a multicomponent intervention in a sample of office workers in England (n=146). The intervention was developed via a community-based participatory research approach using the BCW to identify barriers to the COM-B components of behaviour change.[246] Intervention strategies included: an educational seminar pre-intervention, posters, goal setting diary with educational messages, choice of retro-fit sit-stand desk with training and instruction booklet, self-monitoring and prompts via a DARMA cushion, clusters using sit-stand desks in the same office, feedback on baseline activity and coaching sessions.[247] Significant reductions in occupational activPAL-determined sedentary time were observed at 3 (-51 minutes/workday), 6 (-64 minutes/workday) and 12 (-83 minutes/workday) months compared to the control group.[73] Significant improvements in prolonged sedentary time, standing time, job performance, work engagement, occupational fatigue, sickness presenteeism, daily anxiety, quality of life and daily sedentary time at 6 and 12 months were also observed in the intervention group compared to the control group. This study has many strengths including the cluster RCT design, long-term follow-up, objective measurement of sitting time and the use of multiple intervention strategies. However, due to the trial only having two arms, the extent to which each intervention strategy is effective is unknown. Additionally, workday and non-workday sedentary time was not separately examined thus it is not clear how sedentary behaviour was affected during non-working hours.

Summary

The workplace is an important domain to implement interventions aimed at reducing sedentary behaviour due to a large proportion of the population’s total sedentary time being accumulated at work in long, uninterrupted bouts with associated deleterious health outcomes. Workplace interventions implementing education and counselling strategies have predominantly shown no change in sedentary behaviour. A few reasons for this could be that the previous interventions did not educate the employer, focused on increasing physical activity not reducing sedentary time and less valid measures of sedentary time, such as questionnaires. This is also the case for interventions adopting self-monitoring due to the use of devices measuring steps as opposed to self-monitoring sedentary time and short study durations (<3 months). The use of workplace prompts to reduce sedentary time has shown promising results with reductions in prolonged and overall work sedentary time but not total daily sedentary time due to encouraging very short breaks and sedentary time in other domains were not measured. Additionally, persuasive technology in the form of wrist-worn and smart device applications typically do not measure sedentary time thus prompts are based on inactivity. These studies are also limited by the absence of a control group as a comparison and office workers may be restricted by their current workstation thus unable to reduce sedentary time.

Interventions providing active workstations have produced mixed results with treadmill desks showing reductions in sedentary time and some positive health outcomes without a reduction in work performance over long periods of time (9-12 months) but with a high financial cost attached. Conversely, ‘hot desks’ and pedal exercise machines have produced no change in sedentary time over short periods (<3 months). Retro-fit sit-stand desks have produced reductions in sedentary time and increases in HDL cholesterol with no effect on work performance, presenteeism or absenteeism over short periods of time (<3 months) but have limitations in terms of space and wrist/hand support. Fully-adjustable and individually tailored varieties of sit-stand desks have shown reductions in sedentary time and musculoskeletal discomfort whilst also improving mood, comfort and productivity in short interventions (<4 months). Multicomponent interventions using a combination of previously mentioned workplace intervention strategies including a sedentary behaviour educational element have reduced both workday and daily sedentary time whilst improving blood glucose levels, waist circumference and BMI with no effect on work outcomes.

Summary of the gaps and limitations of previous workplace intervention studies

The main limitations of previous workplace intervention studies are that the samples are generally small with the intervention arm containing less than 20 participants resulting in a lack of power to detect differences in certain measures of sedentary time (e.g. prolonged and breaks), health and work outcomes. The duration of interventions are predominantly less than 3 months thus the maintenance of behaviour over longer periods of time has not been assessed. Few studies have measured the intervention effect on non-working hours sedentary time or the use of active workstations with only interventions providing pedal desks and hot desks including desk use as an outcome measure. Furthermore, few studies have provided participants with devices that allow them to self-monitor their sedentary time and measured the effects of such an intervention strategy.

1.2.10 Thesis rationale

Rationale

This chapter has highlighted that sedentary behaviour is an emerging concern[5] that takes place in numerous domains.[6] The prevalence of sedentary behaviour is increasing worldwide[135] but there are limited large-scale studies in the UK that have assessed the prevalence of domain-specific sedentary behaviour.[248] Furthermore, it is well documented that sedentary behaviour is associated with an increased risk of numerous chronic diseases[11] and all-cause mortality.[249] Reviews have shown that sedentary behaviour is inversely associated with physical activity[250] but links to other health behaviours including smoking,[171] alcohol consumption[172] and healthy eating[173] are less clear. Additionally, no study has investigated the links between domain specific sedentary time and multiple health behaviours.

Most sedentary behaviour in working-aged adults takes place in the workplace domain where very high amounts of prolonged sedentary time have been documented.[182] The first workplace interventions focused on individual elements of behaviour change described by the BCW COM-B system.[202] Intervention strategies provided education and counselling,[55–60,206–208] prompts,[206,215,251] behaviour self-monitoring,[207,210,214] active workstations[64–71,207,225–227,252] and large-scale working environment restructuring.[230,253] Some reductions in sedentary behaviour were observed with strategies focusing on increasing opportunity in the form of sit-stand desk provision in particular.[61,62] However, recent intervention studies have focused on addressing deficits in all aspects of behaviour change by adopting a multicomponent approach.[73,188,190,234,235,237,238,240–242] These studies have provided opportunity (sit-stand desks), motivation (education and counselling) and/or capability (organisational buy-in) with larger improvements in sedentary time on workdays.[73,187,242]

Conversely, there is limited research on the long-term effects of multicomponent interventions in the UK as most research studies are less than three months in duration.[246] The intervention effect on physical activity, health and work-related outcomes is still unclear with studies reporting mixed findings mainly due to small sample sizes.[53,61] Additionally, most research has focused on reducing sedentary time during working hours and has not measured the effects during non-working hours.[189] This is important because sedentary time at work has been shown to be associated with non-work sedentary time in cross-sectional studies but has rarely been explored in intervention studies.[49,85] Furthermore, interventions that have provided persuasive technology in the form of self-monitoring and/or prompting strategies have focused on increasing steps,[207] working hours only[246] or have not provided sit-stand desks.[190] Therefore, no study has assessed the feasibility of a self-monitoring and prompting device that is focused on reducing sedentary time in a sample who have the opportunity (sit-stand desks) to achieve this.

Chapter 2: Study One

Domain-specific sitting time and other lifestyle health behaviours: the Stormont Study

Overview

As highlighted in Chapter 1, evidence of sedentary behaviour prevalence in the UK is limited and no study has explored the links between domain-specific sitting time and multiple other health behaviours. This chapter describes a secondary data analysis of the Stormont Study which surveyed a large sample of office workers from the Northern Irish Civil Service in 2012 and 2014. The online survey included measures of domain-specific sitting time, physical activity, smoking, alcohol and, fruit and vegetable consumption. Thus, this study addressed thesis objectives:

1. To assess the prevalence of sedentary behaviour in a large sample from the UK and highlight important domains of sedentary behaviour.

2. To explore the associations between domain-specific sedentary time and multiple other health behaviours.

3. To examine if any associations between sedentary time and other health behaviours track over time.

2.1 Introduction

The negative health consequences of cigarette smoking, a diet deficient in fruit and vegetables, physical inactivity and alcohol consumption are well established.[254–257] As discussed in Chapter 1, sedentary behaviour has been shown in recent years to be independently associated with numerous chronic diseases including obesity,[24,25] metabolic syndrome,[29] type 2 diabetes,[12] some cancers,[13] cardiovascular disease,[28] depression,[14] and all-cause mortality.[10,11,32] Defined as, "any waking behaviour characterised by an energy expenditure ≤1.5 METs, while in a seated, lying, or reclining posture",[77] sedentary behaviour is increasingly prevalent. A recent study analysed a pooled sample of 9,509 adults from four European countries and found that on average, 530 minutes/day were spent sedentary.[253] However, as highlighted in Chapter 1, limited evidence of domain-specific sedentary behaviour prevalence exists in large UK samples which is necessary to highlight key domains for sedentary behaviour reductions and inform interventions. Furthermore, due to the emergence of sedentary behaviour as an independent risk factor and evidence that health behaviours typically coexist together (e.g. cigarette smoking and alcohol overconsumption),[178] it is necessary to explore the associations between sedentary behaviour and other health behaviours.

Previous studies measuring sitting time as a proxy for sedentary behaviour, have shown that sitting time in certain domains is associated with other individual health behaviours.[258–260] A comprehensive review[250] explored a number of sedentary behaviour variables (TV viewing, total sedentary time, total sitting time, general screen time and occupational sedentary time) and found an inverse association among them all with physical activity levels. Conflicting results have been found for TV viewing and smoking status with five studies showing a positive association and four reporting no association. Total sitting time had no association with smoking status in all five studies reviewed. The relationship between alcohol consumption and sedentary behaviour is also unclear with two studies reporting an inverse association in female only samples but the majority of studies found no relationship when measuring TV viewing or total sitting time.[171] Conversely, a review by Pearson and colleagues[173] found a consistent inverse association between TV viewing and fruit and/or vegetable consumption in samples from eight studies.

Partaking in more than one unhealthy behaviour is likely to increase the negative health consequences.[176] A review exploring the clustering of smoking, nutrition, alcohol and physical inactivity ('SNAP') health risk factors found that most studies reported the clustering of alcohol with smoking and half found that all four health behaviours clustered.[178] However, no study has looked at the effect of domain-specific sitting time on multiple unhealthy behaviours. Additionally, most studies have looked at single domains of sitting time in relation to health behaviours, typically TV viewing. Thus, little is known about how other domains relate to the health behaviours mentioned.[179] Therefore, this study aimed to assess the prevalence of domain-specific sedentary behaviour in a large sample of office workers from the UK and explore links with multiple other health behaviours.

2.2 Methods

2.2.1 Participants and procedure

The data used in this study are from the first and second wave of a survey conducted as part of The Stormont Study which took place in 2012 and 2014, respectively. Specific details of the Stormont Study are discussed elsewhere.[46,261,262] Briefly, the Stormont study measured a large cohort of public sector employees within the Northern Ireland Civil Service (NICS). The NICS is the civil service of the devolved government of Northern Ireland and includes employees of the 12 ministerial departments plus the Public Prosecution Service for Northern Ireland. All employees were invited to take part via occupational email address (N~26,000 out of a total of 27,507) in 2012 where researchers sent an email containing an invitation to participate in the first wave of the study and a link to an online survey. The survey was completed by 10,437 office workers (n=5,235 in 2012 & n=5,202 in 2014) (20% response rate in 2012 and 19% in 2014).[46] 806 Civil Servants completed both the 2012 and 2014 online surveys and were included in the prospective analysis. These participants were also included in the cross-sectional analysis but only their 2012 data were included to maintain an independent sample. The study was approved by the Ethics Committee of the University of Ulster and was conducted in accordance with the Helsinki Declaration.

2.2.2 Measurement of domain-specific sitting time

Office workers reported the amount of time in hours/minutes they typically spend sitting whilst travelling, at work, watching television, using a computer at home and during other leisure-time activities on a workday and non-workday using the Domain-Specific Sitting Time Questionnaire.[263] The 'at work' sitting domain refers to workplace sitting on a workday and working at home on a non-workday thus will be termed as such in this chapter. The 'using a computer at home domain' did not include working at home and 'other leisure time activities' refers to any other sitting time that was not accounted for by the other domains e.g. visiting friends, movies, dining out, etc. For the purposes of this chapter, 'using a computer at home' will be termed 'computer-use' and 'other leisure-time' will be 'leisure-time'. Sitting time in each domain was summed to produce total time spent sitting on a workday and non-workday.

This self-report measure of sitting time has been shown to have acceptable levels of validity when compared to accelerometer-determined sedentary time on weekdays (mean difference = -14±28 mins/day) and weekend days (-4±45 mins/day, both p>0.05).[123] Furthermore, when compared to logbook sitting time, validity coefficients were high for weekday work, home computer use and weekend home computer use (r=0.61-0.74) but lower for other domains (r=0.15-0.50). Reliability coefficients were also high for weekday work, watching TV, using a computer at home and weekend using a computer at home (r=0.68-0.84) but lower for the other domains (r=0.23-0.57).[122] Therefore, this measure is recommended for providing population-level estimates of sedentary time.[123]

2.2.3 Measurement of other health behaviours

Physical activity was self-reported using a single-item measure which asked participants to report the number of days they participated in at least 30 minutes of MVPA over the past week.[264] This questionnaire item was originally developed for the previous 2004 UK guidelines which recommended 5 days of 30 minutes or more of MVPA per week.[265] Therefore, for the purpose of the analyses conducted herein, office workers were classified as meeting UK guidelines if they reported at least 30 minutes of MVPA on 5 or more days in the past week. The use of this measurement tool for physical activity is recommended when determining if respondents are sufficiently active to benefit their health as it has high agreement with accelerometery-determined MVPA undertaken in bouts of ≥10 minutes (76%, k=0.23, 95% CI: 0.05-0.41)[266] and strong reproducibility (r=0.72-0.82).[264]

Participants reported how many units of alcohol they typically consume during the week (Monday-Thursday) and over the weekend (Friday-Sunday). The number of week and weekend units were summed, and participants were categorised as meeting the current UK guidelines if they consumed ≤14 units/week.[267] Short-term recall measures of alcohol consumption have been demonstrated to have good criterion validity and moderate test-retest reliability by a recent review.[268] Additionally, this was supported by a previous review which found that short-term recall measures provided the most accurate alcohol intake measurement in a population.[269] Participants reported if they were a current smoker or non-smoker and if they were the former, they were categorised as unhealthy. This measure of smoking as a health behaviour is the most common and widely reported in epidemiological studies.[178] Self-reported fruit and vegetable intake per day was summed to produce a continuous measure and participants were categorised as meeting the current World Health Organisation (WHO) fruit and vegetable guidelines if 5 or more items per day were reported to be consumed.[270] This 2-item serving measure has shown a positive correlation with 24-hour dietary recall values (r=0.27) and fairly strong test-retest correlation coefficient (r=0.70).[271] The use of daily fruit and vegetable servings has been demonstrated as a good proxy measure for a healthy diet with studies showing a correlation with more comprehensive dietary assessments.[272]

2.2.4 Measurement of socio-demographic variables

Office workers reported their sex, age in years, educational attainment, marital status, work pattern (full- or part-time), salary band, height and weight. BMI was calculated as kg/m^2 and participants were categorised as either normal weight (<25 kg/m^2), overweight (25-29.9 kg/m^2) or obese (≥30 kg/m^2).[273] Reported highest educational attainment was coded into four groups (school level, further education, university degree or higher degree) and marital status was coded into two groups (married/cohabitating or single/divorced/widowed).

2.2.5 Statistical analysis

Cross-sectional

The data from the 2012 and 2014 surveys were pooled for the purposes of the cross-sectional analysis reported in this chapter as the participant characteristics were similar for both the 2012 and 2014 data (mean age = 44.2±9.9 vs 45.1±9.9 years, male = 43.9% vs 46.7%, married or cohabitating = 69.6% vs 70.8%, mean BMI = 27.2±4.9 vs 27.4±5.0, full-time work pattern = 82.7% vs 81.9%). Participants were excluded if they had missing data for sitting time (n=3,007), height/weight (n=61), physical activity (n=72), alcohol consumption (n=69), cigarette smoking status (n=57) and/or fruit and vegetable intake (n=1). The number of health behaviours (alcohol consumption, smoking status, physical activity and fruit & vegetable intake) that did not meet current guidelines were summed for all participants to produce an unhealthy behaviour score which could range from 0 unhealthy behaviours (i.e. participants met all guidelines regarding health behaviours) to 4 unhealthy behaviours (i.e. participants met no guidelines). For the analyses, the highest two categories (a score of 3 and 4) were condensed due to a small percentage of the sample scoring 4 (n=196; 2.7%) to produce four final categories (0, 1, 2 or ≥3 unhealthy behaviours).

Descriptive statistics stratified by unhealthy behaviour score and domain-specific sitting time (travel, work, TV viewing, computer-use, leisure-time) were examined and the differences between groups were analysed using chi-square, independent t-tests and ANOVAs. Pearson's correlational analyses tested the relationship between unhealthy behaviour score and each domain of sitting. Consequently, individual domains of sitting time were split into tertiles and multinomial regression analyses explored the odds of each domain having all possible unhealthy behaviour scores (ref = score of 0) in terms of domain-specific sitting time (ref = low sitting time). Domain-specific sitting time was split into tertiles based on the 33.3rd and 66.6th percentiles because currently there are no clinically meaningful cut-off points for sitting time in terms of health. However, due to grouping within the self-reported domain-specific sitting time data where participants typically reported similar values (i.e. 420 minutes of sitting at work), it was not possible to produce exactly equal tertiles. BMI, age, sex, marital status, survey year, salary band, work pattern and education were adjusted for in the final regression model.

Prospective

Office workers who provided two sets of data (i.e. responded to the 2012 and 2014 surveys) were compared with those who only provided baseline (2012) data for all variables to see if they were significantly different (n=806/4332). This was conducted to test for response bias in the prospective sample using t-tests [age in years, BMI (kg/m^2), domain specific sitting time in minutes/day, physical activity in days/week, alcohol consumption in units/week, fruit and vegetable consumption in portions/day] and chi-squared tests (gender, education, marital status, salary band, work pattern, smoking status, unhealthy behaviour score). T-tests were used to explore any changes in domain-specific sitting time, BMI, physical activity, alcohol and, fruit and vegetable consumption occurring between the 2012 and 2014 surveys in the prospective sample. Differences in unhealthy behaviour score and classification as healthy or unhealthy for individual health behaviours between 2012 and 2014 were analysed using chi-square tests. The associations between domain-specific sitting time at baseline and change in unhealthy behaviour score at follow-up was analysed using Pearson correlations. Following this, tertiles of domain-specific sitting time were used to explore the odds of increasing unhealthy behaviour score compared to maintaining/decreasing after two years using binary logistic regression. Baseline unhealthy behaviour score was adjusted for in the regressions.

Alpha was set at $p<0.05$ except for post-hoc tests in which this value was divided by the number of comparisons made. All analyses were conducted using IBM SPSS Statistics 24 for Windows.

2.3 Results

2.3.1 Cross-sectional

7,170 office workers (68.7% of those starting the surveys) provided sufficient data across the 2012 and 2014 surveys to be included in the cross-sectional analyses reported in this chapter. Participants had a mean age of 44.5±9.9 years, 55.0% were female, 70.1% were married/cohabitating and 82.4% worked full-time. A score of 2 (i.e. partaking in 2 unhealthy behaviours) was the most common unhealthy behaviour score (41.2%) with physical inactivity being the most prevalent unhealthy behaviour (with 77.6% of the sample not meeting guidelines). The most common health behaviour combination was physical inactivity and under consumption of fruit and vegetables (76.4%). On average office workers reported sitting for 643±160 minutes/day on a workday and 491±210 minutes/day on a non-workday. The majority of sitting time was accumulated at work on a workday (383±95 minutes/day) and whilst watching TV on a non-workday (173±101 minutes/day).

Table 2.1 shows the sample characteristics stratified by unhealthy behaviour score. There were significant differences between sexes and survey year for distribution of unhealthy behaviour score with males and those participating in the 2012 survey having a higher percentage scoring ≥3. Additionally, there were significant differences between marital status, education and work pattern groups with those married/cohabitating, educated to school level/further education and in full-time work having a greater proportion of participants exhibiting the highest unhealthy behaviour score (≥3). Furthermore, a significant difference was observed between salary bands with the highest percentage of office workers scoring ≥3 for the unhealthy behaviour score earning >£20,000-£25,000. Age was weakly, inversely correlated (r^2=-0.105, $p<0.01$) and BMI was weakly, positively correlated (r^2=0.077, $p<0.01$) with unhealthy behaviour scores.

Table 2.1: Sample characteristics stratified by unhealthy behaviour score

		Number of unhealthy behaviours			
	Total (n=7170)	0 (n=651)	1 (n=2439)	2 (n=2954)	≥3 (n=1126)
Year of survey[x]					
2012	4332 (60.4)	351 (53.9)	1467 (60.1)	1785 (60.4)	729 (64.7)
Sex[x]					
Male	3321 (45.0)	289 (44.4)	954 (39.2)	1313 (44.5)	665 (59.1)
Age					
mean±SD (years)	44.5± 9.9	45.9±9.8[a]	45.5±9.7[b]	44.1±9.8[abc]	42.7±10.1[abc]
Marital status[x]					
Married/cohabitating	5015 (70.1)	450 (69.1)	1765 (72.5)	2103 (71.3)	697 (62.0)
Education[x]					
School level	1427 (20.0)	124 (19.2)	475 (19.5)	568 (19.3)	260 (23.1)
Further education	2425 (33.9)	210 (32.5)	754 (31.0)	1022 (34.7)	439 (39.0)
University degree	1430 (20.0)	117 (18.1)	492 (20.2)	618 (21.0)	203 (18.0)
Higher degree	1867 (26.1)	196 (30.3)	711 (29.2)	737 (25.0)	223 (19.8)
Salary Band[x]					
>£10,000 - £15,000	196 (2.8)	20 (3.1)	66 (2.7)	89 (3.0)	21 (1.9)
>£15,000 - £20,000	988 (13.9)	83 (12.8)	272 (11.2)	415 (14.1)	218 (19.5)
>£20,000 - £25,000	2078 (29.2)	173 (26.7)	706 (29.1)	842 (28.7)	357 (32.0)
>£25,000 - £30,000	1671 (23.5)	150 (23.2)	576 (23.8)	695 (23.7)	250 (22.4)
>£30,000 - £35,000	807 (11.3)	89 (13.8)	292 (12.0)	321 (10.9)	105 (9.4)
>£35,000 - £40,000	762 (10.7)	70 (10.8)	283 (11.7)	309 (10.5)	100 (9.0)
>£40,000	623 (8.7)	62 (9.6)	229 (9.4)	266 (9.1)	66 (5.9)
Work pattern[x]					
Full-time	5881 (82.4)	545 (84.5)	1962 (80.9)	2370 (80.5)	1004 (89.4)
BMI category[x]					
Normal weight	2561 (35.7)	268 (41.2)	935 (38.3)	1015 (34.4)	343 (30.5)
Overweight	2287 (40.3)	276 (42.4)	954 (39.1)	1181 (40.0)	476 (42.3)
Obese	1722 (24.0)	107 (16.4)	550 (22.6)	758 (25.7)	307 (27.3)

n (%) unless otherwise stated

[x] significant difference between groups ($p<0.05$)

[abc] significantly higher age compared to other groups with the same subscript ($p<0.05$)

Table 2.2 shows domain-specific sitting time stratified by unhealthy behaviour score and classification for individual health behaviours (i.e. whether the guidelines were met or not). Participants who did not meet the guidelines for MVPA sat, on average for 12 minutes/day more at work compared to those who did meet the MVPA guidelines. These individuals also reported sitting for significantly longer during workday travel and workday/non-workday TV viewing. However, this group had a lower average sitting time during workday leisure-time compared to those who met physical activity guidelines. Compared to non-smokers, participants who smoked cigarettes reported higher amounts of sitting time when watching TV on a workday and non-workday and when working from home compared to non-smokers. Those exceeding the recommended alcohol consumption guidelines reported sitting for an additional 40 minutes/day whilst watching TV on workdays and non-workdays compared to those who met the guidelines for alcohol consumption. These individuals also reported sitting for longer at work, during leisure-time on workdays and non-workdays, and during non-workday computer-use. Conversely, those who met the alcohol guidelines also sat for longer whilst traveling on a workday compared to those who did not. Those who met the guidelines for fruit and vegetable intake reported sitting for less time at work, whilst using a computer on a non-workday and TV viewing on a work and non-workday compared to those who did not meet the daily fruit and vegetable intake guidelines.

Table 2.2 Domain-specific sitting time on a work and non-workday by unhealthy behaviour classification and score

			Domain-specific sitting time on a workday (mean±SD mins/day)					**Domain-specific sitting time on a non-workday (mean±SD mins/day)**				
	Guidelines met	n (%)	Travel	Work	TV viewing	Computer use	Leisure time	Travel	Work	TV viewing	Computer use	Leisure time
Total sample	-	7170 (100)	79±54	383±95	94±73	48±77	39±49	61±56	72±109	173±101	70±69	115±91
Physical activity	Yes	1605 (22.4)	74±57	374±97	90±70	48±77	41±50[x]	61±55	72±106	169±96	70±69	116±90
	No	5565 (77.6)	81±54[x]	386±94[x]	95±73[x]	48±77	38±48	61±56	72±110	174±102[x]	70±69	115±91
Alcohol consumption	Yes	5644 (78.7)	81±55[x]	381±96	89±70	49±79	38±48	61±55	71±106	164±96	69±67	114±89
	No	1526 (21.3)	73±53	391±88[x]	111±80[x]	47±72	41±53[x]	59±57	75±119	205±112[x]	74±75[x]	121±97[x]
Fruit & vegetable consumption	Yes	3206 (44.7)	80±55	380±97	89±70	48±79	40±50	60±54	71±103	161±92	66±63	117±91
	No	3964 (55.3)	79±54	385±93[x]	97±75[x]	48±76	38±48	61±57	73±114	183±107[x]	73±73[x]	114±90
Smoking status[z]	Yes	866 (12.1)	78±60	385±92	100±79[x]	44±75	39±52	57±55	89±124[x]	190±109[x]	71±76	119±102
	No	6304 (87.9)	79±54	383±95	93±72	49±78	38±48	61±56	70±107	170±97	69±68	115±89
Unhealthy behaviour score	0	651 (9.1)	79±57	370±101[ab]	81±68[ab]	46±79	42±50	62±57	69±98	150±86[ab]	66±64	117±91
	1	2439 (34.0)	80±55	381±97[a]	89±68[a]	50±80	39±48	60±53	72±104	161±92[ab]	66±64[a]	113±89
	2	2954 (41.2)	81±53	385±93[b]	93±73[ab]	48±76	38±48	61±57	69±109[a]	175±101[ab]	72±70	116±90
	3	1126 (15.7)	75±55	393±88[a]	111±81[a]	46±73	39±51	58±58	82±125[a]	207±117[a]	74±78[a]	117±97

[x] significantly higher sitting time compared to other group [ab] significantly higher sitting time than other groups with the same subscript

[z] No guidelines available for cigarette smoking: 'Yes' denotes smokers, 'No' denotes non-smokers.

Sitting whilst watching TV had the strongest positive association with unhealthy behaviour score with those having an unhealthy behaviour score of 3 reporting sitting for an average of 50 and 30 minutes/day longer whilst watching TV on workdays (r^2=0.165, p<0.001) and non-workdays (r^2=0.114, p<0.001) compared to those with a score of 0. Furthermore, sitting time at work (r^2=0.060, p<0.001) and working at home (r^2=0.024, p<0.045) were positively associated with unhealthy behaviour score with the highest unhealthy behaviour score group averaging more than 20 minutes/day more sitting at work compared to the lowest score group. Non-workday computer-use was also positively related to unhealthy behaviour score (r^2=0.043, p<0.001) but the difference between the highest and lowest unhealthy behaviour score groups was less than 10 minutes/day and there was no association with this domain on a workday. Sitting whilst travelling and during leisure-time were not significantly associated with unhealthy behaviour score on a workday or non-workday.

Tables 2.3 and 2.4 show the associated odds of each tertile of domain-specific sitting time with each unhealthy behaviour score. Office workers who sat for ≥6 hours/day at work were more likely to have an unhealthy behaviour score of 1 or above compared to those who sat for ≤6 hours/day. Sitting for ≥7 hours/day at work was associated with double the odds of being in the highest unhealthy behaviour score category compared to those sitting for ≤6 hours in the fully adjusted model which controlled for BMI, age, sex, marital status, survey year, salary, work pattern and education. Increased odds were also found for high sitters (≥2 hours) in the workday TV viewing domain who were 119% more likely to be in the highest unhealthy behaviour score category compared to low TV sitters (<1 hour). Conversely, sitting whilst using a computer on a workday for <1 hour was shown to lower the chances of having an unhealthy behaviour score of 3 by 31% compared to those who did not sit in this domain.

Table 2.3 Multinomial logistic regression models exploring the association between unhealthy behaviour score and sitting on a workday

Sitting Time Domain Tertile (mins/day)		Unhealthy Behaviour Score (0 = ref, n=651)					
		Unadjusted Model OR (95% CI)			Fully Adjusted Model[a] OR (95% CI)		
Travel	**n**	**1 (n=2439)**	**2 (n=2954)**	**3 (n=1126)**	**1 (n=2439)**	**2 (n=2954)**	**3 (n=1126)**
Low (0-<60)	2173	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Moderate (60-<90)	2127	1.07 (0.86, 1.34)	1.25 (1.00, 1.55)	1.17 (0.91, 1.50)	1.04 (0.83, 1.31)	1.21 (0.96, 1.51)	1.18 (0.92, 1.53)
High (≥90)	2870	1.04 (0.85, 1.28)	1.12 (0.92, 1.37)	0.90 (0.72, 1.14)	1.02 (0.82, 1.25)	1.08 (0.88, 1.33)	0.89 (0.70, 1.13)
Work							
Low (0-<360)	1669	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Moderate (360-<420)	1910	1.41 (1.11, 1.78)[xx]	1.48 (1.18, 1.87)[xx]	1.64 (1.25, 2.15)[xxx]	1.41 (1.11, 1.80)[xx]	1.52 (1.20, 1.92)[xx]	1.67 (1.26, 2.21)[xxx]
High (≥420)	3591	1.42 (1.15, 1.74)[xx]	1.62 (1.33, 1.99)[xxx]	1.96 (1.55, 2.48)[xxx]	1.38 (1.12, 1.71)[xx]	1.62 (1.32, 2.00)[xxx]	2.03 (1.59, 2.61)[xxx]
TV viewing							
Low (0-<60)	1930	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Moderate (60-<120)	1867	1.03 (0.83, 1.29)	0.86 (0.69, 1.08)	0.83 (0.64, 1.08)	1.03 (0.82, 1.29)	0.89 (0.71, 1.11)	0.93 (0.71, 1.22)
High (≥120)	3373	1.32 (1.07, 1.62)[x]	1.40 (1.14, 1.72)[xx]	2.07 (1.64, 2.63)[xxx]	1.37 (1.10, 1.70)[xx]	1.48 (1.20, 1.83)[xxx]	2.19 (1.71, 2.80)[xxx]
Computer use							
Low (0)	2733	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Moderate (1-<60)	1846	0.81 (0.66, 1.01)	0.81 (0.65, 0.99)[x]	0.62 (0.49, 0.79)[xxx]	0.81 (0.65, 1.01)	0.83 (0.67, 1.03)	0.69 (0.54, 0.89)[xx]
High (≥60)	2591	1.09 (0.89, 1.34)	1.05 (0.86, 1.29)	0.98 (0.78, 1.22)	1.14 (0.92, 1.41)	1.05 (0.85, 1.30)	0.92 (0.73, 1.17)
Leisure-time							
Low (0)	3298	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Moderate (1–60)	2791	0.93 (0.77, 1.12)	0.88 (0.73, 1.06)	0.81 (0.66, 1.00)	0.95 (0.78, 1.15)	0.90 (0.75, 1.09)	0.82 (0.66, 1.02)
High (>60)	1081	0.88 (0.69, 1.14)	0.84 (0.65, 1.07)	0.84 (0.63, 1.11)	0.92 (0.71, 1.19)	0.86 (0.67, 1.11)	0.81 (0.60, 1.08)

[a] Adjusted for BMI, age, sex, marital status, survey year, salary, work pattern & education. [x]$p<0.05$ [xx]$p<0.01$ [xxx]$p<0.001$

On a non-workday, sitting whilst travelling for ≥30 minutes/day was associated with a 25% reduction in the odds of having an unhealthy behaviour score of 3 compared to sitting ≤30 minutes/day even after controlling for confounding factors. Office workers who reported sitting for ≤2 hours whilst working at home were 40% less likely to have an unhealthy behaviour score of 3 compared to those who did not sit at all in this domain. Moderate sitters (1-<180 mins/day) in the working at home domain were also significantly less likely to have an unhealthy behaviour score of 2 compared to low sitters (0 mins/day) which remained significant after controlling for BMI, though not in the fully adjusted final model. Office workers who reported sitting for 2-3 hours and ≥3 hours/day on a non-workday whilst watching TV had a 76% and 196% increase in the odds of being in the highest unhealthy behaviour score category compared to those who reported sitting for <2 hours in the final adjusted model. No significant associations were found between unhealthy behaviour score and sitting whilst traveling on a workday, non-workday computer-use or leisure-time sitting on a work and non-workday.

Table 2.4 Multinomial logistic regression models exploring the association between unhealthy behaviour score and sitting on a non-workday

Sitting Time Domain Tertile (mins/day)		Unhealthy Behaviour Score (0 = ref, n=651)					
		Unadjusted Model OR (95% CI)			Fully Adjusted Model[a] OR (95% CI)		
Travel	**n**	**1 (n=2439)**	**2 (n=2954)**	**3 (n=1126)**	**1 (n=2439)**	**2 (n=2954)**	**3 (n=1126)**
Low (0 - <30)	2878	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Moderate (30 - <60)	2541	0.91 (0.75, 1.11)	0.98 (0.80, 1.19)	0.75 (0.60, 0.94)[x]	0.93 (0.76, 1.14)	1.00 (0.82, 1.22)	0.78 (0.62, 0.99)[x]
High (>60)	1751	0.89 (0.72, 1.11)	0.90 (0.72, 1.12)	0.74 (0.57, 0.94)[x]	0.91 (0.72, 1.13)	0.93 (0.74, 1.16)	0.75 (0.58, 0.97)[x]
Work							
Low (0)	4284	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Moderate (1 - <180)	1366	0.94 (0.76, 1.17)	0.74 (0.60, 0.92)[xx]	0.52 (0.40, 0.67)[xxx]	0.98 (0.79, 1.23)	0.81 (0.65, 1.01)	0.61 (0.47, 0.81)[xxx]
High (≥180)	1520	0.98 (0.78, 1.22)	0.89 (0.71, 1.03)	1.14 (0.90, 1.45)	1.01 (0.80, 1.26)	0.91 (0.73, 1.14)	1.15 (0.90, 1.48)
TV viewing							
Low (0 - <120)	3073	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Moderate (121 - <180)	1783	1.27 (1.02, 1.57)[x]	1.37 (1.11, 1.70)[xx]	1.71 (1.34, 2.20)[xxx]	1.32 (1.06, 1.64)[x]	1.44 (1.16, 1.78)[xx]	1.76 (1.37, 2.28)[xxx]
High (≥180)	2314	1.30 (1.05, 1.61)[x]	1.79 (1.45, 2.20)[xxx]	3.32 (2.63, 4.20)[xxx]	1.38 (1.11, 1.72)[xx]	1.82 (1.47, 2.26)[xxx]	2.96 (2.32, 3.77)[xxx]
Computer use							
Low (0 – <30)	1680	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Moderate (30 – <60)	3269	1.06 (0.85, 1.32)	1.07 (0.86, 1.32)	0.82 (0.64, 1.04)	1.04 (0.83, 1.29)	1.05 (0.84, 1.31)	0.85 (0.66, 1.09)
High (≥60)	2221	1.09 (0.86, 1.38)	1.21 (0.96, 1.53)	1.07 (0.83, 1.39)	1.14 (0.89, 1.45)	1.21 (0.95, 1.54)	0.95 (0.72, 1.25)
Leisure-time							
Low (0 – <60)	2916	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Moderate (60 – <120)	2141	0.99 (0.80, 1.22)	1.07 (0.87, 1.32)	0.95 (0.75, 1.20)	0.99 (0.80, 1.22)	1.09 (0.88, 1.34)	0.98 (0.97, 1.25)
High (≥121)	2113	0.91 (0.74, 1.12)	0.98 (0.80, 1.20)	0.95 (0.75, 1.19)	0.91 (0.73, 1.12)	0.98 (0.79, 1.21)	0.92 (0.73, 1.17)

[a] Adjusted for BMI, age, sex, marital status, survey year, salary, work pattern & education. [x]p<0.05 [xx]p<0.01 [xxx]p<0.005

2.3.2 Two-year follow-up

806 participants completed the survey in 2012 and 2014 so were included in the analysis which aimed to explore the associations between domain-specific sitting time and health behaviours over time. The included sample had a lower percentage of males, lower mean age, lower percentage classified as obese, higher percentage classified as normal BMI and a lower percentage of office workers in the lowest and highest education categories (Table 2.5). Additionally, the included sample sat more on average at work on a workday and less whilst doing work at home (Table 2.6).

Table 2.5 Descriptive table comparing the socio-demographic variables between the baseline only responders and prospective sample

		Baseline only (n=4332)	**Prospective sample† (n=806)**
Gender*	Male n (%)	1901 (43.9)	312 (38.7)
Age*	Mean years±SD	44.2±9.9	43.2±9.1
Marital status	Married/cohabitating n (%)	3015 (69.6)	549 (68.1)
Education n (%)*	GCSE or equivalent & lower	887 (20.6)	124 (15.4)
	A/S levels or equivalent	1400 (32.5)	268 (33.3)
	Undergraduate degree	864 (20.0)	277 (34.4)
	Higher degree	1162 (26.9)	136 (16.9)
Salary Band n (%)*	>£10,000 - £15,000	124 (2.9)	0 (0.0)
	>£15,000 - £20,000	660 (15.2)	110 (13.6)
	>£20,000 - £25,000	1248 (28.8)	240 (29.8)
	>£25,000 - £30,000	1008 (23.3)	200 (24.8)
	>£30,000 - £35,000	491 (11.3)	94 (11.7)
	>£35,000 - £40,000	418 (9.6)	90 (11.2)
	>£40,000	383 (8.8)	72 (8.9)
Work pattern	Full-time n (%)	3584 (82.7)	676 (83.9)
BMI n (%)	Normal weight	1573 (36.3)	309 (38.3)
	Overweight	1737 (40.1)	318 (39.5)
	Obese	1022 (23.6)	179 (22.2)

† data from the 2012 survey of the prospective sample

* significant difference between samples (p<0.05)

Table 2.6 shows the change in domain-specific and other health behaviours between 2012 and 2014. After 2 years, there was a significant increase in physical activity (0.3 days/week), sitting on a non-workday whilst traveling (5.2 minutes/day), working (13.8 minutes/day), during computer-use (8.2 minutes/day) and leisure-time (9.9 minutes/day). Alcohol consumption significantly decreased (-0.8 units/week) whereas fruit and vegetable intake and all other domains of sitting time did not change. The unhealthy behaviour score did change significantly after 2-years with less office workers scoring 2 and ≥3 compared to 2012. 55% had no change in health behaviour score, 22% decreased by 1, 16% increased by 1, less than 5% decreased by 2 or 3, 1.5% increased by 2 and none decreased by 4 or increased by more than 2. However, there were no differences in the proportion of office workers classed as healthy for fruit and vegetable intake or smoking. More people were classed as healthy for physical activity and alcohol consumption in 2014 compared to 2012.

There were no significant correlations between sitting time in any domain in 2012 and change in unhealthy behaviour score after 2 years. Additionally, in the binary logistic regression analysis, the odds of increasing unhealthy behaviour score between 2012 and 2014 were not significantly affected by high or moderate sitting time in any domain on a work or non-workday (compared to reference categories: maintaining or decreasing unhealthy behaviour score, low tertile of sitting time). This remained the same even after adjusting for 2012 unhealthy behaviour score.

Table 2.6 Descriptive table comparing domain-specific sitting and other health behaviours between the prospective sample and baseline only sample in addition to the change over time in the prospective sample

		Baseline only^ (n=4332)	2012† (n=806)	2014‡ (n=806)
Sitting time mean mins/day±SD	**Workday travel**	78±55	79±56	81±56
	Workday work#	381± 96	394±86	390±94
	Workday TV viewing	91±74	92±73	92±76
	Workday computer-use	44±75	44±76	42±67
	Workday leisure-time	36±49	36±47	37±48
	Non-workday travel*	60±60	59±55	64±51
	Non-workday work# *	64±106	56±103	70±110
	Non-workday TV viewing	171±104	176±108	178±110
	Non-workday computer-use*	66±67	68±73	77±76
	Non-workday leisure-time*	110±91	110±90	120±89
Physical activity	**Mean days/week±SD***	2.6±2.0	2.6±2.0	3.0±2.1
	Classified as unhealthy n (%)*	3464 (80.0)	647 (80.4)	595 (74.8)
Alcohol consumption	**Mean units/week±SD***	9.2±11.5	9.7±12.6	8.9±11.2
	Classified as unhealthy n (%)*	957 (22.1)	199 (24.7)	149 (18.8)
Fruit & vegetable consumption	**Mean portions/day±SD**	4.4±2.0	4.5±2.1	4.5±2.0
	Classified as unhealthy n (%)	2379 (54.9)	429 (53.3)	420 (52.8)
Smoking	**Classified as unhealthy n (%)**	550 (12.7)	96 (11.9)	82 (10.4)
Unhealthy behaviour score n (%)*	**0**	351 (8.1)	62 (7.7)	88 (11.3)
	1	1467 (33.9)	262 (32.6)	274 (35.1)
	2	1785 (41.2)	345 (42.9)	316 (40.5)
	≥3	729 (16.8)	135 (16.7)	102 (13.1)

^ data from the 2012 survey of the cross-sectional sample (excluding those in the prospective sample)

† data from the 2012 survey of the prospective sample

‡ data from the 2014 survey of the prospective sample

* significant difference between 2012 and 2014 (p<0.05)

significant difference between samples (p<0.05)

2.4 Discussion

The purpose of this study was to assess the prevalence of domain-specific sedentary behaviour in a large sample of office workers from the UK and links with multiple other health behaviours. On average office workers reported sitting for longer on a workday (643±160 minutes/day) compared to a non-workday (491±210 minutes/day) with the majority of sitting time accumulated at work on a workday (383±95 minutes/day) and whilst watching TV on a non-workday (173±101 minutes/day). Results showed an association between self-reported sitting with unhealthy behaviours, though the relationship differed depending on the domain of sitting. Sitting for ≥7 hours at work and ≥2 hours whilst watching TV on a workday both more than doubled the odds of partaking in 3 or more other unhealthy behaviours and sitting whilst watching TV on a non-workday for 3 hours nearly tripled the odds independent of BMI, age, sex and other confounding variables. Conversely, participants grouped into the moderate sitting time category whilst using a computer on a workday and working at home as well as 30 minutes or more of sitting whilst traveling on a non-workday, were associated with lower odds of having 3 or more other unhealthy behaviours. However, the magnitude was small and negligible differences were observed between the highest and lowest unhealthy behaviour score groups, with differences averaging less than 13 minutes. Sitting whilst traveling on a workday, non-workday computer-use and leisure-time sedentary behaviour domains were not associated with other unhealthy behaviours. Furthermore, there were no associations between domain-specific sitting time at baseline and change in unhealthy behaviour score. However, at the two-year follow-up, the majority of the sample had no change in unhealthy behaviour score and there were minimal changes observed in domain-specific sitting time and individual health behaviours.

Similar prevalence rates have been found in other observational studies measuring sitting time via the DSSTQ with Kazi and colleagues[46] observing 625±168 minutes/day sitting on a workday and 469±210 minutes/day on a non-workday. Bennie et al.[140] found that a sample of Australian office workers reported sitting for 540±146 minutes/day and for 300±67 minutes during working hours/day. However, 84% of this sample were classified as physically active (≥150 mins/week of moderate or ≥75 mins/week of vigorous-intensity physical activity or an equivalent combination of both) and daily sitting time was calculated using both workday and non-workday responses potential explaining the lower prevalence rates compared to the current study. Clemes and colleagues[123] found similar prevalence rates in a UK sample on a workday (626±222 minutes/day) but higher amounts were reported on a non-workday (616±280 minutes/day) compared to the current study. The difference in non-workday sitting time was due to higher TV viewing and sitting whilst traveling compared to the current study. However, a convenience sample of 56 adults was obtained in Clemes and colleagues' study compared to the large sample utilised in the current study which may explain the difference in findings.

Previous research which has also examined data from the Stormont study support the current study's findings. A 2016 study[46] explored the influences of socio-demographic factors on domain-specific sedentary behaviour and found a higher prevalence of sedentary behaviour on a workday (625±168 minutes/day) compared to a non-workday (469±210 minutes/day). These results are very similar to the current study with the only difference being that only the 2012 survey data was analysed in the 2016 paper (n=4436) compared to both the 2012 and 2014 surveys in the current study (n=7170). Furthermore, the 2016 study found that higher sitting times were reported by workers aged 18-29 years, obese workers, full-time workers and single/divorced/widowed workers highlighting high risk groups to be targeted by future interventions. Similarly, the current study found that these socio-demographic characteristics influenced domain-specific sedentary behaviour in the thus were controlled for in the analyses to account for any confounding. The 2016 study also concluded that interventions should target both workplace and leisure-time sedentary behaviours supporting the current findings due to finding that workers who reported high amounts of sitting at work also reported high amounts of sitting on non-workdays.

Munir and colleagues[262] also utilised the 2012 Stormont survey data and found a high prevalence of occupational sedentary behaviour (380±98 minutes/day) supporting the current study (383±95 minutes/day). Additionally, it was found that workers with lower reported occupational sedentary time had higher work engagement. Therefore, interventions to reduce occupational sedentary time have the potential to increase work engagement in addition to reduce the odds of partaking in multiple other unhealthy behaviours. However, the causality of these associations are yet to be established and there are no further data collection points planned for the Stormont study.

Large amounts of sitting time were reported in the workplace domain and this study was the first to explore if sitting at work is associated with alcohol consumption and fruit and vegetable intake, in addition to physical activity and smoking. Participants who met the guidelines for MVPA, alcohol and, fruit and vegetable consumption sat for significantly less time than those who did not in this domain. Physical inactivity had the strongest association with workplace sitting and office workers who did not meet MVPA guidelines reported sitting for 12 minutes/day longer on average than those who did. These individual associations explain why sitting at work was inversely correlated with unhealthy behaviour score and this finding is supported by previous research. Data from the AusDiab study[183] found that each 30-minute increase in leisure-time physical activity was associated with a decrease in the odds of men being in the highest occupational sitting group. Additionally, it was observed that men and women in this study who had low levels of occupational sitting were more likely to be active in their leisure-time.

The lack of association between smoking and sitting at work is supported by Tissot et al.,[274] who analysed a survey of employed adults in Quebec and found smoking did not influence work sitting. Uijtdewilligen and colleagues[275] measured weekday sitting time which incorporates sitting time at work in a large sample of young Australian women and found that high risk alcohol drinkers sat for significantly longer than low risk drinkers. The comparison between this study and the current study is limited due to measuring sitting time across the whole weekday, however no previous study has looked at sitting at work and alcohol intake specifically. Similarly, no study has explored fruit and vegetable intake in relation to this sitting domain, though one study found a positive association between energy intake (kJ/day) and occupational sitting in men from the AusDiab study.[183] High occupational sitters have also been shown to sit for longer outside of work compared to low occupational sitters which could also explain the positive association between the workday work domain and unhealthy behaviour score.[49] Thus, interventions are needed to decrease workplace sitting time in order to reduce other associated unhealthy behaviours including physical inactivity, alcohol overconsumption and fruit and vegetable underconsumption.

TV viewing on both a workday and non-workday were associated with all four health behaviours individually which explains the increased odds of a high unhealthy behaviour score. Potential mechanisms for this could be that TV viewing displaces time spent in MVPA[276] and is associated with increased unhealthy food and beverage consumption[277] which could displace fruit and vegetable consumption. Large differences in TV viewing time were shown in relation to meeting the alcohol consumption guidelines. Smoking can be increased by exposure to TV advertisements.[278] Hamer et al.,[279] analysed nearly 4000 adults from the 2003 Scottish Health Survey and found an inverse trend for physical activity and fruit and vegetable intake with those meeting the guidelines sitting less whilst watching TV or screen-based entertainment. Additionally, smokers reported sitting for longer in this domain than non-smokers and this was also seen for alcohol intake. The findings of the current study are further supported by Pereira and colleagues[280] who found that the number of TV viewing hours per day was positively associated with smoking and low fruit consumption in a large sample from the 1958 British birth cohort. Therefore, future research is needed to explore the link between sitting whilst watching TV and other unhealthy behaviours to reduce these behaviours and associated negative health outcomes.

The findings of this study have many implications. Firstly, it highlights the importance of sedentary behaviour as it is highly prevalent, maintained over time and associated with current ‘SNAP’ health behaviours thus, should be considered as part of these lifestyle measures in research and health practise. The results have shown that office workers’ sedentary time is mostly accumulated at work but also large amounts of sedentary time occur whilst watching TV and both domains are associated with partaking in multiple other health behaviours. A significant number of multicomponent interventions have shown reductions in sedentary time at work using active workstations and additional strategies[281] but have not targeted or measured the effect on sedentary time whilst watching TV. Future interventions should consider sedentary behaviours both at work and during TV viewing in order to measure the impact on health and other health behaviours. Furthermore, this study has provided the rational for further research into the causality of the association between sedentary behaviour and other health behaviours so interventions can be designed to reduce the negative health consequences of these behaviours.

Study limitations and strengths

The study is limited because causality could not be confirmed thus it is unclear as to whether high sitting time in key domains is a result of a high unhealthy behaviour score or the reverse. Regardless, this is the first study to look at the relationship between domain-specific sitting time and multiple unhealthy behaviours. Furthermore, the prospective data showed that sitting time and other health behaviours are maintained over time, thus highlighting the importance of the association and warranting further research into the longitudinal trend to establish causality. The large confidence intervals and wide range of sitting times in some domains could be due to the self-report measure and introduction of recall bias. The validity and reliability of the DSSTQ have been found to be low for certain domains including leisure-time on a workday (validity r=0.21-0.26, reliability r=0.34-0.38), weekend day travel (r=0.15-0.20, r=0.31-0.40), working from home (r=0.13-0.38, r=0.23-0.53) and weekend leisure-time (r=0.19-0.42, r=0.31-0.32).[122] This could be partly explained by the fact that sedentary behaviours often occur simultaneously increasing recall difficulty.[93] Furthermore, the DSSTQ only measures total sitting time in each domain thus does not account for breaks in sitting time which can be beneficial for health.[149] Objective measures of sitting time have higher validity and measure how sitting time is accumulated but cannot provide information on the context of the behaviour which is a strength of this study as it has identified key domains for targeted interventions.[282]

A second limitation is that the physical activity measure used in the survey was developed and validated in accordance with previous UK physical activity guidelines thus office workers were categorised as healthy or not based on an outdated reference.[265] Additionally, this single-item measure of MVPA has been shown to underreport activity on average by -1.59 days compared to accelerometery.[266] The other health behaviours were also self-reported and thus could be influenced by inaccurate recall and biases, particularly social desirability bias. Short-term recall measures of alcohol intake can miss infrequent alcohol consumption by asking for ‘a typical week’ and have issues related to memory.[268] On the other hand, utilising self-report measures allowed for a large sample to be obtained and the information was dichotomised reducing the influence of biases. We cannot, however, rule out the possibility of residual confounding. The survey had a low response rate which could influence the representativeness of the sample and inference of the results to the wider population. However, similar response rates are have been reported in workplace wellness studies.[177,283] Furthermore, a large sample was obtained and the average sitting time found was similar to previous studies in office workers.[47]

2.5 Conclusion

Office workers have a high prevalence of sedentary behaviour with the majority occurring in the workplace domain. Additionally, sitting whilst TV viewing is the most prevalent sedentary behaviour on a non-workday. High amounts of sitting time in either of these domains was associated with partaking in multiple other unhealthy behaviours. Additionally, sitting time in the work and TV viewing domains in addition to partaking in multiple unhealthy behaviours were maintained over time. Future research is needed to establish the direction of causation for this association. Interventions should target reducing sitting time at work and whilst watching TV in addition to improving other health behaviours.

Chapter 3: Study Two

The short- and long-term effects of a pilot workplace intervention on sedentary behaviour, physical activity and health markers

Overview

The previous chapter highlighted the workplace as a key domain for interventions as it is where the majority of sedentary time is accumulated in office workers. Additionally, sitting at work was associated with partaking in multiple other unhealthy behaviours thus it is important to reduce it. This chapter describes a pilot RCT study which implemented a multicomponent intervention to reduce sedentary time in office workers. The effects were measured at 3 months and 12 months thus adding to the limited research on the long-term impact of such interventions as discussed in Chapter 1. Therefore, this study addressed thesis objectives:

4. To investigate whether a multicomponent, workplace intervention adopting individual and environmental strategies was an effective way to reduce sedentary time in office workers over the short-term and long-term

5. To investigate whether there was any effect of the multicomponent intervention on health markers and physical activity.

3.1 Introduction

As discussed in the previous two chapters, the prevalence of sedentary behaviour has increased dramatically over the last thirty years due to advances in technology[135] and is highly prevalent in office workers. Chapter 2 found that over 10 hours on a workday and eight hours on a non-workday per day were spent sitting in a large sample of Northern Irish Civil Servants. Additionally, more than 6 of the 10 hours per day spent sitting on a workday took place at work. Similar amounts were found in another sample of UK employees, with an average of 6.5 hours spent sedentary at work out of a total 11 hours sitting per day.[47] Additionally, previous research has shown that workers accumulating high occupational sedentary times also have high amounts of leisure sedentary time.[49] This is a worldwide health concern as sedentary behaviour is associated with an increased risk of type 2 diabetes, obesity, metabolic syndrome, cardiovascular disease, some forms of cancer, depression and all-cause mortality.[9–14,16,28,29,48,284] Therefore, interventions are needed to reduce sedentary time in office workers.

Previous workplace interventions have focused on the use of education and/or counselling,[55–60] pedometers,[207,210,214] and computer prompts[206,213,215] to reduce sedentary time in office workers with mixed results. The main limitations of these interventions were the lack of environmental change to provide workers with the opportunity to change their behaviour and focusing on increases in physical activity with sedentary behaviour as a secondary aim. Other studies have provided workers with activity-permissive workstations giving them the opportunity to reduce sedentary behaviour by standing or moving whilst working.[61,66,226–228,234] However, without educating participants on the dangers of high amounts of sedentary time, only small reductions were reported.[53,61,62,234] The BCW framework[72] suggest that all deficits in the COM-B elements need to be addressed in order to change behaviour thus interventions over the last 5 years have adopted a multicomponent approach providing workers with workplace environment changes, education/counselling and additional tailored strategies by the organisation's management.[187,188,238,240] The majority of these studies have found significant reductions in workplace sedentary time, prolonged (≥30 minutes) sedentary time and an increase in sedentary time breaks for the intervention compared to control group after 4 weeks and 3 months.[53,61]

There is however, limited research regarding the long-term effects of these interventions on workplace sedentary time as most studies are less than 3 months in duration.[281] Results from a natural experiment[285] showed that office workers who received a sit-stand workstation and 4 months of sitting-specific motivational support reduced their sedentary time at work after 4 months and maintained this reduction after 18 months. These results are supported by Garland and colleagues[286] who found that employees who were given an adjustable workstation reported less sitting time after 3 and 6 months compared to employees with traditional desks. Similar results were found in a 12-month quasi-experimental study[287] with reduced sitting time in the multicomponent intervention group compared to the control group. However, these studies lack randomisation[285] and an objective measure of sedentary behaviour.[286,287]

An Australian study[189] addressed these limitations with a long-term cluster-RCT evaluating the effects of a multicomponent intervention on objectively measured workplace sedentary time. The intervention incorporated organisational, physical environment and individual behaviour change strategies and sedentary time was reduced by 45 minutes/8-hour workday after 12 months.[242] A recent study by Munir and colleagues[247] supports these findings, with this study also adopting a cluster RCT design. The intervention group who received a height-adjustable workstation in addition to multiple individual elements including a self-monitoring and prompt tool, reduced workday sedentary time by 83 minutes/workday compared to the control group at 12 months.[73]

Although research into the long-term effects of workplace interventions to reduce sedentary time are emerging, the literature is limited with only one UK study to date. Therefore, the aim of this study was to investigate the effectiveness of a pilot multicomponent workplace intervention to reduce sedentary time over the short (3 months) and long-term (12 months).

3.2 Methods

3.2.1 Design & Participants

This pilot intervention study adopted an RCT design with 2-arms (control and intervention) and followed-up participants at 3- and 12-months post-baseline. A pilot study design was chosen to explore whether the intervention components could work together and if the protocol was appropriate.[288] A convenience sample of Loughborough University office workers were recruited via online university notice boards, departmental emails, posters and flyers. Participants were included if they were aged 18 years or older, worked at least 0.6 full time equivalent or 3 days per week in an office at Loughborough University, had a primarily sedentary job, were able to wear activity monitors with no allergies to medical tape and be physically capable of increasing standing times by at least 2 hours per workday. Participants were excluded if they were pregnant, had any blood-borne viruses, non-ambulatory or if they had any planned absences of over 1-week during the study period. The protocol was approved by the Loughborough University ethics committee and the study was conducted in accordance with the Declaration of Helsinki with all measures undertaken at Loughborough University by a trained researcher (DBS checked).

60 office workers were recruited and invited to take part in focus groups during the development phase to inform the intervention components (see 3.2.4). Based on availability, two focus groups took place in November 2014 with elven office workers in each one (total n=22). Baseline measures (described below) were taken in January/February 2015 following participants providing written informed consent and health screening. Once baseline measurement session were completed, participants were individually randomised into the intervention (n=30) or control group (n=30) by assigning a number to each participant and using an automated random number generator.[289] An individual randomisation method was chosen because participants were spread across the university campus and were based in numerous different buildings and offices. After the 3-month intervention, the baseline measures were repeated (May 2015) for all participants who remained (n=54). Office workers who were lost to follow-up (n=6) could not complete the study due to leaving the university (n=2) or for personal reasons (n=4). Additionally, the intervention participants were

invited to attend a post-intervention focus group in July 2015 to provide feedback and based on availability, 10 office workers attended.

The intervention components including the emails and step challenges ceased after 3 months but the sit-stand desks remained. At 12 months post-baseline (January/February 2016), the same measures were repeated (9 months post-intervention) to measure the long-term effects of the intervention. 36 office workers completed the 12-month follow-up assessments with 24 office workers lost to follow-up. Reasons for non-completion included: no response to emails (n=16), left the university (n=6), time constraints (n=1) or did not want to continue (n=1).

3.2.2 Measurement of health markers

Office workers self-reported their sex, age, ethnicity and highest level of education attained at baseline. In the laboratory, resting blood pressure and heart rate were measured following the European Hypertension Society recommendations[290] using the Omron Intellisense M7 Upper Arm monitor (Omron Ltd, UK). Participants were seated with their back supported and arm resting on a table. The first measurement was taken after 5 minutes of rest where the participant was immobile, not talking, relaxing with legs uncrossed. Two further measurements were taken at 2-minute intervals following the same procedure. The M7 monitor has been shown to be a valid measure of blood pressure and is recommended for professional use.[291] Height was measured in duplicate using a portable stadiometer (Seca 206, Oxford, UK) without shoes. Weight and body composition were assessed via bioelectrical impedance analysis (Tanita BC-418 MA Segmental Body Composition Analyser, Tanita Ltd, UK) and BMI was calculated by the monitor as kg/m^2. Percent body fat measured using the Tanita BIA BC-418 has been shown to be highly correlated with dual-energy X-ray absorptiometry (DEXA).[292]

Waist circumference was measured at the midpoint between the upper edge of the iliac crest and the inferior border of the last palpable rib using anthropometric tape in duplicate. Hip circumference was taken from the widest part of the buttocks with the tape parallel to the floor and waist-to-hip ratio was calculated. 8-hour fasted finger-tip capillary blood measures were taken after heating the hand in a warm-water bath for 5 minutes. Blood glucose and triglycerides were measured using the Accutrend® Plus Complete System (Roche Diagnostics, Mannheim, Germany) which has shown good reproducibility and high concordance with venous laboratory methods in adults.[293] HDL Cholesterol and Total Cholesterol were measured using the Reflotron Blood Analyser (Roche Diagnostics, Mannheim, Germany) which has shown good agreement with conventional wet chemistry methods and is recommended for establishing lipid profiles.[294] LDL Cholesterol was calculated using Friedewald's formula.[295]

3.2.3 Sedentary time, standing and physical activity measurements

Sedentary time, number of sit-stand transitions (transitions), standing time, number of steps and stepping time were measured objectively using the activPAL3 inclinometer. As discussed in Chapter 1, the activPAL is the gold standard measure of sedentary time in free-living conditions[127] in addition to being a valid and accurate measure of standing and stepping time.[95,104,296–299] The activPAL was initialised using the manufacturer proprietary software (activPAL Professional v.7.2.29, firmware version 3.107) and set to record for 8 days from the start of each participant's measurement session. The default sampling frequency (20 Hz) and minimum sitting/upright time period to define a new posture (10 seconds) were used as recommended by the manufacturer. The monitor was then waterproofed by placing it in a nitrile sleeve and wrapping it in hypoallergenic medical dressing (BSN Hypafix). The orientation figure was redrawn on the waterproof covering to ensure the monitor was worn correctly. Participants attached the activPAL to the midline anterior aspect of the upper thigh using a patch of pre-cut hypoallergenic medical dressing during the baseline or follow-up measurement sessions. Participants were given additional patches to reattach the monitor if needed during the measurement period. The monitor was deployed for 24-hours per day for 7 full-days which did not include the initial day the device was attached. An instruction sheet was given to participants reiterating these instructions with associated pictures (Appendix 3.1).

Light physical activity and MVPA was measured using the ActiGraph GT3x+ accelerometer. The device was initialised at a 100hz frequency using the manufacturer proprietary software (ActiLife v6.11.8, firmware version 2.0.0) and set to record for 8 days from the start of each participant's measurement session. The ActiGraph was attached to an elasticated belt worn around the waist above the mid-line of the right thigh and deployed during the measurement session to ensure the correct placement.

Participants were asked to wear the ActiGraph during waking hours except for water-based activities. The ActiGraph has been shown to be a reliable tool for measuring physical activity in adults in free-living conditions.[300] A diary was also completed to establish wear, sleep/wake and work times over the 7 days of device deployment (Appendix 3.1).

3.2.4 Intervention

The pilot multicomponent intervention was informed by the focus groups where discussions were based around the COM-B model of behaviour change as detailed in Chapter 1 and were completed when data saturation was reached (see Appendix 3.2 for focus group schedule).[72] Questions included: 'Would you say you are physically capable of reducing your sitting time at work?' (Capability) Can you think of any feasible strategy to help you to break up your sitting time in your working space?' (Opportunity) 'Would you say that being able to regularly break up sitting would have any impact in your workplace?' (Motivation). The discussions were digitally recorded, transcribed verbatim and subsequent ideas for intervention components were identified.

Based on the focus group feedback, the intervention group received a sit-stand desk (Ergotron Workfit-S) which was attached to their current workstation by the lead researcher with verbal instructions on how to raise and lower the desk. An educational leaflet was given to the intervention participants highlighting the benefits of reducing sedentary time with tips on how to achieve this including ideas for 5- and 10-minute breaks whilst working (Appendix 3.3). In addition, the leaflet included maps of walking routes around campus ranging from 10-25 minutes duration and stated the estimated calories burnt (Appendix 3.4). Intervention participants were given pedometers (New Lifestyles NL-800) and an associated paper diary to record daily step counts. The participants self-recorded step counts were then emailed to the lead researcher and these values informed the individually tailored step count challenges which took place once per month for the duration of the intervention (3 months). A league table for the step count challenges was emailed to all intervention participants during these weeks. Additional motivational emails were sent to individual participants every 2 weeks asking about progress, any changes made, completed walking routes and goals for the subsequent week. Feedback on health markers was also provided after each measurement session (baseline, 3 and 12 months, Appendix 3.5).

Control arm

The control group completed all the same measures as the intervention group and received feedback on their health measures at baseline, 3 months and 12 months. Control participants also received an educational leaflet highlighting the benefits of reducing sitting time with tips on how to achieve this including ideas for 5- and 10-minute breaks whilst working (Appendix 3.3). Between measurement sessions participants were asked to maintain their usual behaviour.

Intervention acceptability

Following the 3-month intervention, the intervention acceptability was assessed via a focus group held with the intervention participants only (see Appendix 3.6 for schedule). Questions included: 'Overall how would you describe your experience of using a standing desk?' 'Have you seen any changes in the time you spend sedentary?' 'What's your opinion on the step count challenges?' The discussions were digitally recorded and lasted 45 minutes in total. The recordings were transcribed verbatim and initial codes were generated. Subsequently, the codes were collated, inductive themes identified and reviewed with supporting quotes.

3.2.5 Data processing

activPAL data were downloaded using the activPAL Professional v.7.2.29 software in 15-second epochs and processed manually using a customised Microsoft Excel macro[301] referring to individual participant self-report diaries. Sleep was excluded and identified as the last standing - sitting/lying transition to the first sitting/lying-standing transition matching the participant diaries. Additionally, the data 60 minutes prior and post each sleeping bout was explored and included as sleep if sitting/lying was ≥30 minutes and <20 steps were recorded.[302] During sleeping bouts, any standing time recorded with <20 steps was included as sleeping time. Participants were included if they had worn the activPAL for at least 4 valid days including 1 non-workday and 3 workdays. Additionally, the first day of wear for each measurement period was discarded to minimise any reactivity bias. A valid day was defined as ≥10 hours wear time.[303] Additional non-wear (not recorded in participant diaries) was identified by ≥3 hours in either a sitting/lying or standing position with no transitions.[304] The total amount of steps, transitions and time spent sitting or lying (sedentary), standing or stepping were calculated by summing the time spent in these behaviours during work time and non-work time in addition to over a whole workday and non-workday using participant diaries. The percentage time spent sedentary, standing and stepping was calculated by dividing the summed values by the wear time and multiplying by 100 to produce comparable data.[303] Step counts and the number of transitions were calculated per hour of wear time by dividing by wear time and multiplying by 60. Activity outcomes were then averaged across valid workdays and non-workdays.[242]

ActiLife software (v.6.11.8) was used to download and process the ActiGraph data in 60-second epochs. A valid day was defined as >10 hours wear time and participants were included if they had at least 4 valid days including 1 non-workday and 3 workdays. Freedson Adult (1998)[96] cut-points applied to the vertical axis were used to define light intensity physical activity (100-1951 cpm) and MVPA (≥1952 cpm). Continuous strings of zero counts lasting for ≥60 minutes were classified as non-wear and excluded from the analysis.[305] Additionally, participant diary information was imported to the software using the 'log diary function' to identify work and non-working hours activity. The data were summarised as the number of minutes participants had spent in light intensity physical activity and MVPA during work time, non-work time and on a whole workday and non-workday. Proportions of wear time were then calculated.

3.2.6 Statistical analysis

Sedentary, standing, stepping time, light physical activity, MVPA and physiological measures were confirmed to be normally distributed by the Shapiro-Wilk test therefore parametric statistical tests were performed. Independent samples t-tests and chi-squared tests explored the differences between participants who completed the follow-up measures and those who did not. Descriptive statistics were produced for all variables with mean ± standard deviation (SD) reported. To control for differences between wear times sedentary, standing, stepping, light physical activity and MVPA were analysed in tests of difference as proportions of wear time. Mixed ANOVAs explored the group x time interactions for all variables and partial eta squared (n^2) was computed to assess the overall effect sizes with $n^2 \geq 0.010$ indicating small, ≥0.059

medium and ≥0.138 large effects for each variable.[306] Due to a reduced sample size at the 12-month follow-up, only descriptive statistics were produced and discussed. All analyses were conducted using IBM SPSS for Windows version 24.

3.3 Results

Figure 3.1 shows the flow of participants through the study. 60 office workers participated in the baseline measures with 43 (72%) providing valid activPAL data at the 3-month follow-up. There were no significant differences between compliant and non-compliant participants in terms of sex, ethnicity, age, or baseline activPAL and health measures ($p>0.05$). The sample was 72% female with 95% white ethnicity and 35% of participants had a university degree. The average age was 43±11 years and the mean BMI was 25±7 kg/m^2. The control and intervention groups did not differ significantly in terms of sex, ethnicity or BMI ($p>0.05$) however, the control group had a significantly younger mean age (38.6±11.0 years) compared to the intervention group (46.9±10.3 years, $p=0.015$). The average activPAL wear time at baseline was 931±38 minutes for a workday and 887±68 minutes on a non-workday. Wear time was similar at the 3-month follow-up with an average of 928±49 minutes on a workday and 883±152 minutes on a non-workday.

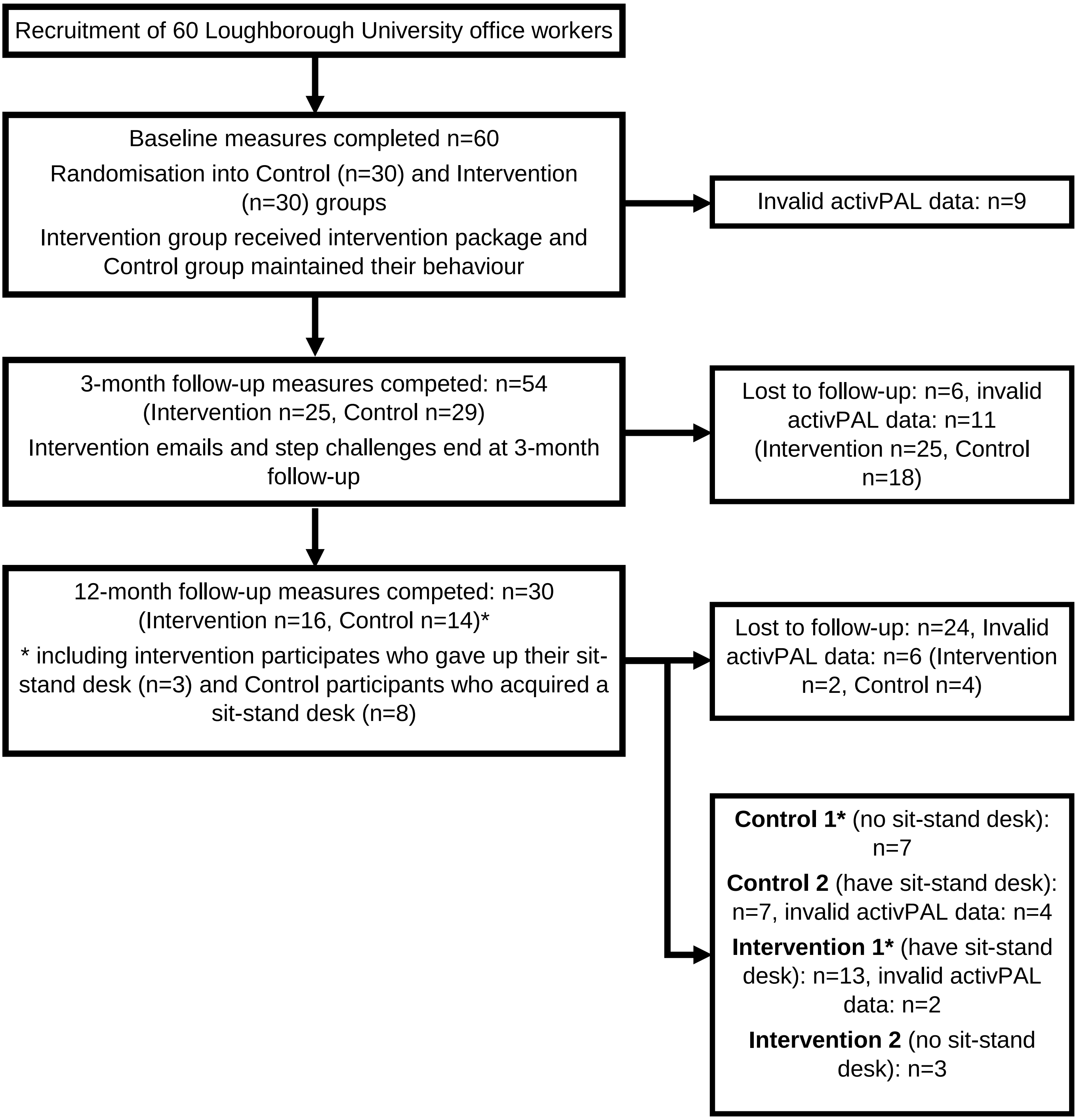


Figure 3.1 Flow diagram of the study sample size and activPAL data available

*only Control group 1 and Intervention group 1 were included in the analyses

3.3.1 3-month follow-up results

Changes in sedentary, standing and stepping time

At baseline on a workday, 60.0±11.6% of activPAL wear time was classified as sedentary, 28.8±10.4% standing and 11.2±2.9% stepping compared to 55.9±12.6% sedentary, 31.5±10.0% standing and 12.6±4.7% stepping on a non-workday for the sample as a whole. During working hours, 62.0±19.3% of wear time was classified as sitting, 27.5±16.8% standing and 9.5±3.0% stepping compared to 58.0±10.9% sitting, 28.6±10.9% standing and 13.4±5.4% stepping during non-working hours on a workday. Table 3.1 shows the change in time spent sedentary, standing, stepping, transitions, light physical activity and MVPA between baseline and the 3-month follow-up for the intervention and control groups. There were no significant group x time interaction effects for any of the sitting, standing or stepping variables. However, at the 3-month follow-up, the intervention group had lower amounts of sitting at work (-11% of wear time, n^2=0.057) and sitting overall throughout waking hours on a workday (-5.8% of wear time, n^2=0.051) compared to the control group. Additionally, the intervention group had higher amounts of standing at work (9.9% of wear time, n^2=0.050) and on a workday overall (5.2% of wear time, n^2=0.048) compared to the control group.

The intervention group on average increased the amount of time spent stepping (1.8% of wear time, n^2=0.041) and step counts (108 steps/hour of wear time, n^2=0.064) on a non-workday compared to the control group. Conversely, the number of sit-stand transitions was reduced by the intervention group during working hours (-0.27 transitions/hour of wear time, n^2=0.057) and on a workday overall (-0.47 transitions/hour of wear, n^2=0.080) compared to the control group.

Table 3.1 Baseline and 3-month follow-up change in activity measures for the intervention and control group (mean±SD)

		Intervention group (n=25)			Control group (n=18)			Intervention – Control group change#	Group x Time interaction
		Baseline	3-month follow-up	Change	Baseline	3-month follow-up	Change		n^2
Work	**Sedentary % of wear time**	59.0±18.5	51.1±21.8	-7.9±25.1	69.0±16.9	72.2±11.9	3.1±18.1	-11.0	0.057
	Standing % of wear time	31.5±16.8	39.4±21.4	7.9±24.3	21.7±15.4	19.7±10.5	-2.0±16.9	9.9	0.050
	Stepping % of wear time	9.5±3.4	9.5±4.1	0.1±4.6	9.3±3.2	8.1±2.8	-1.2±3.3	1.3	0.021
	Steps/hour wear time	514±187	497±173	-16±209	536±195	478±190	-58±194	42	0.011
	Transitions/hour wear time	3.07±1.10	2.41±0.96	-0.67±1.55	2.81±0.75	2.78±0.87	-0.4±0.75	-0.27	0.057
	activPAL wear time (mins/d)	486±62	461±58	-25±62	499±78	486±59	-13±62	-12	0.011
	Light PA % of wear time	21.9±7.2	20.2±7.0	-1.7±6.6	16.5±4.6	17.8±5.0	1.2±4.5	-2.9	0.056
	MVPA % of wear time	3.5±1.9	4.0±1.6	0.5±2.1	4.3±2.0	3.7±1.2	-0.7±1.9	1.2	0.088
	ActiGraph wear (mins/d)	487±61	467±7	-20±62	500±77	484±62	-16±61	-4	0.001
Non-work	**Sedentary % of wear time**	58.7±10.7	57.7±14.6	-1.0±11.4	57.1±11.4	56.3±14.3	-0.7±8.4	-0.3	0.000
	Standing % of wear time	28.9±8.4	29.4±11.9	-0.5±9.1	28.1±8.9	28.0±10.7	0.1±6.1	-0.6	0.001
	Stepping % of wear time	12.5±5.3	12.9±4.5	0.5±5.3	14.2±5.4	14.2±4.6	0.0±2.9	0.5	0.003
	Steps/hour wear time	574±268	638±275	64±283	711±314	729±315	18±140	46	0.030
	Transitions/hour wear time	3.31±0.97	3.23±0.96	-0.08±0.77	3.59±1.15	3.67±1.34	0.08±1.10	-0.16	0.001
	activPAL wear time (mins/d)	448±79	466±74	17±69	429±83	446±69	17±72	0	0.000
	Light PA % of wear time	32.0±7.4	30.7±6.2	-1.3±6.3	34.3±8.4	33.3±10.5	-1.0±7.3	-0.3	0.000
	MVPA % of wear time	3.5±2.2	3.5±2.4	0.0±2.6	3.9±2.6	4.5±2.8	0.6±3.0	-0.6	0.012
	ActiGraph wear (mins/d)	394±87	436±9	43±76	381±101	398±67	18±64	25	0.031
Workday	**Sedentary % of wear time**	58.9±10.2	54.3±12.5	-4.6±13.8	61.6±13.5	62.8±12.6	1.2±10.7	-5.8	0.051
	Standing % of wear time	30.3±9.1	34.5±12.6	4.2±12.8	25.1±10.0	24.1±8.3	-1.0±9.7	5.2	0.048
	Stepping % of wear time	10.9±2.7	11.2±3.1	0.3±2.9	11.4±2.9	11.4±4.0	0.0±2.9	0.3	0.003
	Steps/hour wear time	560±168	591±202	31±175	595±172	593±206	-2±147	33	0.010
	Transitions/hour wear time	3.27±0.92	2.92±0.87	-0.36±0.96	3.10±0.67	3.20±0.67	0.11±0.41	-0.47	0.080
	activPAL wear time (mins/d)	934±44	926±56	-8±41	927±30	932±40	5±42	-13	0.024
	Light PA % of wear time	27.0±5.7	26.1±5.3	-0.9±3.8	25.9±6.2	25.6±7.5	-0.3±5.2	-0.6	0.005
	MVPA % of wear time	4.0±1.4	3.5±2.4	0.4±1.8	4.9±2.2	4.3±1.5	-0.6±1.8	1.0	0.073
	ActiGraph wear (mins/d)	881±76	904±70	23±73	881±66	883±41	2±50	21	0.026
Non-workday	**Sedentary % of wear time**	56.1±13.2	54.7±11.1	-1.4±11.3	56.0±12.4	55.6±16.1	-0.4±11.3	-1.0	0.002
	Standing % of wear time	32.3±11.0	31.7±8.9	-0.6±10.2	30.0±9.0	29.3±11.7	-0.7±9.1	0.1	0.000
	Stepping % of wear time	11.6±3.6	13.6±4.3	2.0±4.1	12.9±4.2	13.2±5.5	0.2±4.4	1.8	0.041
	Steps/hour wear time	556±208	670±271	113±259	638±214	622±297	15±234	108	0.064
	Transitions/hour wear time	3.17±0.93	3.23±0.96	0.06±0.77	3.44±1.16	3.67±1.34	0.23±0.74	-0.17	0.013
	activPAL wear time (mins/d)	901±60	891±193	-11±199	868±75	872±67	4±70	-15	0.002
	Light PA % of wear time	32.5±8.6	34.3±9.7	1.8±7.7	31.5±11.3	34.0±13.4	2.4±9.9	-0.6	0.002
	MVPA % of wear time	3.5±2.4	4.3±2.7	0.8±2.7	5.5±2.7	5.2±4.7	0.3±4.0	0.5	0.025
	ActiGraph wear (mins/d)	866±74	874±71	7±54	813±84	833±64	20±66	-13	0.012

mean difference between groups

Changes in physical activity and health markers

No significant group x time interaction effects were observed for any of the physical activity variables. However, large effect sizes were found for the amount of time spent in MVPA during working hours (1.2% of wear time, n^2=0.088) and on a workday overall (1.0% of wear time, n^2=0.073) in favour of the intervention compared to the control group. The amount of time spent in light physical activity was also reduced by the intervention group compared to the control group (-2.99% of wear time, n^2=0.056).

Table 3.2 shows the change in physiological outcomes for the control and intervention groups between baseline and the 3-month follow-up. There were minimal changes in physiological measures over time with the intervention group reducing waist circumference (-1.9 cm, n^2=0.050), waist-to-hip ratio (-0.03, n^2=0.053), resting heart rate (-4.5 beats/minute, n^2=0.110), HDL-Cholesterol (-0.11 mmol/L, n^2=0.047) and total cholesterol (-0.19 mmol/L, n^2=0.043). However, these results were not statistically significant as no significant group x time interaction effects were found.

Qualitative feedback

The post-intervention focus group revealed that the office workers found the intervention to be highly acceptable. Participants perceived the intervention to have benefited their health: ‘I have lost weight’, ‘I feel more relaxed at work’, ‘my previous back, neck and shoulder pain has gone’. The main theme that emerged was that participants were more aware of their sedentary time and number of steps thus they felt the intervention had reduced their sedentary time. Other benefits mentioned were: ‘100% better work performance’, ‘concentration has gone up’, ‘less claustrophobic’. The sit-stand desk was the most liked aspect of the intervention and none of the participants wanted to go back to a traditional desk. However, negative aspects of the sit-stand desks including the lack of desk space and space for only one screen were mentioned. The pedometers were also highly popular and participants were motivated by monitoring their steps. Conversely, the step challenges were disliked: ‘artificial’, ‘not motivating’, ‘ashamed if at the bottom’. One participant suggested that focusing on increasing your own score would be better than competing with other people. Overall participants said the experience was good and that they would all recommend the intervention to a friend.

Table 3.2 Baseline and 3-month follow-up change in health markers for the intervention and control group (mean±SD)

		Intervention group (n=25)			Control group (n=18)			Intervention – Control group change#	Group x Time interaction n^2
		Baseline	3-month follow-up	Change	Baseline	3-month follow-up	Change		
Body Composition	**Weight (kg)**	68.3±10.2	68.4±10.5	0.1±1.6	72.6±14.3	73.2±15.0	0.6±2.1	-0.5	0.019
	BMI (kg/m²)	23.1±2.7	23.1±2.4	0.0±0.5	24.2±4.2	24.4±4.4	0.2±0.7	-0.2	0.018
	Fat (%)	29.8±8.9	29.7±8.8	-0.1±1.6	25.9±10.0	25.8±10.2	-0.0±3.0	-0.1	0.000
	Fat mass (kg)	20.0±7.2	20.1±7.6	0.1±1.4	19.4±9.4	19.6±10.1	0.2±2.3	-0.1	0.002
	Fat-free mass (kg)	45.8±6.2	45.9±5.9	0.2±1.0	56.3±10.7	56.9±10.7	0.6±1.5	-0.4	0.026
	Waist circumference (cm)	84.9±10.6	81.7±10.4	-3.1±4.3	83.0±11.8	82.1±11.2	-1.2±4.5	-1.9	0.050
	Hip circumference (cm)	102.8±7.3	101.1±8.7	-1.7±4.7	103.5±8.5	101.8±9.4	-1.7±4.2	0.0	0.000
	Waist-to-hip-ratio	0.83±0.08	0.81±0.6	-0.02±0.05	0.80±0.07	0.81±0.07	0.01±0.05	-0.03	0.053
Blood Pressure	**Systolic blood pressure (mmHg)**	115.9±11.7	117.0±13.4	1.2±11.3	115.5±12.5	117.7±16.0	2.2±9.8	-1.0	0.003
	Diastolic blood pressure (mmHg)	76.0±7.6	74.4±7.4	-1.6±4.6	75.6±8.7	75.8±9.5	0.2±5.7	-1.8	0.033
	Resting heart rate (beats/min)	66.2±9.3	61.4±8.7	-4.8±7.1	64.3±9.9	64.1±8.4	-0.3±5.7	-4.5	0.110
Blood markers (mmol/L)	**Fasting blood glucose**	4.86±0.50	4.76±0.58	-0.10±0.4	4.79±0.45	4.51±0.37	-0.28±5.3	0.18	0.038
	Triglycerides	1.20±0.44	1.16±0.52	-0.04±0.36	0.96±0.43	0.95±0.23	-0.01±0.40	-0.03	0.002
	HDL Cholesterol	1.27±0.30	1.15±0.22	-0.12±0.23	1.02±0.26	1.01±0.24	-0.01±0.29	-0.11	0.047
	LDL Cholesterol	3.68±0.97	3.88±0.84	0.20±0.75	3.01±0.64	3.32±0.88	0.31±0.57	-0.11	0.006
	Total Cholesterol	5.35±1.00	5.28±0.95	-0.07±0.32	4.45±1.01	4.57±1.14	0.12±0.57	-0.19	0.043

mean difference between groups

3.3.2 Sub-analysis: 12-month follow-up

30 office workers attended the 12-month follow-up measurement session and 24 provided valid activPAL data (80%). These participants had higher amounts of baseline workday sit-stand transitions (0.55±0.25 transitions/hour of wear time) and higher non-working hours step counts (182±88 steps/hour of wear time) compared to office workers who were lost to follow-up. There were no significant differences between participants who provided valid activPAL data and those who did not in this sub-sample (p>0.05). Due to the length of time and nature of the study, some cross-contamination between the groups occurred with some control participants gaining a sit-stand desk and some intervention participants giving up their sit-stand desk. Therefore, only office workers who remained in their original group were analysed (n=18; intervention group n=11, control group n=7). Only descriptive statistics were explored due to the small sample size and low statistical power.

Figures 3.2-3.5 graphically show the change in sedentary and standing time for the intervention and control group between baseline, 3 and 12 months and Table 3.3 shows the change in these variables in addition to physical activity measures. At the 12-month follow-up, the intervention group had maintained a reduced amount of sedentary time at work (-18.4±12.4% of wear time) and on a workday overall (-8.0±8.3% of wear time) compared to baseline in addition to an increased amount of standing at work (16.5±12.4% of wear time) and on a workday (7.1±7.8% of wear time). Conversely, during non-working hours, the intervention group increased sedentary time at the 12-month follow-up compared to baseline by 4.2% with a 3.7% reduction in standing time. Furthermore, the intervention group increased non-workday sedentary time by 3.5% with a reduction in standing of 2.9% compared to baseline. The control group maintained a very similar distribution of activity with no differences of >±3.1% of wear time for sedentary, standing or stepping time during work/non-work or on a workday/non-workday. Similarly, when between-group differences were explored, the intervention group had lower amounts of sedentary time during working hours (-21.1±8.4% of wear time) and on a workday (-9.6±5.1% of wear time) compared to the control group at the 12-month follow-up in addition to higher amounts of standing at work (19.9±6.8% of wear time) and on a workday overall (9.2±4.0% of wear time). No other between group differences were observed.

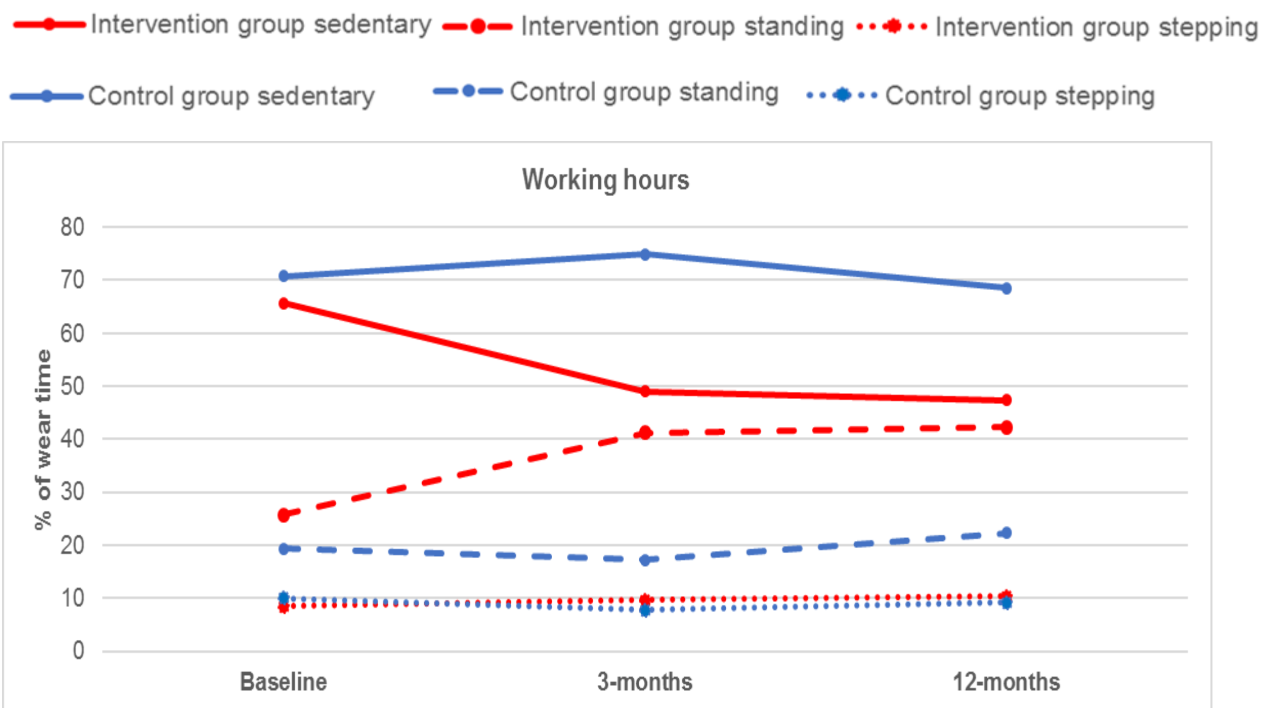


Figure 3.2 Changes in sedentary, standing and stepping time (% of wear time) between baseline, 3- and 12-month follow-ups by group during working hours

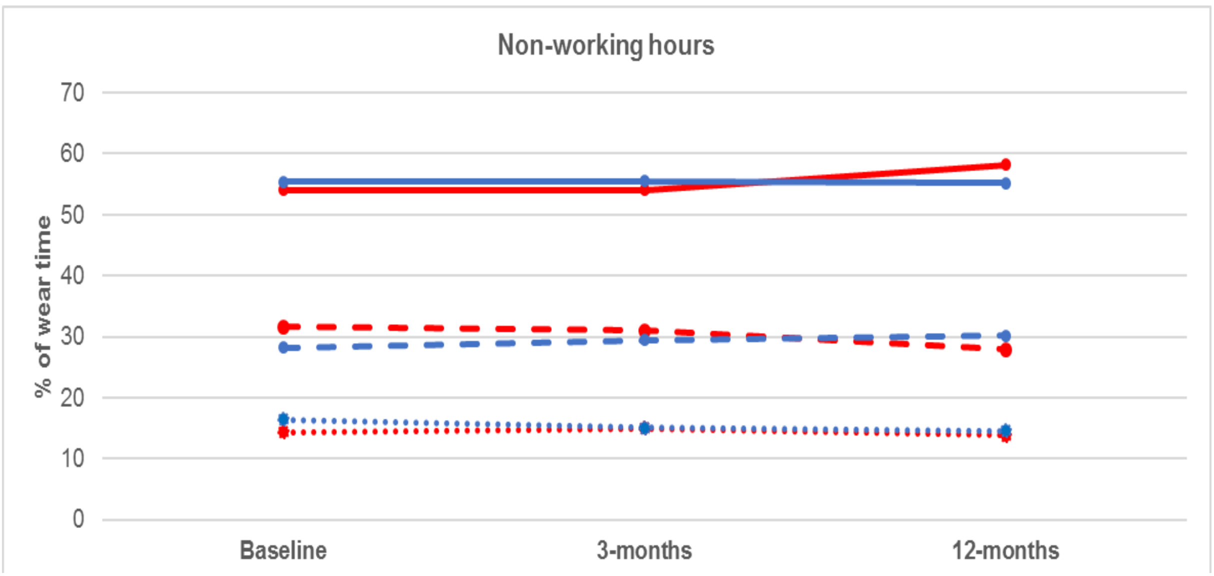


Figure 3.3 Changes in sedentary, standing and stepping time (% of wear time) between baseline, 3- and 12-month follow-ups by group during non-working hours

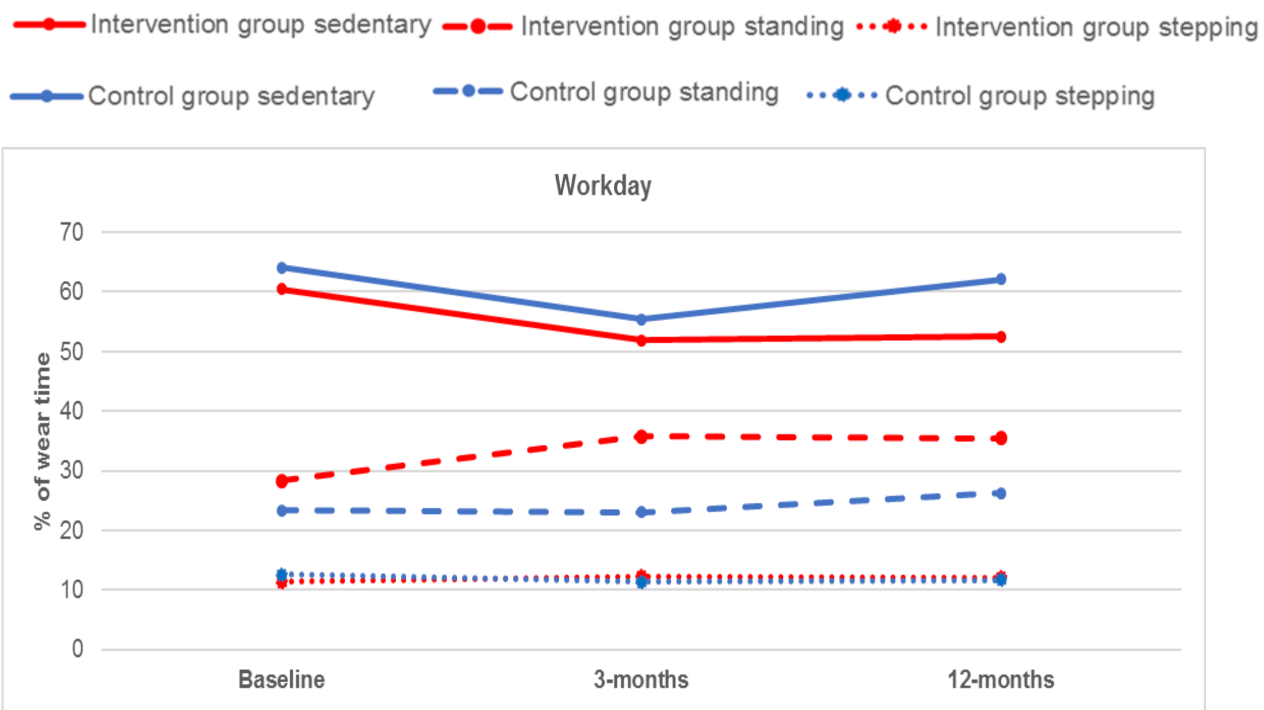


Figure 3.4 Changes in sedentary, standing and stepping time (% of wear time) between baseline, 3- and 12-month follow-ups by group on a workday

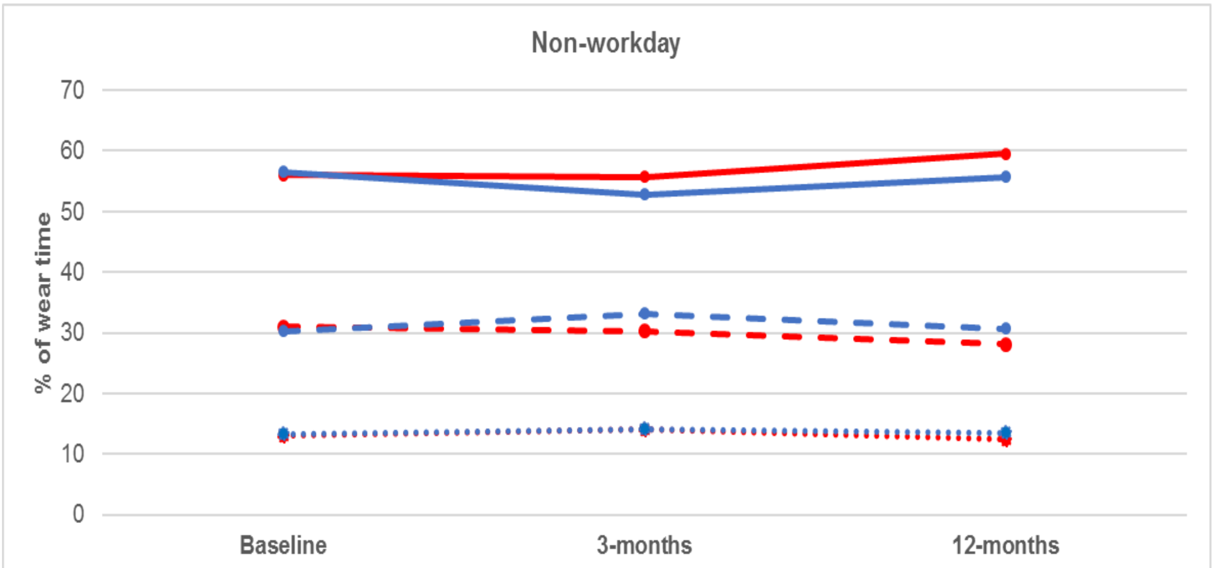


Figure 3.5 Changes in sedentary, standing and stepping time (% of wear time) between baseline, 3- and 12-month follow-ups by group on a non-workday

Tables 3.3 and 3.4 show the descriptives of health markers and activity measures for both groups across the three time points. The control group increased the amount of time in light physical activity on a non-workday between baseline and the 12-month follow-up (5.1±11.5% of wear time) but reduced the amount of time in MVPA (2.9±2.1% of wear time) thus, the intervention group had a larger amount of MVPA than the control group at the 12-month follow-up (2.4±0.9% of wear time). The intervention group did not show any differences in light physical activity or MVPA between baseline and the 12-month follow-up. Conversely, the intervention group had a lower average resting heart rate (-5.2±7.9 beats/minute), fasting blood glucose (-0.45±0.72 mmol/L), LDL cholesterol (-0.58± 1.29 mmol/L) and a higher average HDL cholesterol level (0.44±0.29 mmol/L) at the 12-month follow-up compared to baseline. However, all improvements were also found in the control group.

Table 3.3 Descriptives of the baseline, 3-month and 12-month follow-up activity measures (means±SD) for the intervention and control group

		Intervention group (n=11)				Control group (n=7)			
		Baseline	3-month follow-up	12-month follow-up	12-month change	Baseline	3-month follow-up	12-month follow-up	12-month change
Work	Sedentary % of wear time	65.7±18.2	49.0±22.8	47.4±20.3	-18.4±12.4	70.7±8.8	74.9±10.9	68.5±10.9	-2.2±6.5
	Standing % of wear time	25.7±17.1	41.2±22.7	42.3±19.0	16.5±12.4	19.3±7.0	17.2±8.4	22.3±9.7	3.1±4.9
	Stepping % of wear time	8.5±3.0	9.7±3.1	10.4±3.6	1.8±12.4	10.0±3.0	7.8±3.0	9.2±2.2	-0.9±3.0
	Steps/hour wear time	467±175	555±178	549±186	82.9±139	586±176	445±165	510±104	-77±197
	Transitions/hour wear time	3.45±1.54	2.34±0.95	2.71±1.89	-1.24±1.18	2.96±0.70	2.83±1.00	2.64±0.82	-0.33±0.63
	activPAL Wear time	479±74	481±56	498±53	19±64	521±102	491±37	496±49	-77±197
	Light PA % of wear time	20.2±7.0	19.0±5.3	22.1±6.5	1.8±5.4	15.7±3.1	16.9±5.2	19.3±3.6	2.6±1.7
	MVPA % of wear time	3.3±1.8	3.9±1.2	4.1±2.5	0.9±1.8	4.7±0.9	3.6±1.2	4.4±1.5	0.8±1.0
	ActiGraph wear (mins/day)	487±78	487±48	494±63	6±81	519±103	494±39	495±46	-24±84
Non-work	Sedentary % of wear time	54.0±7.2	54.0±12.8	58.2±8.8	4.2±9.5	55.4±9.4	55.5±7.7	55.2±8.7	-0.2±7.3
	Standing % of wear time	31.6±6.8	31.0±11.7	27.9±9.1	-3.7±8.3	28.2±6.7	29.4±6.8	30.2±8.5	2.0±5.1
	Stepping % of wear time	14.3±4.5	15.0±3.7	13.8±3.3	-0.5±3.4	16.4±5.2	15.1±3.4	14.6±1.7	-1.8±5.5
	Steps/hour wear time	724±279	782±246	702±232	-22±213	809±244	782±228	728±86	81±279
	Transitions/hour wear time	3.44±1.03	3.49±1.38	3.43±1.29	-0.01±0.61	3.68±1.42	3.61±0.64	3.39±0.70	-0.29±1.66
	activPAL Wear time	471±101	468±78	452±73	-19±62	409±109	452±49	437±69	28±85
	Light PA % of wear time	26.7±6.0	25.5±4.6	26.9±6.0	0.3±4.1	23.9±3.2	24.2±4.7	26.2±2.7	2.3±1.6
	MVPA % of wear time	4.3±1.4	5.1±2.1	4.8±1.8	0.5±2.0	5.5±2.6	4.3±1.8	4.7±2.5	-0.8±1.6
	ActiGraph wear (mins/day)	907±81	949±45	928±15	22±101	883±72	884±49	870±87	-13±35
Workday	Sedentary % of wear time	60.5±10.8	51.9±14.1	52.5±13.2	-8.0±8.3	64.1±3.9	55.4±9.4	62.1±2.4	-1.9±3.5
	Standing % of wear time	28.3±10.6	35.7±14.7	35.4±12.8	7.1±7.8	23.3±2.9	23.0±6.0	26.2±2.7	2.8±3.2
	Stepping % of wear time	11.3±2.4	12.3±2.2	12.1±1.9	0.8±2.1	12.6±2.4	11.3±1.5	11.7±1.3	0.9±3.4
	Steps/hour wear time	587±148	664±124	624±95	37±121	677±152	607±117	613±81	-64±204
	Transitions/hour wear time	3.58±1.58	2.89±0.95	3.07±1.43	-0.51±0.87	3.17±0.44	3.16±0.53	2.97±0.61	-0.20±0.42
	activPAL Wear time	950±49	950±44	949±40	-1±46	930±33	943±25	933±55	3±55
	Light PA % of wear time	26.7±6.0	25.5±4.6	26.9±6.0	0.3±4.1	23.9±3.2	24.2±4.7	26.2±2.7	2.3±1.6
	MVPA % of wear time	4.3±1.4	5.1±2.1	4.8±1.8	0.5±2.0	5.5±2.6	4.3±1.8	4.7±2.5	-0.8±1.6
	ActiGraph wear (mins/day)	907±81	949±45	928±15	22±101	883±72	884±49	870±87	-13±35
Non-workday	Sedentary % of wear time	56.0±13.2	55.7±9.9	59.5±13.8	3.5±10.8	56.5±11.8	52.8±8.1	55.7±14.9	-0.7±19.1
	Standing % of wear time	31.0±10.9	30.3±8.6	28.1±11.5	-2.9±8.0	30.3.±9.3	33.2±10.5	30.7±11.0	0.5±13.0
	Stepping % of wear time	13.0±3.5	14.0±2.6	12.4±3.1	-0.6±3.9	13.3±3.8	14.1±4.8	13.5±5.0	0.2±7.9
	Steps/hour wear time	651±206	710±164	618±181	-32±221	657±183	671±265	678±356	21±476
	Transitions/hour wear time	3.36±0.92	3.28±0.88	3.31±0.96	-0.05±0.92	3.70±1.4	4.04±1.48	3.22±0.98	-0.48±0.99
	activPAL Wear time	927±65	947±55	916±67	-11±60	903±48	868±71	886±52	-17±48
	Light PA % of wear time	32.9±7.5	34.2±8.7	34.0±8.6	1.0±7.6	31.1±12.2	33.8±12.7	37.7±5.3	5.1±11.5
	MVPA % of wear time	5.0±2.4	4.7±2.3	4.7±2.5	-0.3±2.2	5.4±2.6	5.9±6.0	2.3±1.4	-2.9±2.1
	ActiGraph wear (mins/day)	881±89	891±89	885±97	4±80	858±88	825±80	846±112	-39±78

Table 3.4 Descriptives of the baseline, 3-month and 12-month follow-up health markers (means±SD) for the intervention and control group

		Intervention group (n=11)				Control group (n=7)			
		Baseline	**3-month follow-up**	**12-month follow-up**	**12-month change**	**Baseline**	**3-month follow-up**	**12-month follow-up**	**12-month change**
Body Composition	**Weight (kg)**	67.0±10.8	66.8±10.9	67.5±12.2	0.6±2.5	70.1±13.8	70.6±13.5	68.6±13.4	-1.4±4.3
	BMI (kg/m^2)	23.3±2.4	23.3±2.5	24.3±3.8	0.2±0.9	23.3±3.5	23.5±3.4	22.7±3.0	-0.5±1.6
	Fat (%)	30.3±7.4	29.6±8.3	30.0±8.3	-0.3±2.6	25.7±8.1	25.3±9.1	23.0±7.9	-2.7±3.5
	Fat mass (kg)	20.3±6.6	19.9±7.6	20.5±8.2	0.2±2.4	17.9±6.5	17.9±7.5	15.8±6.7	-2.1±3.4
	Fat-free mass (kg)	42.7±3.8	43.0±3.5	47.1±9.8	0.2±1.1	52.2±13.0	57.4±11.6	52.9±12.3	0.6±1.8
	Waist circumference (cm)	83.2±11.0	80.0±11.6	82.5±13.5	-0.8±3.5	80.1±9.0	79.2±7.9	77.6±8.5	-2.5±4.7
	Hip circumference (cm)	101.4±6.2	100.0±9.3	100.8±8.6	-0.7±3.3	102.5±7.1	98.8±6.0	99.0±6.0	-3.5±5.1
	Waist-to-hip-ratio	0.82±0.07	0.80±0.05	0.81±0.07	-0.00±0.03	0.78±0.07	0.81±0.08	0.78±0.07	0.00±0.03
Blood Pressure	**Systolic blood pressure (mmHg)**	118±14	120±12	119±13	1±10	117±13	121±18	122±14	4±10
	Diastolic blood pressure (mmHg)	78±9	76±8	78±12	1±8	77±9	78±8	79±11	1±8
	Resting heart rate (beats/min)	68±6	62±8	63±8	-5±8	65±9	65±6	64±13	-1±5
Blood markers (mmol/L)	**Fasting blood glucose**	5.03±0.33	4.99±0.58	4.58±0.80	-0.45±0.72	4.79±3.02	4.56±0.22	4.40±0.73	-0.39±0.76
	Triglycerides	1.25±0.46	1.23±0.55	1.30±0.29	0.05±0.38	1.14±0.31	0.88±0.15	1.10±0.41	-0.04±0.28
	HDL Cholesterol	1.32±0.29	1.22±0.20	1.75±0.38	0.44±0.29	1.00±0.20	1.08±0.33	1.79±0.32	0.80±0.42
	LDL Cholesterol	3.79±1.28	4.02±1.01	3.21±0.95	-0.58±1.29	3.11±0.70	3.67±0.62	2.03±0.72	-1.09±0.46
	Total Cholesterol	5.64±1.16	5.49±1.10	5.52±0.96	-0.11±0.49	4.42±0.89	4.69±0.68	4.37±0.60	0.03±0.60

3.4 Discussion

The primary purpose of this pilot study was to investigate the effectiveness of a pilot multicomponent workplace intervention to reduce sedentary time over the short- (3 months) and long-term (12 months). After the 3-month intervention, no significant differences between the intervention and control groups were found when baseline values were accounted for. However, the intervention group increased stepping time and step counts on a non-workday and reduced the number of sit-stand transitions at work and on a workday compared to baseline. Additionally, a trend towards replacing sedentary time with standing time was observed in the intervention group at work and on a workday overall compared to baseline but this was non-significant. A similar trend was observed after 12-months with the intervention group reducing sedentary time at work by 18% and by 8% of wear time on a workday overall. An associated increase in standing time was found of 16.5% and 7.1% of wear time respectively. However, these improvements were found after 3 months in the 12-month sub-sample thus were maintained during the following 9 months. The intervention group showed a minimal reduction in waist circumference (3 months), waist-to-hip ratio (3 months), HDL-cholesterol (3 months), Total cholesterol (3 months), resting heart rate (3 and 12 months), fasting blood glucose (12 months) and LDL cholesterol (12 months) compared to baseline. Additionally, the control group showed an increase in HDL cholesterol (12 months) compared to baseline. The intervention group showed an increase in the amount of time spent in MVPA during working hours and on a workday overall compared to the control group after 3-months. Conversely, the intervention group reduced the amount of time spent in light physical activity during working hours at the 3-month follow-up control group.

One interesting finding was that the intervention group showed a trend towards reducing the number of sit-stand transitions during working hours and on a workday overall at the 3- and 12-month follow-ups. This suggests that with the addition of a sit-stand desk and other intervention components, office workers tended to stay in one posture for a longer amount of time compared to baseline. This is contradictory to previous multicomponent intervention studies which have generally found that the intervention group increases the number of sit-stand transitions as a result of implementing sit-stand desks.[73,240,241] A potential reason for this discrepancy is that the current study did not recommend any period of time for breaking up prolonged sedentary time whereas previous interventions have recommended changing posture every 30-minutes for example.[189] Furthermore, no information was provided concerning the negative consequences of prolonged standing. However, this controversial result was not found to be statistically significant compared to the control group after 3-months thus should be interpreted with caution.

Previous multicomponent interventions have reported a reduction in sitting time of 89 minutes/8-hour workday (18.5%) for Australian office workers who received a multicomponent intervention and 33 minutes/8-hour workday (6.8%) for those who received a sit-stand desk only compared to the control group.[188] An associated increase in standing time was also reported for both groups compared to the control group supporting the findings of the current study which observed a trend towards reductions in sedentary time that were replaced almost exclusively by increased standing. However, the improvements observed in the current study were not significant compared to the control group. The additional organisational element of the Australian study could partly explain the significant results in which managers emailed employees supportive sit less, stand up and move more messages. Additionally, more individual strategies were offered compared to the current study including face-to-face coaching, three telephone calls and a self-monitoring tool where office workers could write their self-evaluated progress. The Australian sample also were more sedentary at work compared to the current sample at baseline (77% vs 62% respectively) indicating the samples may not be comparable.

Conversely, the current study did observe a 2% increase in stepping time and an increase in step counts of 113 steps per hour of wear time on a non-workday in the intervention sample compared to baseline. Although non-significant when compared to the control group over time, this is potentially a result of some of the intervention elements focusing on increasing step counts compared to reducing sedentary time. For example, previous studies that have provided pedometers to participants as an intervention strategy have observed an increase in stepping time[238] and step counts[207,210] but not a reduction in sedentary time. However, a trend towards decreased workplace and overall workday sedentary time in the intervention group was observed in the current study (-7.9±25.1% and -4.6±13.8% of wear time respectively).

The novel aspect of this study is that the intervention effect was measured 9 months after the intervention had finished (except for the sit-stand desks). It was demonstrated in the sub-sample who were followed up at this time point that the trend towards a reduction in sedentary time was maintained by the intervention group. This finding is supported by Zhu and colleagues[285] who conducted a natural experiment where workers received a sit-stand workstation and additional intervention strategies as a result of a major office re-design. Compared to the control group who did not receive sit-stand desks, the intervention group reduced their sedentary time by 11.8% and increased their standing time by 7.8% during working hours after 4 months and maintained these changes after 18 months (10.9% and 3.6% respectively). In addition, no change in MVPA was observed and mixed results were reported for cardio-metabolic measures after 18 months. Conversely, an increase in sit-stand transitions was shown in the intervention group compared to the control group after 4 months which is contradictory to the current study. This could be due to the additional intervention element of treadmill workstations which were available to use in the 18-month study.

The SMArT Work study[73] found a significant reduction in sedentary time at 3 (-51 minutes/workday), 6 (-64 minutes/workday) and 12 months (-82 minutes/workday). However, the trend observed in the current study was a reduction in sedentary time at 3 months and the same amount of sedentary time was observed at 12 months as opposed to a further reduction reported by the SMArT Work study. A potential reason for this is that all of the current intervention strategies ceased after 3 months in the present study apart from the environmental sit-stand desk component while the SMArT Work intervention elements were maintained for the 12-month duration.[307] Similarly, Stand up Victoria[189] also found a reduction in sedentary time at 3 (99 minutes/8-hour workday) and 12 months (45 minutes/8 hour workday) but no significant change in stepping time. Additionally, the Australian study concluded that the intervention observed a small benefit for improving cardiometabolic health after 12 months but not for all biomarkers supporting the current study which showed minimal improvements in health measures after 12 months.[243] However, comparison between these two cluster RCT studies and the present study should be treated with caution as the follow-up samples in the clusters RCTs were much larger than in the present study.

The majority of workplace intervention studies focus on measuring the effect on sitting and standing during working hours only whereas the current study also measured non-working hours and non-workday behaviour.[53,61] At the 12-month follow-up the intervention group showed an increase in sedentary time (and associated decrease in standing time) during non-working hours on a workday and on a non-workday overall. Compared to baseline, the intervention group increased sedentary time by 4.2% and 3.5% during non-working hours and overall on a non-workday with associated decreases in standing time whereas the control group maintained the same amount of sedentary and standing time as at baseline. Thus, although there was a trend toward a reduction in occupational sedentary time in the intervention group, non-working hours sedentary time increased. This compensation effect was also observed in a study by Mansoubi and collegues[308] where office workers with given sit-stand desks reduced the proportion of sedentary time by 20% during working hours after 3-months but also increased the proportion of sedentary time during non-working hours by 8%.

Strengths and limitations

Strengths of this study include the participant-led multicomponent intervention approach targeting both the individual and the environment in order to facilitate maximum change in behaviour. Randomisation of office workers into the control and intervention group reduced bias and allowed for a true comparison of results. The intervention took place in a natural office setting reducing experimental bias and providing real world context. The inclusion of 3- and 12-month follow-ups showed both the short- and long-term effects of the intervention. Objective measures of behaviour and physiological outcomes eliminate potential biases associated with self-report methods. Conversely, limitations of this study include the small sample size at the 3- and 12-month follow-ups limiting statistical power to test for differences. Contamination also occurred with some office workers who were randomised into the control arm for the 3-month intervention acquiring a sit-stand desk prior to the 12-month follow-up. A potential reason for this is that office workers were randomised after the development phase focus groups thus, it is possible that some participants were randomised into the control group but had been influenced into changing their behaviour as a result of the focus groups. Furthermore, individual randomisation was chosen due to the spread of participants across campus however, it is possible that some control participants came into contact with intervention participants which could have subsequently influenced their behaviour.

Additionally, there was a high drop-out rate after 12 months which could have introduced bias towards compliant participants. The primary intervention aim was to reduce sedentary time however, the inclusion of pedometers and step challenges which focus on increasing physical activity could have limited the effectiveness of the intervention. The strategies aimed at increasing physical activity were included as a result of the development phase focus groups but previous studies have found no significant reductions in sedentary time following pedometer interventions.[207,210] The lack of an organisational element and inclusion of a self-monitoring device not focused on sedentary time may have attenuated the change in behaviour and future studies should consider this when developing interventions.

3.5 Conclusion

This pilot multicomponent intervention providing sit-stand desks and additional individual strategies showed a trend towards reducing sedentary time during working hours and on a workday overall. However, the small sample size limited the statistical power to detect significant differences and generalisability. Additionally, the self-monitoring aspect of the intervention was focused on increasing step counts rather than reducing sedentary time. However, there was evidence that reducing occupational sedentary time over the long-term (12 months) could lead to compensation during non-working hours. Therefore, future research should implement interventions that focus on reducing sedentary time in working and non-working domains using self-monitoring tools that measure sitting time as opposed to step counts. Furthermore, cluster RCTs with adequate statistical power are needed to measure the effect of these interventions on health markers and physical activity.

Chapter 4: Study Three

Reducing sedentary time using behavioural feedback and prompts in a sample of office workers with sit-stand desks: The Ctrl Alt Del feasibility study

Study Overview

The previous chapter highlighted that workplace multicomponent interventions have the potential to reduce occupational sedentary behaviour over the long-term. However, potential compensation during non-working hours was observed with increases in sedentary time and reductions in standing time 12-months post-baseline. Additionally, the intervention implemented pedometers which did not allow office workers to self-monitor their sedentary time thus could have attenuated the results. Therefore, this chapter describes a study that explored the feasibility of a self-monitoring and prompting device to reduce sedentary time in a sample of office workers who have sit-stand desks. As highlighted in Chapter 1, no study has implemented such a device in a sample of office workers who have sit-stand desks. Therefore, this study addressed thesis objectives:

6. To assess the feasibility of a sedentary behaviour self-monitoring and prompting device (LUMO) to reduce sedentary time in a sample of office workers who already have sit-stand desks.
7. To gather preliminary data on the impact the above intervention on sedentary time, physical activity, desk use, health- and work-related outcomes.

4.1 Introduction

Office workers are highly sedentary and have been found to spend an average of 11 hours sedentary on a workday of which 6.5 hours were accumulated at work.[47] Therefore, this population is a high risk group for the associated negative health outcomes of sedentary behaviour including numerous chronic diseases and all-cause mortality.[10–14,16,28,29,48] Significant reductions in sedentary time at work over the long-term have been observed in multicomponent interventions and a trend toward this was found in the previous chapter.[53,73,187,242] According to the behaviour change wheel (BCW), the intervention provided environmental restructuring, education and competition addressing the three-key conditions of behaviour change (capability, opportunity and motivation). However, in terms of motivation, previous interventions have focused on self-monitoring of steps and competing against other participants in step challenges.[207,210,238] Although an increase in stepping was observed there were no reductions in sedentary time. Other workplace sedentary behaviour interventions have provided prompts to stand after an hour via a computer[206] or wrist-worn device.[213] These prompts were in the form of a notification message on the computer screen and/or a beep from the wrist watch or vibration. However, no reduction in sedentary time was found but there was an increase in the number of breaks from prolonged sitting bouts.[206] The main limitation with the prompting techniques used in previous interventions is that they are not based on the workers' behaviour but on set times. For example, the worker could be already standing when prompted.

Self-monitoring and feedback have been found to be amongst the most potent behaviour change technics.[309] Control theory states that setting goals, monitoring behaviour, receiving feedback and reviewing goals are central to self-management and behavioural control.[310] Modern technology can be utilised in this way and 'persuasive technology' is a term used to describe technology that is designed to change the user's attitude and behaviour.[209] For example, the SMArT Work study[246] adopted a multicomponent approach and provided participants with a DARMA cushion (Darma, CA, USA) on their office chair. The cushion allowed participants to self-monitor sitting time through an associated smart phone application and provided a vibration prompt where the user could define the frequency. The intervention found a reduction in occupational and daily sedentary time over the long-term but did not look at the feasibility of the Darma cushion specifically thus it is unclear how much of the change in behaviour was due to this intervention strategy.[73] Additionally, the effect of the intervention on non-working hours was not explored.

Conversely, the LUMOBack (LUMO) device is a waist-worn device that allows self-monitoring of sedentary time, standing and physical activity through a smart device application.[311] Additionally, the user can choose to be prompted via a notification on the smart device after a period of prolonged sedentary time that can be defined by the user. Some research studies have utilised this device to reduce sedentary time with mixed results. When used as an intervention tool in a sample of office workers (n=66) in Australia,[312] a reduction in sedentary time was observed during working hours and overall after 12-months. However, the reduction was not significantly different to the group that received organisational strategies only (n=87). A potential reason for this could be due to the prolonged sedentary prompt appearing on participant's phone as opposed to through a vibration on the wearable device. Sanders and colleagues modified the LUMO device to achieve this and prompted participants every 30 minutes but no change in office workers sedentary time was observed after the five-week intervention.[112] The main limitation of these two studies is that neither samples had access to a sit-stand desk so the opportunity to reduce sitting time was restricted. Therefore, the aim of this study was to explore the feasibility of a self-monitoring and prompting device to reduce sedentary time in a sample of office workers who have sit-stand desks.

4.2 Methods

4.2.1 Participants

Loughborough University office workers with sit-stand desks were recruited (February–July 2017) via online university notice boards, departmental emails, posters and flyers. Participants were included if they were aged 18 years or older, worked at least 0.6 full time equivalent or 3 days per week in an office at Loughborough University, had a primarily desk-based job where most of the workday was spent at a sit-stand workstation, able to wear an activity monitor for a 5-week period with no allergies to medical tape and physically capable of increasing standing times by at least 2 hours per workday. Participants were excluded if they were pregnant, non-ambulatory or if they had any planned absences of over a period of 1-week during the study period. All participants provided informed consent and the protocol was approved by the Loughborough University ethics committee (reference number: C17-08). The study was conducted in accordance with the Declaration of Helsinki and all measures were undertaken at Loughborough University by a trained researcher (DBS checked).

4.2.2 Design and procedure

This feasibility study had a pre-post design with a 4-week intervention period as shown in Figure 4.1. A feasibility design was chosen due to the novelty of this study thus the questions of whether the device works as an intervention component, if it should be used and if so, how it should be used in this population needed addressing.[288] The study was named Ctrl Alt Del with the messages: 'Take Ctrl of your work behaviour, Alt-ernate between sitting and standing, Del-ete the sedentary habit, reset to a more active workday'. At baseline, all questionnaire items, health and work-related outcomes were measured, and activity monitors were deployed along with a paper-based diary. After 7 consecutive measurement days of habitual sedentary behaviour and physical activity, office workers were provided with an educational leaflet and the LUMO intervention for 4 weeks. During the last week of the intervention, the baseline measures were replicated.

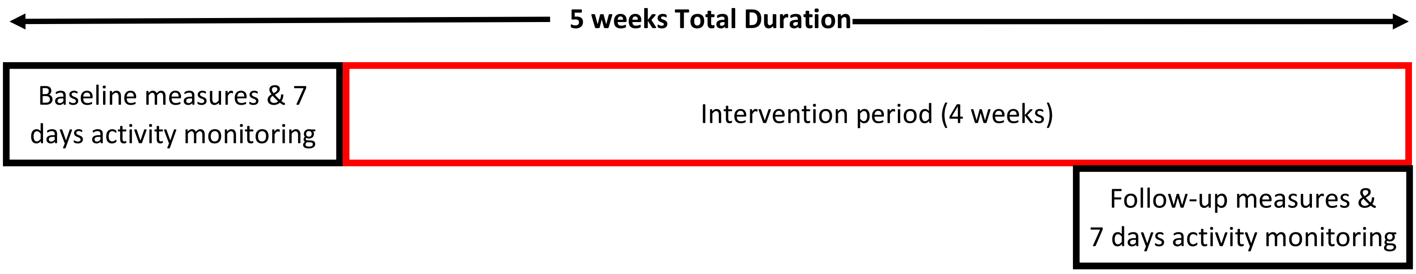


Figure 4.1 Ctrl Alt Del study design

4.2.3 Intervention

Sedentary behaviour educational leaflet and feedback on health markers

As discussed previously, to successfully change behaviour according to the COM-B model,[72] interventions need to address deficits in all essential aspects of Capability, Opportunity and Motivation. Participants already had the opportunity to reduce sedentary time as they had sit-stand desks. Psychological capability and reflective motivation can be achieved through increasing knowledge and understanding.[202] Thus, after the baseline measures, participants received an educational leaflet (Appendix 4.1) describing the risks of sedentary behaviour, recommendations to reduce sedentary time and how to use and correctly position their sit-stand desks.[313] The leaflet contained the new work recommendations from the consensus statement[50] which include: initially, gradually accumulate at least 2 hours/day standing or light activity and then progress to 4 hours/day during working hours, seated work should be regularly broken up with standing-based work and vice versa, standing for prolonged periods should also be avoided and position needs to be checked and corrected regularly especially in the presence of any musculoskeletal symptoms. Furthermore, participants received a feedback sheet detailing their results from the measurement of health markers after the baseline and post-intervention sessions. The feedback sheet followed the same format as the previous intervention in Chapter 3 but did not include the sections on waist-circumference, finger prick test or peak flow test (see Appendix 3.5).

Provision of the LUMO application and prompts

Providing participants with a LUMO device also addressed the Capability and Motivation elements of behaviour change. As discussed in Chapter 1, the LUMO is a small (4.15 x 10 x 0.8cm, 25g) and flexible sensor which is worn on a belt just below the waist.[311] The LUMO measures the angle of the pelvis with a resolution of 1° using inertial sensors which continually collect data at 25Hz. These embedded posture sensors send data to machine learning algorithms and built in personalised calibration algorithms which adapt to the user's body shape and movement behaviour. Thus, the senor detects posture, sitting, and standing with the addition of a pedometer to measure walking time and number of steps.[112] The device links to an application that can be installed on an Apple smart device via Bluetooth which shows the user their movement data over the course of a day, week or month allowing the user to self-monitor their sitting time. Figure 4.2 shows the LUMO 'max cards' which illustrate the amount of time spent sitting, standing, steeping and lying down (A), and the number of stand-ups (B) and step counts (C). Figure 4.3 shows the LUMO 'min cards' which appear on the screen under the avatar when the application in opened and summarise the amount of time spent sitting (A), number of stand-ups (B) and step count (C) for that day.

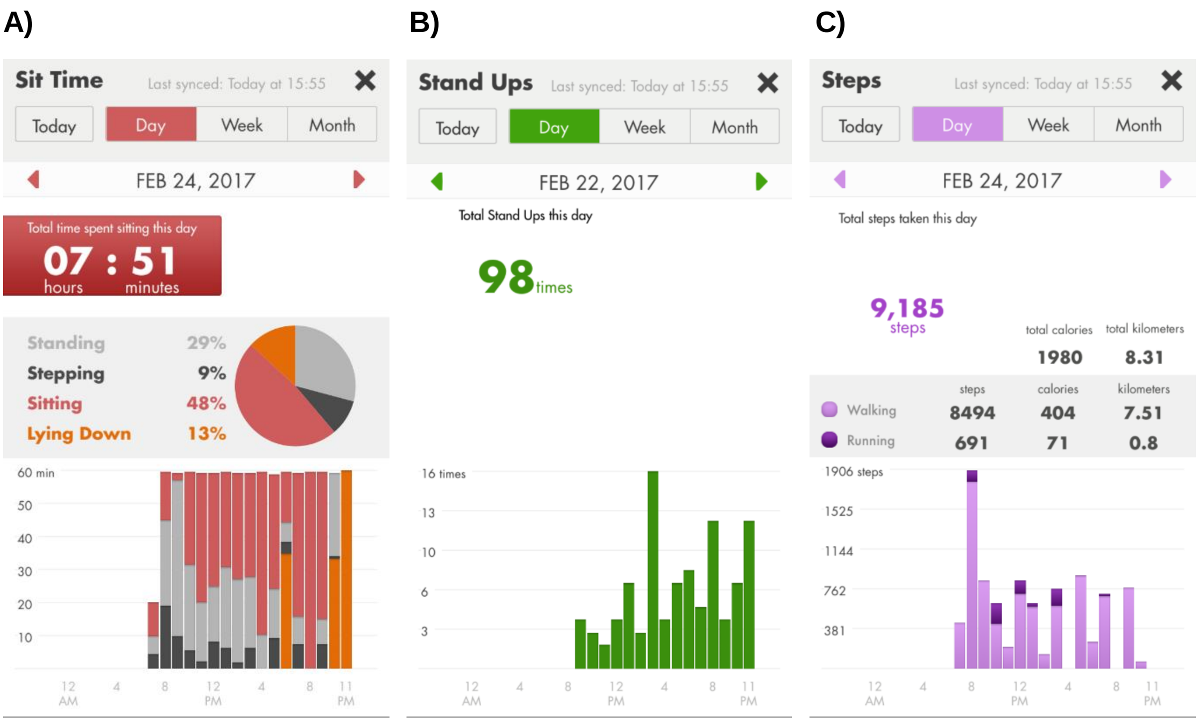


Figure 4.2 LUMO application max cards: A) the proportion of the day spent sitting, standing, stepping and lying down; B) daily number of stand ups; C) daily step count

A) B) C)

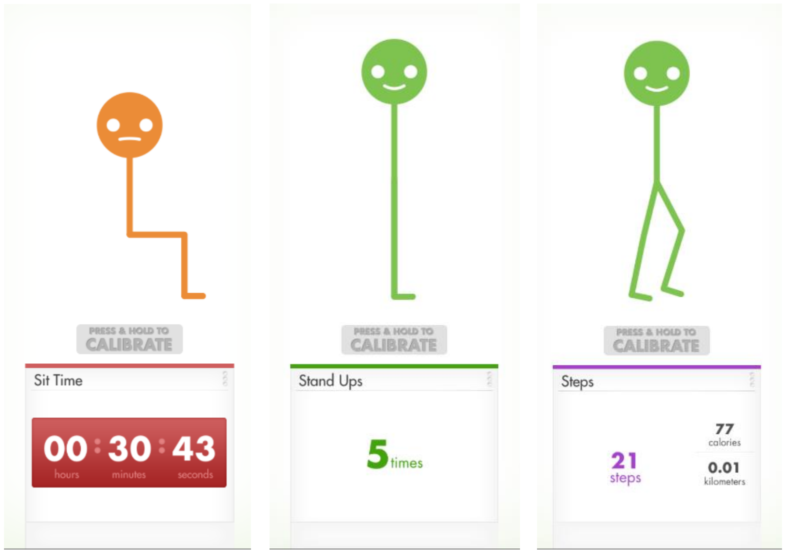


Figure 4.3 LUMO application min cards: A) daily sitting time; B) daily number of stand ups; C) daily step count (calories and kilometres)

During the baseline measurement week, participants wore a LUMO device as a 'logger' (without the vibrations or application) to record sedentary behaviour and activity data (described in section 4.2.3). Thus, each participant attended an intervention session wearing the LUMO device. The LUMO application was either installed on the participant's smart device via a link sent prior to the intervention session or if the participant did not have a smart device, they were given an iPod with the application already installed. The participant logged into the application with the username and password used during their baseline measurement week and the data were synced from the device to the application via Bluetooth. Once this was completed, the full calibration procedure was carried out by the participant using the application with the assistance of the researcher. Following this, participants were shown how to navigate the application and how to interpret their baseline data.

Additionally, the LUMO device was set-up to alert the participant when they had been sitting for a prolonged period which was set at 30 minutes by the researcher, in the form of a vibration through the sensor. As discussed previously, breaking up prolonged sitting has been found to be beneficial to health[34,41,42,149] and a period of 30 minutes was chosen because of the reported reductions in postprandial glycemia and insulinemia.[40,43,157,314] Participants were asked to wear the LUMO during all waking hours except during water-based activities and to charge the device overnight using the cable (and USB plug if required) provided. Furthermore, participants were given a printed set of instructions to take away that contained the main points covered during the training session and troubleshooting advice (Appendix 4.2).

4.2.4 Outcome measures

Feasibility

Due to the lack of information available on the percentage of office workers at Loughborough University who have sit-stand desks, it was not possible to calculate the recruitment rate. Therefore, retention and compliance rates were focused on. The retention rate was calculated by dividing the number of participants who completed the intervention by those who started. Reasons for withdrawal were logged through field notes if participants stated them. LUMO wear adherence was measured using the processed data from the LUMO device (described under section 4.2.4). The number of valid days available for the LUMO data was totalled and described in comparison to a full set of data (35 days per participant). Wear time was calculated for workdays, non-workdays, during working hours and non-working hours across the five weeks of the study using self-reported information from participant diaries. Additionally, participants were asked how often they wore and calibrated the LUMO in the post-intervention questionnaire (Appendix 4.3).

Engagement with the LUMO application was recorded using Flurry App Analytics (Flurry, Yahoo, San Francisco).[315] This software is connected to the LUMO application and collects real-time data on user engagement that can be downloaded from the online platform.[112] The total amount of time, number of sessions and lengths of session on the application were analysed over the four intervention weeks. Additionally, the number of taps on the sitting, stand ups, and steps max cards (see Figure 4.2) were explored in addition to the number of times each of the min cards (Figure 4.3) were on view.

Acceptability

The acceptability of each component of the intervention was assessed via a survey where participants responded using a five-point Likert scale (‘strongly agree’ to ‘strongly disagree’) to statements regarding satisfaction, comfort, ease of use, usefulness of the intervention to reduce sitting time, and if use of the components would (if possible) be continued. Adverse events during the intervention were reported via an open-ended question on the follow-up questionnaire. Post-intervention semi-structured interviews were also undertaken with all participants who completed the follow-up measures to discuss the above topics (see Appendix 4.4 for interview schedule). The one-on-one interviews were digitally recorded and lasted between 14 and 46 minutes (mean duration 27 minutes). The recordings were transcribed verbatim and initial codes were generated. Subsequently, the codes were collated, inductive themes identified and reviewed with supporting quotes.

Objective sitting, standing and physical activity measurement

Sitting time, number of sit-stand transitions, prolonged sitting bouts (30-60 minutes and >60 minutes), standing time, stepping time (light and MVPA) and number of steps (light and MVPA) were measured using the activPAL3 inclinometer. As discussed in Chapter 1, the activPAL is the gold standard measure of sitting time in free-living conditions[127] in addition to being a valid and accurate measure of standing and walking time.[95,104,296–299,304] The activPAL was initialised and deployed as described in Chapter 3 which involved waterproofing the device by placing it in a nitrile sleeve and wrapping it in hypoallergenic medical dressing (BSN Hypafix). Participants attached the activPAL to the midline anterior aspect of the upper thigh using patches of pre-cut hypoallergenic medical dressing during the baseline and follow-up measurement sessions. The monitor was deployed for 24 hours per day for 7 full-days which did not include the initial day the device was attached. An instruction sheet was given to participants reiterating these instructions with associated pictures (Appendix 4.5).

The LUMO was worn by all participants for the duration of the study and, in addition to providing feedback and prompts, was used as a secondary measure of sitting, standing, and stepping time. During the baseline week, the LUMO was initialised as a logger (no feedback or prompts) using the researcher’s smart device and participants put the LUMO on during the baseline measurement session so it could be calibrated. The LUMO was then worn during all waking hours except for water-based activities for 7 consecutive days in addition to the first day and charged overnight.

Following the baseline week, participants were given access to the LUMO application (feedback and prompts), either via their own Apple smart device or from an iPod provided, and the device was initialised to be fully functional for the rest of the study

(4 weeks including follow-up). As described in Chapter 1 the LUMO is a valid measure of sitting[113] and stepping[316] but is the secondary measure to the gold standard activPAL in this study. Therefore, the LUMO data was used to describe the change in sitting, standing and stepping during working and non-working hours over the study period as the activPAL processing method only allowed the workday as a whole to be extracted. During the baseline and follow-up measurement periods, participants completed a daily diary to record the date, wake/sleep times, working hours and device start/removal times (Appendix 4.5). A less detailed diary was also completed during weeks 2-4 where the date, working hours and desk time were recorded (Appendix 4.2).

Measurement of health markers

The same procedure was followed as detailed in the previous chapter for the following measurements. Resting heart rate, systolic and diastolic blood pressure (Omron Technology, Sibiu, Romania) were taken after a period of relaxation and repeated three times with a rest period in-between. Height was measured in duplicate without footwear to the nearest 0.1 cm using a stadiometer (Seca 213, Birmingham, UK). A bio-electrical impedance scale was used to measure weight and body composition (Tanita BC418MA, Manchester, UK). BMI was calculated by dividing body weight in kilograms by height in metres squared.[317]

Work-related measures

A self-report questionnaire (Appendix 4.3) was issued to participants during the baseline and follow-up measurement sessions. It included a single-item measure of job satisfaction rated on a seven-point Likert scale (1=extremely dissatisfied, 7=extremely satisfied) which has been found to correlate highly with multiple-item questions[318] and may contain more face validity.[319] Job performance was also measured using a single-item question and on a 7-point Likert scale (1-very poorly and 7=extremely well).[320] Absenteeism and presenteeism were measured in response to the questions, 'How many whole days have you been off work because of a health problem?' and 'How many whole days have you attended work while suffering from health problems?' respectively over the last 4 weeks.[321] The typical number of hours sleep at night were measured in response to the question, 'During the past 4 weeks, typically how many hours of actual sleep did you get at night?' The Utrecht Work

Engagement Scale-9[322] measured work engagement in terms of vigour, dedication and absorption which is recommended for research and has good construct validity.[323] Occupational fatigue was measured using the Need for Recovery Scale[324] which has been found to have favourable test-retest reliability and sensitivity to detect change.[325]

Measurement of desk time and use

Participants were also asked how long they had used a sit-stand desk for and if they used it for sitting only, standing only or sitting and standing. Furthermore, participants were asked to report how long they spent sitting at their desk and how long they spent sitting/standing before alternating positions. Participants also reported how long they spend at their desk per workday in the daily diary.

Other measures

Sociodemographic questions were included in the questionnaire including: age, sex, marital status, ethnicity, education and employment status including the number of worked hours per week and years spent in a sedentary job. Additionally, the same measures used in Study One (Chapter 2.3) were used to measure physical activity,[264] smoking status, usual alcohol and fruit/vegetable consumption. Participants were then classified as meeting the current UK guidelines or not in the same way as described in Chapter 2.3. Technology readiness was measured using the TRI 2.0 questionnaire (A. Parasuraman and Rockbridge Associates, Inc., 2014.)[326] which is a streamline version of the Technology Readiness Scale but has shown high reliability and validity.[326] Readiness and self-efficacy to reduce sitting time were measured using a 10-point scale (1=low score and 10=high score) and current use and attitude towards technology for reducing sitting time/increasing physical activity were measured at baseline only.

4.2.5 Data processing

activPAL data were downloaded using the activPAL Professional v.7.2.29 software and processed using the Processing PAL application.[106] The application uses an algorithm to identify sleep, non-wear and invalid data from activPAL 'Event' files in order to classify waking wear data. This automated method has been shown to be highly agreeable with diary reported wear times (median k=0.94). A valid day was classified as ≥10 hours of wear during waking hours.[107] Additionally, the first day of wear for each measurement period was discarded to minimise any reactivity bias. Once the data were processed, a visual check was performed by creating heatmaps of the data.[107] Any occasions that had been potentially coded incorrectly due to disparities with other days of data, were recorded and checked against the participants' diaries. The data were checked by two researchers with any disagreements discussed and the data corrected if required. Following this, the data were split into work and non-workdays using participant diaries and participants were included in the analyses if they had worn the activPAL for at least 4 valid days including 1 non-workday and 3 workdays.[303] To account for differences in wear times, all outcomes were expressed as proportions of wear time and used in the analyses as opposed to absolute minute data.[308] Activity outcomes were then averaged across valid workdays and non-workdays except for the number of sit-stand transitions, MVPA stepping time and number of MVPA steps which were processed and analysed as average daily values.[242]

The LUMO data were requested from a data scientist at Lumo Bodytech and uploaded onto an internet platform from which it was downloaded into an Excel file by the researcher. The data were processed manually using a customised Microsoft Excel macro in a similar way to the activPAL data described in Chapter 3.2.5 referring to individual participant self-report diaries. The raw data were converted from percentages of five minutes to seconds and the first day was removed as it was not a full measurement day. Participants only wore the LUMO during waking hours and non-wear was identified by the device when it was charging or lying flat. However, there were some instances of the device recording activity during non-waking hours either due to participants wearing the device, not charging it or not lying it flat. In these instances, the participant diaries were used to exclude non-waking hours wear time. Additionally, the manual processing rules adopted for activPAL data processing in Chapter 3.2.5 were applied if this occurred. Thus, the data 60 minutes prior to and post each sleeping bout identified by the participants diary was explored and included as sleep if sitting/lying was ≥30 minutes and <20 steps were recorded. Furthermore, during sleeping bouts, any standing time recorded with <20 steps was included as sleeping time. Additional non-wear (not recorded in participant diaries) was identified by ≥3 hours in either a sitting/lying or standing position.[304] A valid day of LUMO wear was defined as ≥10 hours which is commonly accepted for objective monitoring devices.[107] The data were then separated into workdays, non-workdays, working hours and non-working hours using participant diaries and averaged across valid workdays and non-workdays.[242] The percentage of time spent sitting, standing and stepping was calculated by dividing the summed values by the wear time and multiplying by 100 to produce comparable data.[303]

The Flurry data were downloaded into Excel from the online platform[315] and processed so that only data during the four week intervention period were included for each participant. The total session time, number of sessions, number of taps on each max card and number of times each of the min cards were on view, were summed for each day and then averaged across each week for all participants. Reported sit-stand desk use was also averaged over each measurement week for all participants.

4.2.6 Data analysis

Statistical analyses were conducted using SPSS version 24. Due to the feasibility design and small sample size, no statistically significant differences were explored thus descriptive statistics were calculated. The retention rate was calculated by dividing the number of participants who completed the follow-up by the number who were measured at baseline. The mean and SD were calculated for all continuous variables including age (years), number of years in a sedentary job, number of hours worked/week, number of months using a sit-stand desk, desk time (minutes/day), time spent sitting at sit-stand desk (minutes/day), time spent sitting/standing before alternating (minutes/day), readiness to reduce sitting time (10-point scale), confidence to reduce sitting time (10-point scale) and TRI 2.0 score (0-5) at baseline only.

Compliance was described using the mean number of valid LUMO wear days over the study period and average daily wear time per week. Application engagement was described by the mean±SD number of sessions, length of session, number of max card taps and number of times the min cards were on show per week of the intervention. Daily reported desk time was averaged per week and described using the mean±SD. Differences between baseline and follow-up for self-report desk sitting/standing time, health markers, work measured and activPAL measured sitting, standing and stepping variables were described as the calculated mean difference with 95% CIs in addition to the number and proportion of participants who improved (i.e. reduced sitting time, increased standing time).

4.3. Results

4.3.1 Feasibility

Eligibly, uptake and retention

During the 6-month time frame for recruitment, 29 office workers expressed an interest in participating of which 20 were eligible. Reasons for exclusion included absences from work >1 week during the study period (n=3), no sit-stand desk (n=3) and current standing time significantly great (n=3). Figure 4.4 shows the flow of participants through the study. Baseline measures were completed by 19 office workers with one withdrawing before the session, and before providing written informed consent to participate due to an absence of >1 week during the study period. Valid activPAL data were obtained from 18 (95%) office workers at baseline and LUMO data were valid for 14 participants (74%, device problems n=4). 17 workers (89% of the consenting sample) completed the intervention with all having some valid LUMO and Flurry data. Two participants withdrew during the intervention period due to absences of >1 week (n=1) and a family emergency (n=1). All 17 completers participated in the follow-up measures and full data were obtained for all devices except for the LUMO (device problems n=5). One adverse event was reported by a participant in which they had a skin reaction to the adhesive used to attach the activPAL.

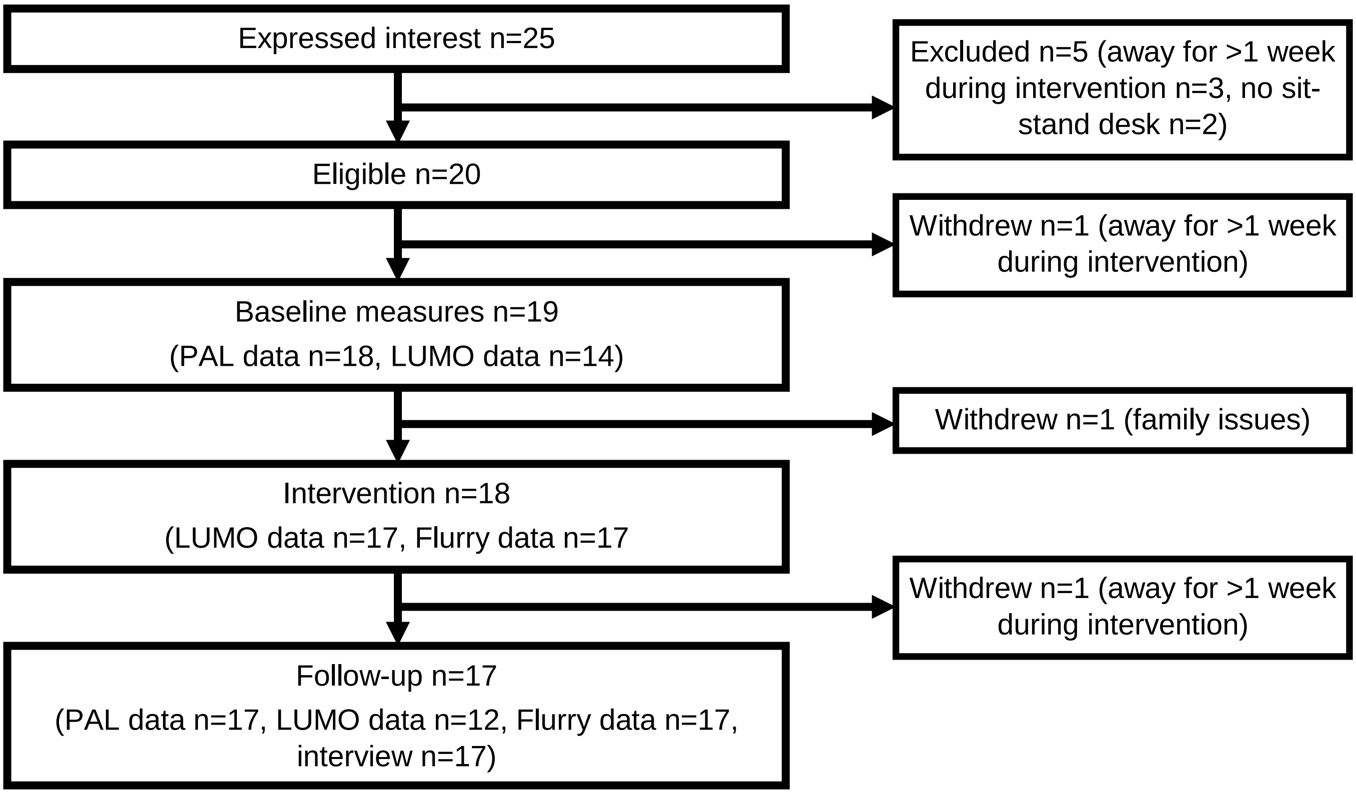


Figure 4.4 Flow diagram of participants through the study

Participant characteristics

Table 4.1 shows the baseline characteristics of the sample. The majority of the sample were female (78.9%), White British (68.4%), married (63.2%) and had a professional or doctoral degree (36.8%). The office workers had a mean age of 39.7±12.4 years, were all non-smokers and the majority met fruit and vegetable (73.7%) and alcohol (84.2%) guidelines but not physical activity guidelines (36.8%). On average, the participants had worked in a sedentary/desk-based job for 12.7±13.7 years and worked 33.9±5.7 hours per week with 68.4% working in an open-plan office. Table 4.2 shows the baseline self-report data for sit-stand desk use and attitudes towards sitting. The office workers had used a sit-stand desk for 13±9 months on average and spent 7.0±1.1 hours per day at the desk. Of this time, 5.5±1.2 hours were spent sitting with one office worker only using their sit-stand desk in the sitting position.

Table 4.1 Baseline sample characteristics

Descriptor		Whole sample (n=19)
Sex n (%)	**Male**	4 (21.1)
Age mean±SD	**years**	39.7±12.4
Ethnicity n (%)	**White**	3 (15.8)
	White British	13 (68.4)
	Indian	2 (10.5)
	Chinese	1 (5.3)
Marital status n (%)	**Married/cohabitating**	12 (63.2)
Education n (%)	**Further education**	2 (10.5)
	University degree	5 (26.3)
	Master's degree	5 (26.3)
	Professional/Doctorate degree	7 (36.8)
Smoker n (%)	**No**	19 (100.0)
Previous smoker n (%)	**No**	17 (89.5)
Meets fruit and veg guidelines n (%)	**Yes**	14 (73.7)
Meets alcohol guidelines n (%)	**Yes**	16 (84.2)
Meets physical activity guidelines n (%)	**Yes**	7 (36.8)

Although no participants monitored their sitting and/or standing time at their desk prior to the intervention, on average it was reported that 3±1.3 hours were spent sitting before alternating to standing and 1.2±1 hours were spent standing before alternating to sitting at work per day. 52.6% of participants did use some form of technology to help increase activity and/or reduce sitting time at baseline including pedometers, wearable devices and mobile phone applications. Additionally, 89.5% believed technology could help to increase activity and/or reduce sitting time with over half of the sample reporting that computer prompting software and wearable activity monitors with or without prompts could be beneficial. On average readiness to reduce sitting time was reported as 6.7±2.3 and confidence to reduce sitting time was 7.9±2.1 out of 10. Furthermore, the sample had a score of 3.02±0.53 out of 5 for technology readiness.

Table 4.2 Baseline self-report data for sit-stand desk use and attitudes towards sitting (n=19)

Descriptor		
Worked hours/week	**mean±SD**	33.9±5.7*
Months worked in a sedentary job	**mean±SD**	152±164*
Open plan office	**Yes n (%)**	13 (68.4)
Self-reported desk-time	**Minutes/day mean±SD**	419±64
Self-reported sitting time at desk	**Minutes/day mean±SD**	330±71
Time using sit-stand desk	**Months mean±SD**	13±9
Sit-stand desk use	**Sitting only n (%)**	1 (5.3)
	Sitting and standing n (%)	18 (94.7)
Sitting time at desk before standing	**Minutes/working hours mean±SD**	180±76*
Standing time at desk before sitting	**Minutes/working hours mean±SD**	72±62*
Currently monitor sitting/standing desk time	**No n (%)**	18 (100.0)*
Currently use technology to increase activity/reduce sitting time n (%)	**No n (%)**	9 (47.4)
	Pedometer	1 (5.3)
	Other wearable device	6 (31.6)
	Wearable device with prompts turned on	2 (10.5)
	Mobile phone application	1 (5.3)
Believe technology could help increase their activity/decrease sitting n (%)	**No**	2 (10.5)
	Computer prompting software	12 (63.2)
	Pedometer	2 (10.5)
	Waist-worn device that monitors sitting time and an associated application	4 (22.2)
	Waist-worn device that monitors sitting time, an associated application and prompts	7 (36.8)
	Other wearable activity monitoring device	10 (52.6)
	Other wearable activity monitoring device with prompts	11 (57.9)
	Mobile phone application	7 (36.8)
	Other – vibration on activPAL	1 (5.3)
Readiness to reduce sitting time	**0-10 scale mean±SD**	6.7±2.3
Confidence in reducing sitting time	**0-10 scale mean±SD**	7.9±2.1
TRI 2.0	**0-5 with 5 indicating higher readiness mean±SD**	3.02±0.53

* n=17 worked hours, n=16 time in sedentary job, n=18 desk monitoring, n=17 sitting minutes before standing at desk, n=17 standing at desk before sitting.

4.3.2 Acceptability

LUMO wear adherence and missing data

402 valid days of LUMO data were available for analysis (75 days week 1, 105 days week 2, 91 days week 3, 69 days week 6, 62 days week 5) with an average of 21.2±10.5 days (60.6%) per participant (n=19). 1 participant had all 35 days of valid LUMO data, 11 participants had some missing LUMO data due to an upload failure (142 days lost in total) with one participant having no LUMO data available due to this fault, 12 participants had missing data due to non-wear (86 days lost) with 5 participants having missing data due to a combination of LUMO upload problems and

non-wear. Additionally, 35 days were lost by 2 participants withdrawing after 2 and 3 weeks respectively. In the post-intervention questionnaire, 50% of participants reported wearing the LUMO on most days with 50% wearing the LUMO every day. Furthermore, the majority of participants re-calibrated the LUMO device after putting it back on after a period of non-wear with two participants reporting never re-calibrating.

Figure 4.5 shows the mean wear time on a workday compared to a non-workday across the 5-week measurement period. Wear time on a workday was consistently higher than on a non-workday with the highest average wear time during week 5 (891±73 minutes/day, n=12) and the lowest during week 4 (856±66 minutes/day, n=13). On a non-workday, the highest average wear time was during week 1 (821±67 minutes/day, n=13) and the lowest was during week 3 (781±131 minutes/day, n=13). Therefore, on average wear time on valid days was high at over 13 hours per day. Figure 4.6 shows the mean wear time during working and non-working hours on a workday during the measurement period. Wear time during working hours was also high with the highest during weeks 1 (459±84 minutes/day, n=14) and 4 (459±72 minutes/day, n=13) whereas the lowest was during week 2 (420±71 minutes/day, n=16). Similarly, wear time during non-working hours was also high with 463±67 minutes/day (n=12) recorded on average during week 5 whereas week 4 showed the lowest average wear time (396±77 minutes/day, n=13).

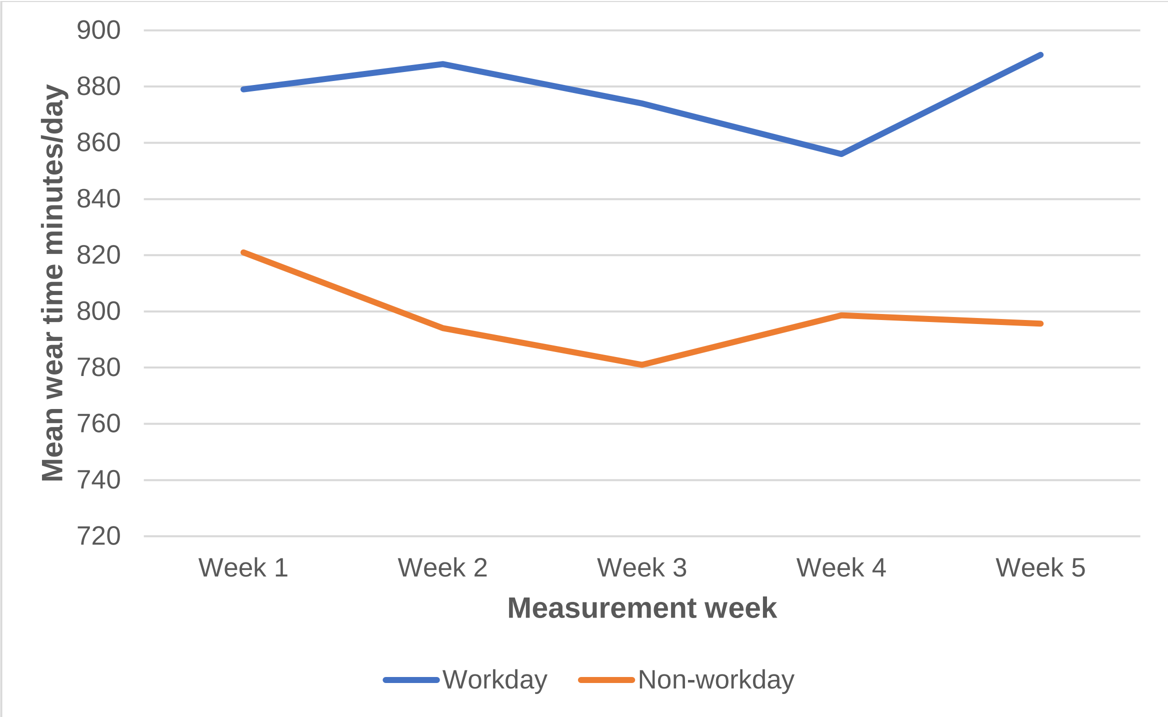


Figure 4.5 Mean LUMO wear time on a work and non-workday across the measurement period

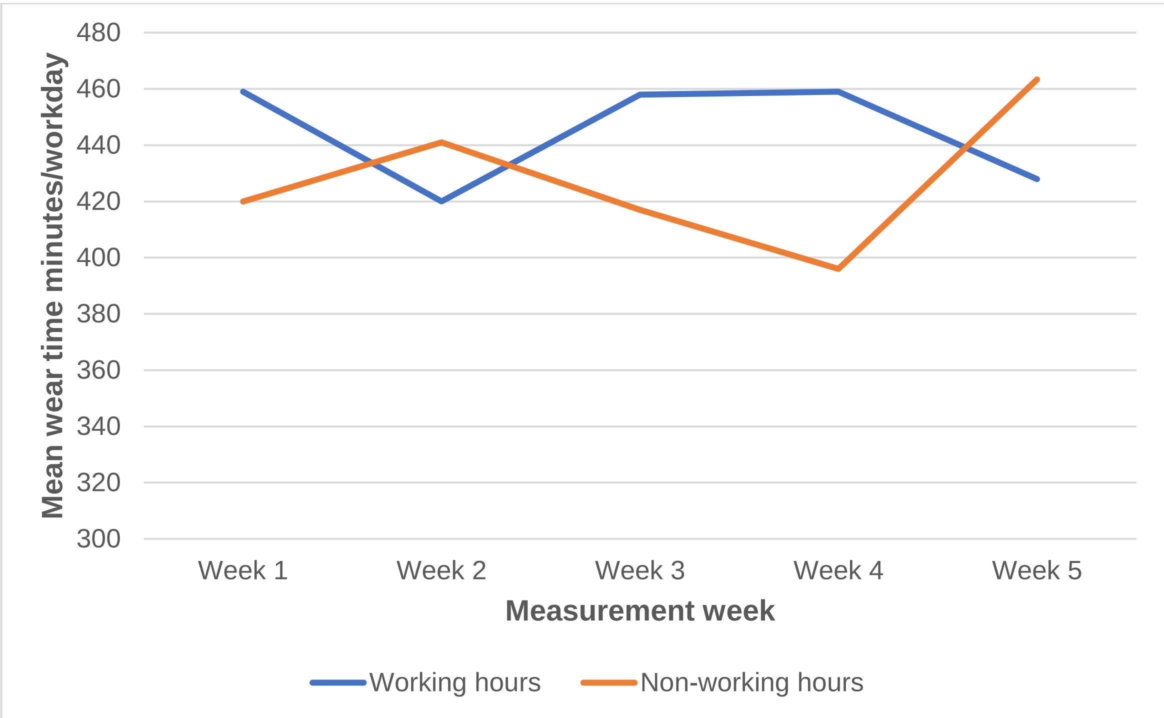


Figure 4.6 Mean LUMO wear time during working hours and non-working hours on a workday across the measurement period

Smart device application engagement

Data concerning usage of the smart device application were available for all participants who completed the intervention (n=17). All but one office worker (94%) actively engaged with the application and 63% of participants reported in the follow-up questionnaire that they checked the LUMO application at least once per day. Figure 4.7 shows the average number of sessions and time spent on the LUMO application per week of the intervention. Application engagement was highest during the first week of the intervention with an average of 26.2±33.2 sessions and 30.3±26.5 minutes spent on the application. Engagement then reduced in week 2 (19.1±38.7 sessions, 15.7±26.4 minutes) and again in week 3 (12.0±22.3 sessions, 11.22±14.7 minutes) with a minor increase during the final week (13.4±28.4 sessions, 12.1±14.7 minutes). Figure 4.8 shows the mean number of times each of the max cards were tapped during the intervention period. A similar pattern of engagement was found with the largest number of taps during week 1 of the intervention followed by a decrease in week 2, a further decrease in week 3 and then a minor increase during week 4. The highest engagement was found with the sitting max card across the course of the intervention with the highest number of taps during week 1 (19.3±31.9 taps) and lowest during week 4 (7.6±12.3 taps). Engagement with the standing max cards was also highest during week 1 (4.2±9.8 taps) but lowest during week 3 (1.4±3.5 taps). However, more taps were observed for the stepping max card compared to the standing max card during weeks 2 (4.2±11.6 taps), 3 (1.5±2.3 taps) and 4 (2.8±5.5 taps). This pattern of engagement was confirmed with the number of times each of the application min cards were on view during each week of the intervention period (Figure 4.9).

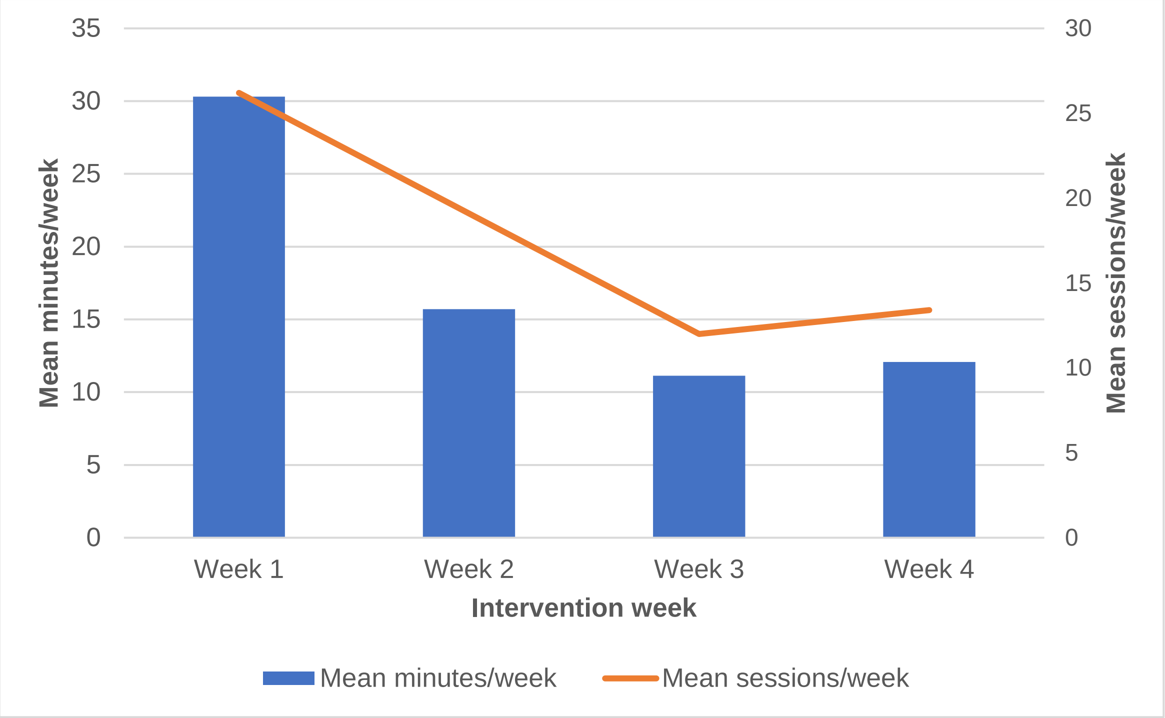


Figure 4.7 Mean minutes and sessions per intervention week spent on the smart device application

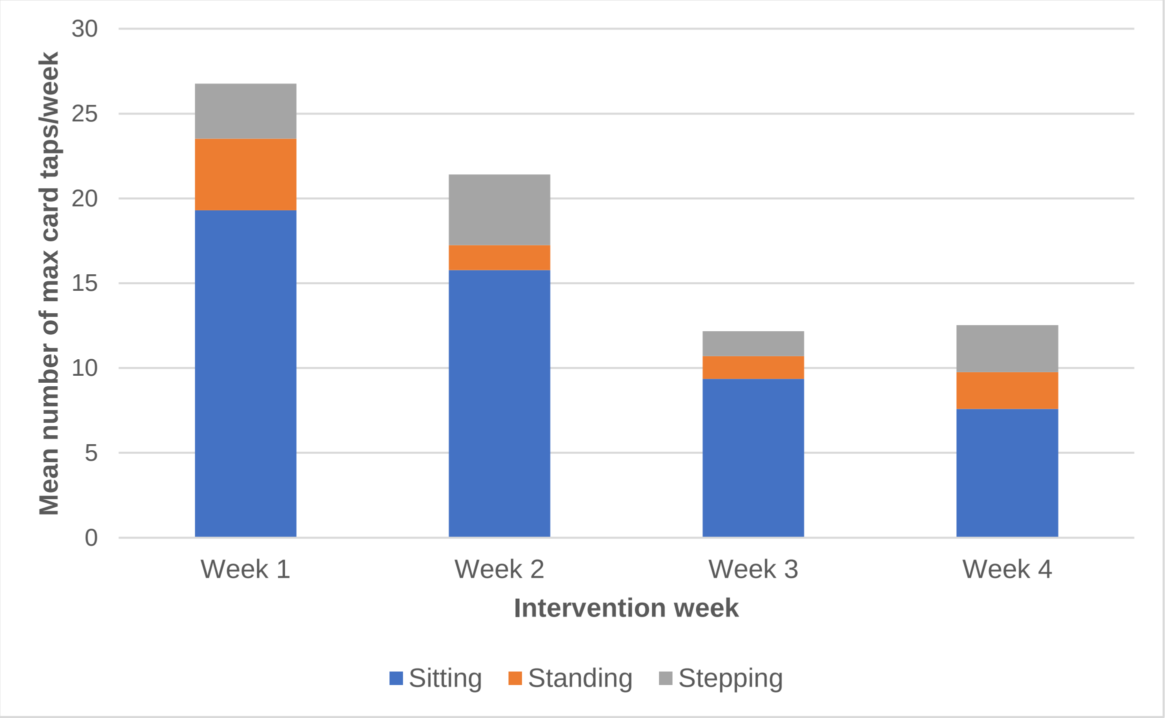


Figure 4.8 Mean number of times each of the application max cards were tapped during each intervention week

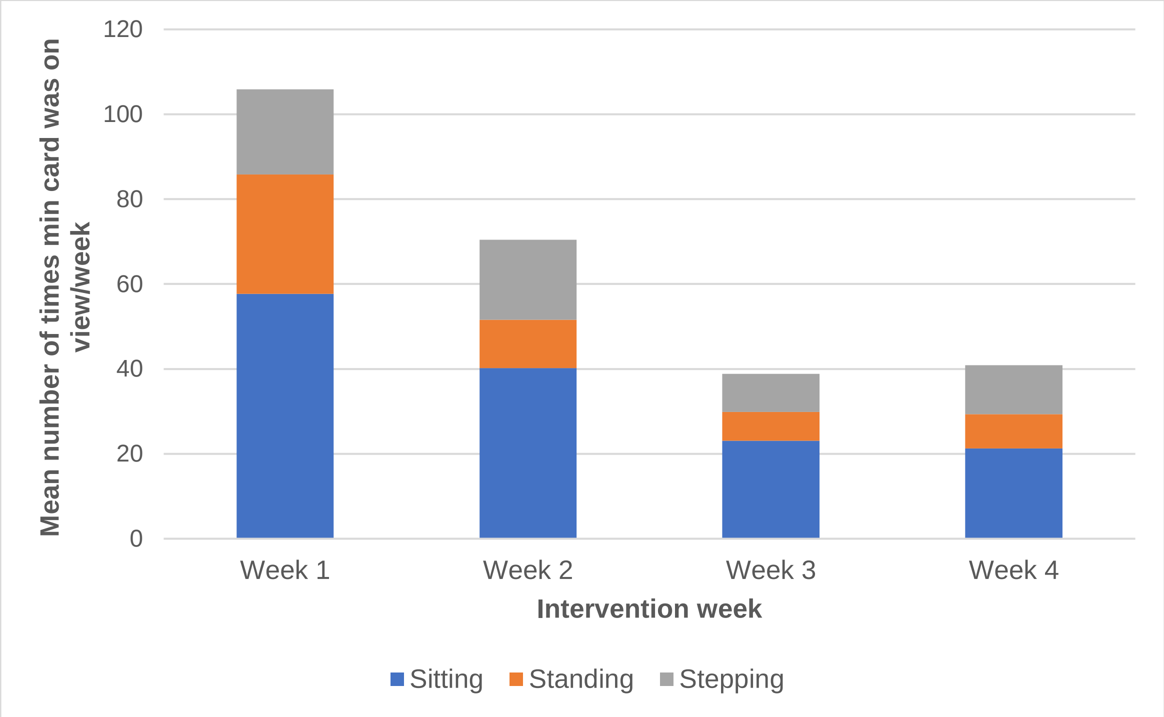


Figure 4.9 Mean number of times each of the application min cards were on view during the intervention period

4.3.3 Changes in sedentary, standing and stepping time

activPAL data

At baseline, on average, 9.5±1.4 hours/day were spent sedentary on a workday and 8.2±1.7 hours/day on a non-workday. The change in sedentary, standing and stepping time between baseline and follow-up for a workday and non-workday are shown in Table 4.3. At baseline on a workday, office workers spent 59.9% of wear time/day sedentary, 29.0% standing and 11.1% stepping. Conversely on a non-workday, 55.1% of the day was spent sedentary, 30.1% standing and 14.8% stepping. At follow-up, sedentary time on a workday reduced by 4% with the majority of office workers reducing the number and time spent in prolonged sedentary bouts (>30 minutes) notably reducing time spent sedentary in >60 minutes bouts by 3.0%. Additionally, 64.7% of office workers increased workday standing and stepping time by an average of 3.3% and 1.1% respectively.

Table 4.3 Changes in workday and non-workday sedentary, standing and stepping time between baseline and follow-up measured via activPAL (n=17)

	Baseline Mean (SD)	Follow-up Mean (SD)	Mean diff. (95% CI)	n improved (%)
Workday				
Sedentary time (% of wear time)	59.9 (8.1)	56.0 (9.5)	-4.3 (-8.5 to -0.2)	11 (64.7)
Time spent in 0-30 minute sedentary bouts (% of sedentary time)	49.4 (16.1)	52.0 (14.0)	2.6 (-5.0 to 10.3)	8 (47.1)
Time spent in 30-60 minute sedentary bouts (% of sedentary time)	26.8 (9.6)	27.2 (10.4)	0.4 (-5.2 to 5.9)	10 (58.8)
Time spent in ≥60 minute sedentary bouts (% of sedentary time)	23.8 (14.9)	20.9 (13.6)	-3.0 (-10.8 to 4.9)	9 (52.9)
No. of sedentary bouts (bouts/hour of wear time)	3.38 (0.76)	3.42 (1.01)	0.04 (-0.37 to 0.44)	10 (58.8)
Sedentary time in 0-30 minute bouts (% of sedentary bouts)	89.4 (5.5)	89.9 (6.0)	0.5 (-2.3 to 3.3)	8 (47.1)
Sedentary time in 30-60 minute bouts (% of sedentary bouts)	6.8 (3.9)	7.0 (4.7)	0.2 (-2.1 to 2.5)	10 (58.8)
Sedentary time in ≥60 minute bouts (% of sedentary bouts)	2.9 (2.4)	2.3 (2.1)	-0.6 (-1.9 to 0.7)	9 (52.9)
Standing time (% of wear time)	29.0 (7.5)	32.0 (10.4)	3.3 (-1.0 to 7.5)	11 (64.7)
Stepping time (% of wear time)	11.1 (2.6)	12.0 (3.7)	1.1 (-0.3 to 2.5)	11 (64.7)
Wear time (minutes/day)	940.6 (55.2)	946.3 (40.5)	3.9 (-33.6 to 41.3)	8 (47.1)
Non-workday				
Sedentary time (% of wear time)	55.1 (11.5)	55.7 (10.1)	0.6 (-7.9 to 9.1)	8 (47.1)
Time spent in 0-30 minute sedentary bouts (% of sedentary time)	49.9 (13.7)	49.6 (10.9)	-0.2 (-9.2 to 8.7)	8 (47.1)
Time spent in 30-60 minute sedentary bouts (% of sedentary time)	27.2 (10.6)	22.7 (12.4)	-4.5 (-12.8 to 3.7)	11 (64.7)
Time spent in ≥60 minute sedentary bouts (% of sedentary time)	22.9 (12.7)	27.7 (13.5)	4.8 (-5.3 to 14.9)	9 (52.9)
No. of sedentary bouts (bouts/hour of wear time)	3.35 (1.11)	3.46 (0.96)	0.21 (-0.30 to 0.73)	6 (35.3)
Sedentary time in 0-30 minute bouts (% of sedentary bouts)	89.8 (4.6)	91.0 (5.3)	1.3 (-2.0 to 4.5)	8 (47.1)
Sedentary time in 30-60 minute bouts (% of sedentary bouts)	6.7 (3.0)	5.7 (4.1)	-1.0 (-3.4 to 1.4)	11 (64.7)
Sedentary time in ≥60 minute bouts (% of sedentary bouts)	2.9 (2.5)	2.6 (1.9)	-0.3 (-1.8 to 1.1)	9 (52.9)
Standing time (% of wear time)	30.1 (9.8)	29.8 (9.1)	-0.2 (-5.9 to 5.5)	8 (47.1)
Stepping time (% of wear time)	14.8 (5.0)	14.5 (4.9)	-0.3 (-4.3 to 3.7)	8 (47.1)
Wear time (minutes/day)	894.6 (65.8)	894.8 (71.6)	0.2 (-36.2 to 36.6)	10 (58.8)

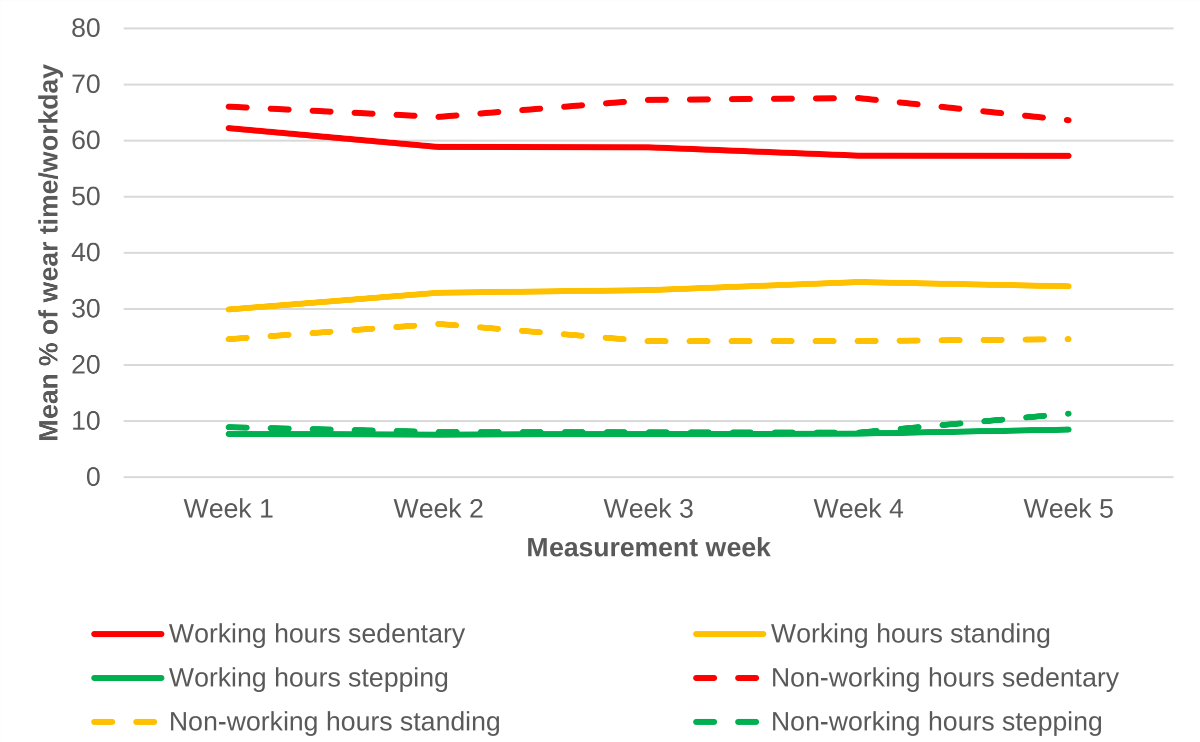
On a non-workday, no changes were observed for sedentary, standing or stepping time but the majority of office workers reduced the number and time spent sedentary in 30-60 minute bouts with a 4.8% increase in the time spent sedentary in >60-minute bouts. Overall, the majority of office workers increased the number of sit-stand transitions per day (58.8%) but no difference was observed for MVPA stepping time or number per day between baseline and follow-up (Table 4.4).

Table 4.4 Changes in mean daily sedentary, standing and stepping time between baseline and follow-up measured via activPAL (n=17)

	Baseline Mean (SD)	**Follow-up Mean (SD)**	**Mean diff. (95% CI)**	**n improving (%)**
Sit-stand transitions (transitions/hour of wear time)	3.4 (0.8)	3.5 (0.8)	0.1 (-0.2 to 0.4)	10 (58.8)
Stepping time (% of wear time)	12.4 (3.0)	13.1 (3.3)	0.7 (-1.1 to 2.6)	11 (64.7)
Time spent in MVPA stepping (% of stepping time)	62.6 (8.3)	63.6 (8.9)	0.9 (-1.7 to 3.6)	9 (52.9)
Step number (steps/hour of wear time)	309 (81)	335 (106)	26 (-27 to 79)	11 (64.7)
MVPA step number (% of step number)	82.3 (5.3)	82.8 (5.4)	0.5 (-1.1 to 2.2)	9 (52.9)
Wear time (minutes/day)	922.2 (47.1)	922.3 (40.4)	0.1 (-20.7 to 21.0)	10 (58.8)

LUMO data

Figure 4.10 shows the change in sedentary, standing and stepping time measured via the LUMO across the measurement period during working and non-working hours. On average, 296±101 minutes/day were spent sedentary during working hours and 274±58 minutes/day during non-working hours at baseline. Generally, sedentary time during working hours reduced and standing increased over the intervention period with stepping time increasing during week 5. Conversely, sedentary time during non-working hours reduced during weeks 2 and 5 but was above baseline level during weeks 3 and 4. In addition, an increase in standing time was observed during week 2 followed by similar levels to baseline during weeks 3, 4 and 5. Non-working hours stepping time was reduced during weeks 2, 3 and 4 with an increase above baseline level during week 5.

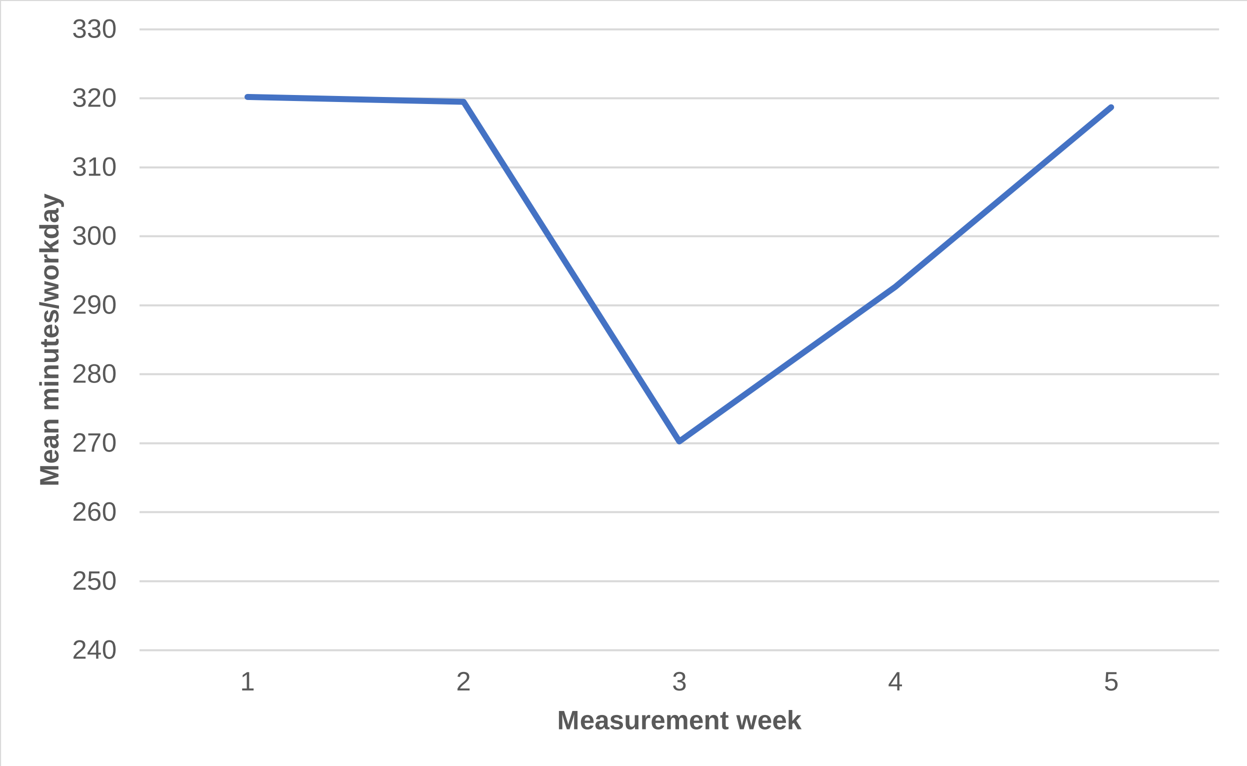


*n=14 week1, n=16 week 2, n=15 week 3, n=13 week 4, n=12 week 5.

Figure 4.10 Mean change in sedentary, standing and stepping time during work and non-working hours (on a workday) across the measurement period*

4.3.4 Change in sit-stand desk use

Figure 4.11 shows the amount of time office workers reported being at their sit-stand desk over the course of the study. An average of 320 minutes was spent at sit-stand desks on a workday during weeks 1 (320±111 minutes/day), 2 (320±116 minutes/day) and 5 (319±122 minutes/day); however, there was a reduction during weeks 3 and 4 to 270±109 and 293±124 minutes, respectively. 4-weeks post-baseline, self-reported sitting at sit-stand desks was reduced by 22 minutes/workday (95%CI: -45 to 1 minute/workday) and the amount of time spent sitting before alternating to standing was also reduced by 58 minutes (95% CI: -93 to -23 minutes). Conversely, no change was observed between self-reported time spent standing at a sit-stand desk before alternating to sitting (mean diff.=2, 95% CI: -34 to 37 minutes).



*n=19 week 1, n=15 week 2, 3 and 4, n=16 week 5.

Figure 4.11 Self-reported desk time per workday across the measurement period

4.3.5 Questionnaire feedback

Follow-up questionnaires on acceptability showed that participants found the intervention was useful for reducing sitting time, increasing sit-stand transitions, increasing standing time and increasing sit-stand desk use at work but not useful for increasing step count, incidental activity or MVPA. Additionally, participants found some benefits of the intervention during leisure-time with the majority reporting it was 'somewhat useful' for reducing sitting time, increasing sit-stand transitions and standing time. Both the vibration prompt and the application were rated as useful for reducing sitting time at work with the vibration prompt rated on average more useful than the application for increasing sit-stand transitions and standing time. During leisure-time, the vibration prompt and application were considered somewhat useful at reducing sitting time with the application also considered somewhat useful at increasing standing time. Conversely, most participants thought the intervention as a whole in addition to the vibration prompt and smart device application individually, were not useful during travelling for any of the outcomes. See Table 4.5 for responses.

Table 4.5 Self-reported usefulness of intervention and individual components (n=16)

		Not sure n (%)	Not useful n (%)	Somewhat useful n (%)	Useful n (%)	Extremely useful n (%)
Intervention usefulness at work for:	Reducing sitting time	0 (0.0)	1 (6.3)	3 (18.8)	10 (62.5)	2 (12.5)
	Increasing sit-stand transitions	1 (6.3)	1 (6.3)	3 (18.8)	9 (56.3)	2 (12.5)
	Increasing standing time	1 (6.3)	1 (6.3)	2 (12.5)	8 (50.0)	4 (25.0)
	Increasing step count	5 (31.3)	5 (31.3)	3 (18.8)	2 (12.5)	1 (6.3)
	Increasing incidental activity	1 (6.3)	5 (31.3)	3 (18.8)	6 (30.0)	1 (6.3)
	Increase MVPA	3 (18.8)	9 (56.3)	2 (12.5)	2 (12.5)	0 (0.0)
	Increase sit-stand desk use	1 (6.3)	1 (6.3)	5 (31.3)	5 (31.3)	4 (25.0)
Intervention usefulness whilst travelling for:	Reducing sitting time	2 (12.5)	12 (75.0)	2 (12.5)	0 (0.0)	0 (0.0)
	Increasing sit-stand transitions	3 (18.8)	11 (68.8)	2 (12.5)	0 (0.0)	0 (0.0)
	Increasing standing time	2 (12.5)	11 (68.8)	3 (18.8)	0 (0.0)	0 (0.0)
	Increasing step count	0 (0.0)	12 (75.0)	3 (18.8)	0 (0.0)	1 (6.3)
	Increasing incidental activity	3 (18.8)	10 (62.5)	2 (12.5)	0 (0.0)	1 (6.3)
	Increase MVPA	4 (25.0)	12 (75.0)	0 (0.0)	0 (0.0)	0 (0.0)
Intervention usefulness during leisure-time for:	Reducing sitting time	4 (25.0)	2 (12.5)	7 (43.8)	3 (18.8)	0 (0.0)
	Increasing sit-stand transitions	6 (37.5)	2 (12.5)	6 (37.5)	2 (12.5)	0 (0.0)
	Increasing standing time	3 (18.8)	3 (18.8)	7 (43.8)	3 (18.8)	0 (0.0)
	Increasing step count	3 (18.8)	6 (37.5)	3 (18.8)	3 (18.8)	1 (6.3)
	Increasing incidental activity	4 (25.0)	5 (31.3)	4 (25.0)	2 (12.5)	1 (6.3)
	Increase MVPA	3 (20.0)	7 (46.7)	1 (6.7)	4 (26.7)	0 (0.0)
Vibration prompt usefulness at work for:	Reducing sitting time	0 (0.0)	2 (12.5)	5 (31.3)	5 (31.3)	4 (25.0)
	Increasing sit-stand transitions	2 (12.5)	3 (18.8)	3 (18.8)	6 (37.5)	2 (12.5)
	Increasing standing time	1 (6.3)	3 (18.8)	3 (18.8)	6 (37.5)	3 (18.8)
	Increasing step count	3 (20.0)	9 (60.0)	1 (6.7)	2 (13.3)	0 (0.0)
	Increasing incidental activity	2 (12.5)	7 (46.7)	2 (12.5)	5 (31.3)	0 (0.0)
	Increase MVPA	0 (0.0)	12 (75.0)	2 (12.5)	2 (12.5)	0 (0.0)
	Increase sit-stand desk use	1 (6.3)	2 (12.5)	3 (18.8)	8 (50.0)	2 (12.5)
Vibration prompt usefulness whilst travelling for:	Reducing sitting time	1 (6.3)	13 (81.3)	1 (6.3)	1 (6.3)	0 (0.0)
	Increasing sit-stand transitions	1 (6.3)	13 (81.3)	2 (12.5)	0 (0.0)	0 (0.0)
	Increasing standing time	1 (6.3)	13 (81.3)	2 (12.5)	0 (0.0)	0 (0.0)
	Increasing step count	1 (6.3)	13 (81.3)	2 (12.5)	0 (0.0)	0 (0.0)
	Increasing incidental activity	1 (6.3)	15 (93.8)	0 (0.0)	0 (0.0)	0 (0.0)
	Increase MVPA	1 (6.3)	15 (93.8)	0 (0.0)	0 (0.0)	0 (0.0)
Vibration prompt usefulness during leisure-time for:	Reducing sitting time	3 (18.8)	4 (25.0)	5 (31.3)	4 (25.0)	0 (0.0)
	Increasing sit-stand transitions	6 (37.5)	4 (25.0)	3 (18.8)	3 (18.8)	0 (0.0)
	Increasing standing time	7 (43.8)	3 (18.8)	4 (25.0)	2 (12.5)	0 (0.0)
	Increasing step count	2 (12.5)	8 (50.0)	4 (25.0)	2 (12.5)	0 (0.0)
	Increasing incidental activity	1 (6.3)	7 (43.8)	5 (31.3)	3 (18.8)	0 (0.0)
	Increase MVPA	4 (25.0)	10 (62.5)	1 (6.3)	1 (6.3)	0 (0.0)
Application usefulness at work for:	Reducing sitting time	0 (0.0)	1 (6.7)	5 (33.3)	6 (40.0)	3 (20.0)
	Increasing sit-stand transitions	1 (6.3)	3 (18.8)	8 (50.0)	3 (18.8)	1 (6.3)
	Increasing standing time	0 (0.0)	3 (18.8)	5 (31.3)	4 (25.0)	4 (25.0)
	Increasing step count	1 (6.7)	6 (40.0)	5 (33.3)	2 (13.3)	1 (6.7)
	Increasing incidental activity	1 (6.3)	6 (37.5)	3 (18.8)	5 (31.3)	1 (6.3)
	Increase MVPA	1 (6.3)	7 (43.8)	5 (31.3)	3 (18.8)	0 (0.0)
	Increase sit-stand desk use	1 (6.3)	2 (12.5)	6 (37.5)	5 (31.3)	2 (12.5)

Table 4.5 cont.: Self-reported usefulness of intervention and individual components (n=16)

		Not sure	Not useful	Somewhat useful	Useful	Extremely useful
Application usefulness whilst travelling for:	Reducing sitting time	2 (12.5)	13 (81.3)	1 (6.3)	0 (0.0)	0 (0.0)
	Increasing sit-stand transitions	2 (12.5)	14 (87.5)	0 (0.0)	0 (0.0)	0 (0.0)
	Increasing standing time	1 (6.3)	14 (87.5)	0 (0.0)	0 (0.0)	0 (0.0)
	Increasing step count	1 (6.3)	14 (87.5)	0 (0.0)	1 (6.3)	0 (0.0)
	Increasing incidental activity	1 (6.3)	14 (87.5)	0 (0.0)	0 (0.0)	1 (6.3)
	Increase MVPA	1 (6.3)	14 (87.5)	1 (6.3)	0 (0.0)	0 (0.0)
Application usefulness during leisure-time for:	Reducing sitting time	0 (0.0)	5 (31.3)	4 (25.0)	6 (37.5)	1 (6.3)
	Increasing sit-stand transitions	4 (25.0)	6 (37.5)	4 (25.0)	1 (6.3)	1 (6.3)
	Increasing standing time	0 (0.0)	6 (37.5)	5 (25.0)	5 (20.5)	0 (0.0)
	Increasing step count	1 (6.3)	7 (43.8)	3 (18.8)	5 (31.3)	0 (0.0)
	Increasing incidental activity	1 (6.3)	9 (56.3)	1 (6.3)	4 (25.0)	1 (6.3)
	Increase MVPA	2 (12.5)	10 (62.5)	2 (12.5)	2 (12.5)	0 (0.0)

Overall, the office workers reported that the LUMO was easy to understand (93.8%), use (87.5%) and calibrate (87.5%) with the majority also agreeing that it did not require a lot of effort to use the LUMO (87.5%). Participants agreed that it was easy to calibrate the LUMO using the application (87.5%) and that without help from anyone else, they trusted themselves to use the LUMO (75%). In terms of comfort, the LUMO was rated 3.06±0.93 on a 5-point-scale (1=not at all comfortable, 5=very comfortable). When asked about the individual aspects of the intervention, the majority of participants reported that they would not wear the LUMO with the vibration prompts but without the associated application (66.7%) or vice versa (56.3%) as neither would be as effective as the current intervention using them in combination (68.8% and 75.0% respectively). Furthermore, the majority of participants were satisfied with the intervention (81.3%) and its components with only one person reporting that they were not satisfied with the intervention, one with the vibration prompts (6.3%) and two with the LUMO application (12.5%). Conversely, 69% of participants reported that they would not carry on with the intervention if possible but 63% would recommend it to a friend.

4.3.6 Interview feedback

During follow-up interviews with the office workers (n=17), the acceptability of the intervention was discussed, and four themes emerged: 1) Task dependent, (2) Device problems, (3) Application or prompt preference, and (4) Increased awareness of behaviour. Textbox 1 contains supportive quotes for each of the four themes.

Textbox 1:

Supportive quotes from individual participant interviews for the themes identified

1) **Task dependent:**

"I was in a meeting once and it buzzed quite loudly. Everyone looked at me funny." [Female 01]
"I felt like I was too busy to stand sometimes when it buzzed." [Female 03]
"It depends what work I am doing. I can't do thinking work standing. I can do admin and send emails." [Female 05]
"I think it was good for work time but it is not unreasonable to sit for longer than half-an-hour in the evenings." [Female 07]
"Definitely more responsive at work. At work you have the option. Watching TV or a film at home I was relaxing." [Female 19]

2) **Device problems:**

"It was really frustrating when the app got it wrong." [Female 01]
"Most of the time it was ok but when it was on my skin it was uncomfortable and sweaty." [Female 04]
"It was sweaty whilst training. Irritating and cut in if it was too tight but if it was looser, I was more aware of it." [Female 14]
"I always had to think about which clothes to wear. It tends to wear up, especially when wearing a dress." [Female 16]

3) **Application or prompt preference:**

"I felt annoyed that it (prompt) had broken my concentration… I felt rebellious not to stand because it was telling me to." [Female 02]
"The app was simple, easy to use. I liked to see the little man running." [Female 06]
"The prompts were useful when sitting at my desk." [Male 11]
"The buzz didn't have an effect on me. I stand when I feel like standing and sit when I feel like sitting." [Male 12]
"I liked the app, fascinating to see how long I was sitting and standing. Comparing the days was interesting." [Female 14]

4) **Increased awareness of behaviour:**

"I feel pleased with myself for raising my consciousness of my activity levels and that I do a lot already." [Female 08]
"It concentrates the mind. I am conscious about making the effort to stand-up more now." [Male 09]

Task dependent

Most participants highlighted that the intervention was acceptable at work and that when they were prompted, they would stand at their desk or go for a short walk. However, the intervention was less accepted during non-working hours with many participants highlighting that they would not get up whilst TV viewing and that there should be a ‘do not disturb’ function to turn the prompts off. Travelling was highlighted as compulsory sitting and that it should be recognised separately. Additionally, many participants mentioned that work tasks requiring high concentration were easier to complete sitting down whereas emailing and taking phone calls were better suited to standing.

Device problems

Generally, participants confirmed that the LUMO device was comfortable, but they preferred not to wear it in contact with the skin. However, irritation due to the Velcro being misaligned, pressure on the back whilst driving and the device moving up and down were frequently mentioned. Participants felt like they had to wear clothing suitable for the device and would have preferred something more discreet or similar to the activPAL device. Participants also experienced problems with the accuracy of the LUMO, expressing frustration when this occurred and a loss of trust in the device. There were reports of inaccurate steps, prompts occurring whilst standing and general misrepresentation of behaviour.

Application or prompt preference

There was a general preference towards the application element of the LUMO with participants commenting positively on the avatar, pie charts and record of behaviour. However, a number of participants felt that they were familiar with how sedentary and/or active they were so did not engage with the information within the application. Additionally, the addition of targets and feedback on progress within the application were amongst the suggested improvements. Negative comments were expressed regarding the prompt where participants were annoyed that it was ‘buzzing’ in situations where they felt they could not change their behaviour especially during leisure-time. A number of participants described how they started to anticipate the prompt and had already made a decision as to whether they were going to change their behaviour or not. Furthermore, having a computer or mobile phone message was suggested in preference to a vibration prompt.

Increased awareness of behaviour

Overall the intervention had increased the participants' awareness of their behaviour with a number commenting on their baseline levels of sitting and how they would like to carry on reducing sitting times at work. Although the majority of participants would not carry on wearing the LUMO if they had the option, a number expressed an interest in purchasing a wrist-worn activity monitor or timing the amount of time spent sitting at their desk. Continuing to increase standing time at the sit-stand desk was stated by the majority of participants as an ongoing aim after the end of the intervention.

4.3.7 Changes in health and work-related measures

Table 4.6 shows the change in health and work-related measures between baseline and follow-up. The majority of office workers showed an improvement in fat mass (64.7% improved) and fat percentage (58.8% improved). In addition, reductions were observed in systolic (76.4% of participants) and diastolic (52.9% of participants) blood pressure with a decrease of 5.4 mmHg and 1.3 mmHg respectively. Conversely, self-reported sleep time decreased at follow-up by an average of 25 minutes per night. Minimal changes were observed for work-related outcomes with 50% of office workers reporting higher job performance and work engagement scores compared to baseline. Furthermore, the need for recovery after work score was reduced for 46.7% of office workers and only one participant reported a reduction in job satisfaction.

Table 4.6 Mean change in health and self-reported work-related measures between baseline and follow-up (n=17)

	Baseline Mean (SD)	Follow-up Mean (SD)	Mean diff. (95% CI)	n improved (%)
Health measure				
Weight (kg)	65.7 (11.2)	66.0 (11.2)	0.2 (-0.2 to 0.6)	7 (41.2)
BMI (kg/m^2)	24.1 (4.3)	24.2 (4.2)	0.1 (-0.1 to 0.3)	7 (41.2)
Fat (%)	27.7 (8.6)	26.8 (9.2)	-0.1 (-1.7 to -0.1)	11 (64.7)
Fat mass (kg)	19.1 (8.9)	18.6 (8.7)	-0.6 (-2.6 to 1.4)	10 (58.8)
Fat-free mass (kg)	46.7 (9.9)	48.0 (9.2)	1.3 (-0.2 to 2.7)	5 (29.4)
Systolic blood pressure (mmHg)	109.5 (11.2)	104.2 (11.5)	-5.4 (-9.2 to -1.5)	13 (76.4)
Diastolic blood pressure (mmHg)	75.3 (7.7)	74.1 (10.0)	-1.3 (-4.6 to 2.0)	9 (52.9)
Heart rate (beats/min)	62.5 (11.8)	63.5 (12.0)	0.9 (-2.4 to 4.8)	7 (41.2)
Sleep (mins/night)*	396 (68)	371 (78)	-25 (-47 to 2)	1 (6.7)
Work-related measure*				
Work engagement (score/9)	4.1 (0.9)	4.3 (0.9)	0.2 (0 to 0.4)	8 (50.0)
Work recovery (score/11)	3.7 (2.9)	3.1 (2.9)	-0.6 (-1.6 to 0.4)	7 (46.7)
Job satisfaction (score 1-7)	5.2 (1.4)	5.4 (1.2)	0.2 (-0.4 to 0.8)	5 (33.3)
Job performance (score (1-7)	4.9 (1.0)	5.4 (0.7)	0.5 (0.1 to 0.9)	8 (50.0)
Absenteeism (days/month)	0.3 (1.0)	0.3 (0.6)	0.1 (-0.7 to 0.6)	2 (13.3)
Presenteeism (days/month)	1.1 (2.1)	0.2 (0.8)	-0.9 (-2.1 to 0.4)	4 (26.7)

*n=15 sleep, absenteeism, presenteeism, job satisfaction, work recovery, n=16 job performance, work engagement

4.4 Discussion

Principal findings

The primary aim of this study was to assess the feasibility of a sedentary behaviour self-monitoring and prompting device (LUMO) to reduce workplace sitting time in a sample of office workers who already have sit-stand desks. 85% of office workers completed the five-week study and wore the LUMO on most days (60.6%). 94% of the sample engaged with the application with the sedentary time aspect receiving the most taps. The prompts were acceptable during working hours but not during non-working hours where sedentary time was viewed as relaxing. Overall, the intervention increased participants' awareness of sedentary time and the potential to reduce sedentary time was observed on a workday particularly in prolonged sedentary bouts of over 30 minutes.

Feasibility of the intervention

The LUMO device seems feasible as an intervention tool with a high retention of participants across the five-week study period. Similar rates were reported in the COPD-seat trial[327] for the group who received the LUMO (75%). This study also had high compliance rates with participants wearing the LUMO for most days with high wear times on those days. Conversely, participant interviews revealed that most participants experienced some discomfort with the waist-worn monitor that would prevent them from wearing it long-term. Additionally, some participants reported the need to remove the monitor whilst exercising due to concerns about comfort which impacts on the accuracy of the data collected. A more discreet location was suggested either on the wrist or on the thigh where the monitor would not move around and not impact on clothing choices. These concerns have been highlighted previously in studies implementing the LUMO where participants have reported the waist location uncomfortable[327] and hard to wear with clothing.[328] Furthermore, a few participants reported concerns about the accuracy of the LUMO especially in terms of stepping time and counts with one office worker developing a loss of trust in the device. This is supported by a LUMO validation study where in free-living conditions the LUMO underestimated stepping time (mean bias of 2.3 minutes) and number of steps (mean bias of 153 steps) compared to the activPAL.[112] However, these differences were not significant and many commercial devices produce different stepping data from the standard.[113]

Acceptability

The intervention acceptability was good with 81% of office workers reporting that they were satisfied, 63% would recommend to a friend and all office workers wore the LUMO at least on most days during the intervention. However, 69% of participants reported that they would not carry on with the intervention if possible, indicating that this intervention would not be acceptable over the long-term. Themes from the post-intervention interviews suggest that the intervention was effective at increasing participants' awareness of their behaviour but that the device would need improving for future use as a persuasive technology device. This is due to participants experiencing problems with the device, a preference towards the application or the prompt and that the potential to change sedentary time is task dependent.

The key theme that emerged from participant interviews was that the LUMO was acceptable during working hours only and that behaviour change depended highly on the activity being undertaken. The prompts were acceptable while participants were at their sit-stand desks during working hours but it was reported that sitting was required during certain tasks. For example, a few participants spoke about tasks that required high amounts of concentration were easier to achieve while seated with some participants planning their work schedule around sitting versus standing tasks to enable a balance of both during the working day. A similar finding was reported by an Australian sit-stand desk intervention[329] where office workers sat down for large word processing tasks and stood for emailing. However, only positive changes in work related outcomes measured in this study were found and previous research has found no impairment on executive function whilst standing.[330] Chau and colleagues[329] also found that a lack of desk space was a barrier to using sit-stand desks in the standing position due to desk design. This was also commented on during participant interviews with a preference towards desks that were fully-adjustable as opposed to retro-fit desks which could further reduce workplace sitting time.

Sitting was the most engaged with element of the smart-device application and the self-monitoring aspect of the LUMO was the most highly accepted. Many positive aspects were reported including the avatar mimicking participant's real-time behaviour, being green and happy when the behaviour was desired, easy to access and interpret the data in pie charts and bar graphs. The ability to look back on data from the baseline week allowed participants to track their progress and this was seen as highly motivating and interesting. This is supported by Brakenridge and colleagues[328] who found that the real-time feedback element was key in a multicomponent intervention with office workers over year. However, patients did not engage with the application during the COPD-seat trial[327] which did not provide training on the smart devices used and had a low proportion of smart phone users in contrast to the current study. In the current study, participants did not like the avatar shown as unhappy whilst sitting because this was interpreted as irritating due to participants perceiving some sitting as a break and not always as something negative. Additional ways to improve the application included the inclusion of targets to compare against with feedback on progress towards these and a competition element where you could compete against other users.

Conversely, the prompting in a form of a vibration was generally disliked with mostly negative comments emerging during the interviews except whilst at sit-stand desks where it had the most impact on breaking up sitting time. Brakenridge and colleagues[312] reported a similar finding where the unedited LUMO device was deployed and less than half of participants turned the sitting notification on even though the prompting frequency could be individually set. Furthermore, the vibration prompts used to correct posture in the Australian intervention had low acceptability with participants reporting the prompts as distracting and annoying to the extent where the function was turned off. Participants described numinous occasions where the prompt was undesirable including whilst watching TV, in the cinema, during eating, in meetings, whilst travelling and after long periods of standing or stepping. A common reason for this was due to standing being culturally unacceptable in these situations thus participants did not want to change their behaviour. Additionally, standing or stepping was not always possible with the example of driving commonly mentioned and some sitting was seen as resting where participants had already decided to ignore the prompts. Therefore, having user control over the prompt frequency, an integrated diary feature that would prompt only in situations where standing was possible, a proximity sensor that would turn prompts on when at a sit-stand desk or a screen-based prompt rather than vibration were suggested improvements.

Preliminary pre-post outcome data

A trend towards reductions in workday sedentary time and prolonged sedentary bouts was observed with an increase in sit-stand transitions, standing and stepping. Additional trends towards improvements were observed for fat percentage, fat mass, systolic blood pressure, job performance, work engagement and need for recovery after work. These findings are supported by previous workplace interventions implementing sit-stand desks[64–67,69,188,331] and multicomponent designs[73,187,242]. Conversely, other workplace interventions that have implemented pedometers[207,210] and computer prompts[206,213] have found no reductions in sedentary time over the short-term even with the addition of sit-stand desks.[234] Furthermore, the use of the LUMO in a previous workplace interventions has not resulted in sedentary time reductions over the short-term.[76,112] The discrepancy in results could be due to the current study sample having sit-stand desks at work where the environment is conducive to reducing sedentary time and separating work and non-workdays for analysis. Additionally, the current sample scored highly on the readiness to reduce sitting scale and had very high confidence in reducing sitting time prior to the intervention. However, the current study was not powered to measure the statistical significance of the findings and thus should be interpreted with caution.

The potential to reduce workday sedentary time demonstrates a change in behaviour which can be explained using the BCW.[202] The device used in this intervention addressed the Capability and Motivation areas of the COM-B system. The self-monitoring aspect of the device helped improve psychological capability and provided reflective motivation by increasing sitting time awareness and understanding. Additionally, the vibration prompts from the device provided automatic motivation encouraging habit formation in addition to increasing awareness of the target behaviour. With the additional aspect of sit-stand desks already in place, the Opportunity condition was met in the workplace enabling behaviour change to occur. Conversely, the lack of environmental change i.e. no intervention element addressing the physical and social opportunity during non-working hours could explain why no reduction in sedentary time occurred in this domain.

Another finding was that time spent in prolonged sedentary bouts of over one hour was higher at follow-up on a non-workday with participants reducing time spent in 30 to 60-minute bouts. Additionally, an increase in sedentary time during non-working hours was also observed during week two and three but this study was not statistically powered to detect significant differences so results should be interpreted with caution. However, sedentary time accumulated in prolonged bouts has been shown to be detrimental to health[149] and the majority of workplace sedentary behaviour interventions do not measure non-working hours and/or non-workday sedentary time thus the effects of the intervention on sedentary behaviour during these domains is unclear. One study which did measure working and non-working hours found that after 6 weeks of a sit-stand desk intervention, sedentary time during working hours decreased but sedentary time during non-working hours increased by 6% and 8% at 3 months compared to baseline.[308] Therefore, future workplace studies should consider the intervention effects on non-working hours and measure all domains of sedentary time.

Limitations and Strengths

The results of this study are limited by the small sample consisting of predominantly White British females thus conclusions are only applicable to this population and inadequate power was obtained to explore statistically significant changes in behaviour. Furthermore, the pre-post design limits the evaluation of behaviour change measures as there is no control group to compare to and findings could be due to other factors. Recruitment rates were unobtainable due to the absence of a database containing sit-stand desk users within the population targeted. Additionally, the intervention was only short-term and sit-stand desk use was measured via self-report potentially effected by biases. Furthermore, due to the activPAL processing procedure used in this study, the software was unable to separate working and non-working hours thus sedentary, standing and stepping times during these domains could not be compared using the activPAL. Finally, the LUMO device is no longer being manufactured so the conclusions drawn should be considered when developing future interventions and deploying similar devices. Conversely, this study has many strengths. It is the first to explore the feasibility of a device in a population who have sit-stand desks that prompts the user based on their behaviour and allows them to monitor sedentary time. Detailed objective data were obtained for engagement, sedentary, stepping and standing time in addition to interview and questionnaire data. Furthermore, monitoring was continuous during the five-week study and due to participant diaries, comparison of work versus non-workdays and working versus non-working hours were available for comparison.

4.5. Conclusions

In conclusion, a self-monitoring and prompting device is a feasible way to reduce sedentary time in office workers with sit-stand desks over the short-term. A potential to reduce prolonged sedentary time at work was shown and participants found the prompt useful within this domain. Conversely, the prompt was less acceptable during non-working hours and allowing the user to edit the prompt settings would have improved this. Participants were highly engaged with the application allowing them to self-monitor sedentary time and adding targets to work towards would potentially improve the associated outcomes. Future research adopting an RCT design is needed to explore the long-term effects of an improved self-monitoring and prompting device in addition to sit-stand desks on sedentary time in adults. Furthermore, future workplace studies should consider the effects of intervention strategies on sedentary time during non-working hours in addition to working hours.

Chapter 5: General Discussion

Overview

The previous three chapters described studies that aimed to fill the gaps identified from the literature review in Chapter 1 and address each of the thesis objectives. Each of these chapters discussed the specific study findings, strengths and limitations. Therefore, this chapter summaries the findings of the thesis in relation to the aims and objectives, provides a general discussion of the results, acknowledges the strengths and limitations, suggests areas for future research and provides overall conclusions.

5.1 Key findings

This thesis aimed to provide a significant contribution to the growing body of sedentary behaviour research in office workers by investigating the gaps highlighted in the literature review (Chapter 1). Therefore, Study One (Chapter 2) explored the prevalence of domain-specific sedentary behaviour in a large sample of office workers from Northern Ireland and links with other health behaviours. Study Two (Chapter 3) investigated the effectiveness of a pilot multicomponent workplace intervention to reduce sedentary time over the short (3 months) and long-term (12 months). Finally, Study Three (Chapter 4) explored the feasibility of a self-monitoring and prompting device to reduce sedentary time in a sample of office workers who have sit-stand desks. Table 5.1 summarises the key findings of each of the three studies in relation to the thesis objectives.

Table 5.1 Summary of each study with the objectives and key findings

Objectives	Chapter	Methods	Key findings related to objectives	Strengths	Limitations
1. To assess the prevalence of sedentary behaviour in a large sample from the UK and highlight important domains of sedentary behaviour. 2. To explore the associations between domain-specific sedentary time and other health behaviours. 3. To examine if any associations between sedentary time and other health behaviours track over time.	2	Online survey data from Northern Irish Civil Servants analysed cross-sectionally (n=7170) and between the two data collection points 2 years apart (n=806): • DSSTQ on work and non-workdays. • Other health behaviours: physical activity, fruit and vegetable consumption, cigarette smoking and alcohol consumption.	1. Participants reported 643±160 minutes sitting on a workday and 491±210 mins sitting on a non-workday. The majority of workday siting took place at work (383±95 mins/day) and whilst TV viewing on a non-workday (173±101 mins/day). 2. ≥7 hours sitting at work and ≥2 hours TV viewing on a workday both more than doubled the odds of partaking in ≥3 unhealthy behaviours [OR=2.03, 95% CI, (1.59-2.61); OR=2.19 (1.71-2.80)] and ≥3 hours of TV viewing on a non-workday nearly tripled the odds [OR= 2.96 (2.32-3.77)]. 3. No associations between domain-specific sitting time at baseline and change in unhealthy behaviour score were found in the prospective analysis with the majority of participants maintaining baseline levels of all behaviours.	• Large sample of office workers. • First study to look at the link between domain-specific sitting time and multiple other health behaviours. • Explored individual domains of sitting on both work and non-workdays.	• Only two time points so causality cannot be established. • Self-report measures.

Table 5.1 (continued): Summary of each study with the objectives and key findings

Objectives	Chapter	Methods	Key findings related to objectives	Strengths	Limitations
4. To investigate whether a multicomponent, workplace intervention adopting individual and environmental strategies was an effective way to reduce sedentary time in office workers over the short- and long-term. 5. To investigate whether there was any effect of the multicomponent intervention on health markers and physical activity.	3	Pilot RCT with an intervention and control arm. Office workers recruited from Loughborough University. Intervention group (n=30): • Sit-stand desk. • Educational leaflet. • Tips leaflet. • Fortnightly motivational emails. • Pedometer. • Monthly step challenges. • Feedback on health markers. Control group (n=30): • Feedback on health markers. • Educational leaflet. • Maintained normal behaviour. 3-month intervention with measurement sessions at baseline, 3 months and 12 months: • Sedentary, standing, stepping time (activPAL3). • Light and MVPA (ActiGraph GTX3). • Body composition, blood pressure and blood markers. • Focus group (3-month follow-up only).	4. No significant differences between groups. Trends: the intervention group reduced sedentary time at work by -7.9±25.1% and overall workday by -4.6±13.8% 3 months post-baseline. A reduction was observed in the intervention group 12 months post-baseline in sedentary time at work (-18.4±12.4%) and on a workday overall (-8.0±8.3%). Intervention was acceptable after 3 months. The intervention group showed an increase in sedentary time outside of work on a workday (4.2±9.5%) and overall on a non-workday (3.5±10.8%) after 12-months compared to baseline. 5. Intervention group increased step counts (113±259 steps/hour wear time) and stepping time (2.0±4.1% of wear time) 3 months post-baseline. No significant differences in physical activity or health measures between groups at 3 months or trends at 12 months.	• Intervention developed using the COM-B model and participant feedback. • RCT design. • 12-month follow-up. • Objective measures. • Comparison of work and non-work sedentary time.	• Reduced sample size at 3 (n=25 intervention, n=18 control group) and 12 months (n=11 intervention, n=7 control) limiting statistical power. • Retro-fit sit-stand desks provided limited space. • Pedometers provided no feedback on sedentary time. • No measure of sit-stand desk use.

Table 5.1 (continued): Summary of each study with the objectives and key findings

Objectives	Chapter	Methods	Key findings related to objectives	Strengths	Limitations
6. To assess the feasibility of a sedentary behaviour self-monitoring and prompting device (LUMO) to reduce sedentary time in a sample of office workers who already have sit-stand desks. 7. To gather preliminary data on the impact the above intervention on sedentary time, physical activity, desk use, health- and work-related outcomes.	4	Feasibility study with a pre-post design. Office workers with sit-stand desks recruited from Loughborough University (n=20). 4-week intervention: • Provision of a self-monitoring device (LUMO) that provides feedback through a smart device application on sedentary, standing and stepping time. • Vibration prompts through the LUMO device every 30 mins of uninterrupted sedentary time. • Sedentary behaviour educational booklet. • Feedback on baseline health-measures. Measures at baseline and after 4 weeks: • LUMO wear time, sedentary, standing and stepping. • Engagement with the LUMO application. • Sedentary, standing, stepping time, prolonged sedentary bouts, sit-to-stand transitions and MVPA stepping (activPAL3) • Self-reported daily desk time and use. • Heart rate, blood pressure and body composition. • Self-reported: Job satisfaction, job performance, work engagement, absenteeism, presenteeism and need for recovery after work. • Semi-structured interviews (follow-up only). • Acceptability questionnaire (follow-up only).	6. LUMO wear time was high with an average of 21.2±10.5 days (n=19) out 35-day maximum wear (60.6%). LUMO application engagement was high with an average of 26.2±33.2 sessions and 30.3±26.5 mins per week. Sedentary time was the most engaged with aspect of the application. Participants reported that the acceptability of the LUMO depended on the task undertaken, problems with the device, preference towards the application or the prompt but overall it increase awareness of sedentary behaviour. 7. Reduced sedentary time (-4%) and prolonged bouts of sedentary time >60 mins (-3%) on a workday. Reduction in sitting at sit-stand desks (-22 mins/workday, 95%CI: -45 to 1) and the amount of time spent sitting before alternating to standing (-58 minutes, 95% CI: -93 to -23). No difference in MVPA stepping. Improvements were seen for fat percentage and mass, blood pressure, job performance, work engagement, need for recovery and job satisfaction. Non-workday sedentary time >60 min bouts increased (4.8%). Increases in non-working hours sedentary time were apparent in weeks 3 and 4.	• First to use a device to self-monitor sedentary time with prompts in a sample with sit-stand desks. • Continuous measurement for 5-weeks. • Objective measures. • Working and non-working hours separated for comparison.	• Small sample (n=17 at follow-up). • No control group. • Short duration. • Some LUMO data was lost when uploaded to the cloud.

Study One

This study utilised a large, secondary data sample of Northern Irish office workers who completed an online survey on two occasions which were two years apart. The cross-sectional analysis combined the data from both measurement points (n=7170) to address thesis objective one: *To assess the prevalence of sedentary behaviour in a large sample from the UK and highlight important domains of sedentary behaviour.* It was found that office workers reported sitting on average for 643 minutes/day on a workday and 491 minutes/day on a non-workday. Additionally, the majority of sitting time was accumulated at work on a workday (383 minutes, 60% of total sitting time) and whilst TV viewing on a non-workday (173 minutes, 35% of total sitting time). Therefore, office workers sit for longer on workdays compared to non-workers spending over 6 hours sedentary at work.

The cross-sectional data were also used to address thesis objective two: *To explore the associations between domain-specific sedentary time and other health behaviours.* Not meeting national physical activity guidelines was associated with higher amounts of sitting time whilst travelling (workday), at work (workday), and whilst TV viewing (work and non-workday) but with lower sitting time during leisure-time (workday). Meeting alcohol guidelines was associated with higher sitting times whilst travelling (workday) and lower sitting times at work (workday), during TV viewing (work and non-workday), leisure-time (work and non-workday) and computer-use (non-workday). Office workers who smoked sat for longer whilst TV viewing (work and non-workday) and at work (non-workday). Conversely, office workers who met the national fruit and vegetable guidelines sat less during work (workday), TV viewing (work and non-workday) and computer-use (non-workday).

Using these health behaviours, an unhealthy behaviour score was calculated for all the office workers by adding up the number of health behaviours that they did not meet the current national guidelines for (0-4). The multinomial regression analyses revealed that office workers who sat for ≥7 hours at work (workday) had double the odds of being in the highest unhealthy behaviour score category compared to those sitting for ≤6 hours in the fully adjusted model (controlled for BMI, age, sex, marital status, survey year, salary, work pattern and education). Additionally, ≥2 hours TV viewing on a workday more than doubled the odds of partaking in ≥3 unhealthy behaviours and ≥3 hours of TV viewing on a non-workday nearly tripled the odds. Therefore, office workers who accumulate large amounts of sitting time at work (workday) and whilst TV viewing (work and non-workday) also partake in other unhealthy behaviours including physical inactivity, smoking, high alcohol consumption and under consumption of fruit and vegetables.

Finally, office workers who completed the survey at both measurement points (n=806) were included in the analysis to address thesis objective three: *To examine if any associations between sedentary time and other health behaviours track over time.* At the two-year follow-up, there were no significant associations between sitting time in any domain and change in unhealthy behaviour score. Additionally, the majority of office workers remained in the same unhealthy behaviour score category and only minimal changes were observed in domain-specific sitting time and individual health behaviours. Therefore, domain-specific sitting time and the other health behaviours analysed in this study were maintained at the same level over the two-year period.

In conclusion, study one showed that office workers are highly sedentary and that most sitting time is accumulated during the work domain on a workday. High amounts of sitting time in this domain and TV viewing on a work and non-workday are associated with increased odds of partaking in multiple other unhealthy behaviours including physical inactivity, smoking, high alcohol consumption and under consumption of fruit and vegetables. Furthermore, both domain-specific sitting time and other health-related behaviours are maintained over time. Therefore, multicomponent interventions are needed to reduce sitting time in office workers and target other health-related behaviours.

Study Two

This study was a pilot randomised controlled trial which implemented a multicomponent intervention that was informed by focus groups and based on the COM-B model of behaviour change. The intervention strategies included feedback on health measures at baseline, the provision of a retro-fit sit-stand desk, a sedentary behaviour educational leaflet that also contained suggested walking routes, fortnightly motivational emails, a pedometer and monthly step count challenges. The control group also received feedback on their baseline health measures and a sedentary behaviour educational leaflet but continued their normal routine. The intervention lasted 3 months but the sit-stand desks remained for 12 months. Measures were taken at baseline, 3-months and 12-months. In this study, the primary outcome, the proportion of time spent sedentary at work, was objectively measured using the activPAL. This study addressed thesis objective four: *To investigate whether a multicomponent, workplace intervention adopting individual and environmental strategies was an effective way to reduce sedentary time in office workers over the short- and long-term.*

At baseline, the total sample (n=60) were sedentary for 60% (559 minutes/day) of their waking hours wear time, stood for 28.8% (268 minutes/day) and were stepping for 11.2% (104 minutes/day) on a workday. On a non-work day, participants spent 55.9% (496 minutes/day) of their waking hours wear time sedentary, 31.5% (279 minutes/day) standing, and 12.6% (112 minutes/day) stepping. No significant differences between the intervention and control groups were observed. After 3 months, a trend towards reductions in the proportion of time spent sedentary at work (-7.9%) and on a workday overall (-4.6%) were observed in the intervention group compared to baseline. The intervention group's reduction in sedentary time was accompanied by an increase in standing during working hours (+7.9%) and on a workday overall (+4.2%). However, the intervention group also decreased the number of sit-stand transitions (-0.67±1.55 transitions/hour of wear time) during working hours compared to the baseline. The intervention was reported to be acceptable from the focus groups and an increase in awareness of sedentary time emerged as a key theme.

24 office workers attended the 12-month follow-up and provided valid activPAL data however, some cross-contamination occurred with some control participants gaining a sit-stand desk during the 9-month period after the last follow-up. Therefore, 18 office workers who had remained in their respective baseline groups were used in the analysis. Office workers in the intervention group (n=11) showed a trend towards maintaining a reduction in sedentary time at work (-18.4%) and on a workday (-8.0% of wear time) with an associated increase in standing (16.5% and 7.1% of wear time respectively) compared to baseline. There were no differences over time or between groups for sedentary or standing time during non-working hours or on a non-workday at 3-months. Conversely, at the 12-month follow-up, the intervention group showed a trend towards higher amounts of sedentary time during non-working hours and on a

non-workday compared to baseline (+4.2% and +3.5% wear time respectively). There was an associated decrease in standing for the intervention group during non-working hours and on a non-workday (2.7% and 1.9% of wear time respectively) and also a slight reduction in stepping time compared to baseline (0.5% and 0.6%). Conversely, the control group showed no difference in non-working hours or on a non-workday overall sedentary time 12-months post-baseline (-0.2% and -0.7% of wear time respectively). Although statistical tests could not be performed due to the small sample, this is an interesting finding because the baseline non-working hours and overall non-workday sedentary time proportions were similar between the control and intervention groups (≤1.4% difference) indicating this difference could be due to the intervention.

Finally, this study addressed thesis objective five: *To investigate whether there was any effect of the multicomponent intervention on health markers and physical activity.* The intervention group increased non-workday stepping time (2.0±4.1% of wear time) and step counts (113±259 steps/hour of wear time) 3-months post-baseline but this was not significant compared to the control group. No significant differences were observed between the groups for time spent in ActiGraph-determined light physical activity or MVPA. Some changes in health measures were found with the intervention group having favourable changes in waist circumference, heart rate and HDL cholesterol. After 12 months, no meaningful changes were observed for physical activity or health outcomes over time in either group.

In summary this study found that a multicomponent intervention providing sit-stand desks and additional individual strategies showed a trend towards reducing sedentary time during working hours and on a workday overall. However, a trend towards increased sedentary time during non-working hours and on a non-workday in the intervention group was observed 12-months post-baseline. No changes were found in health markers and physical activity measures after 12-months however, this could be due to the small sample size.

Study Three

This was a feasibility study that provided office workers who had sit-stand desks with a self-monitoring and prompting device (LUMO) for four weeks. Thus, thesis objective six was addressed: *To assess the feasibility of a sedentary behaviour self-monitoring and prompting device (LUMO) to reduce workplace sedentary time in a sample of office workers who already have sit-stand desks.* Office workers wore the LUMO for 10 hours or more on average and on 61% of the measurement days. The smart device application that allowed self-monitoring of behaviour was highly engaged with and an average of 30 minutes per week was spent on the application. The sedentary time information was the most engaged with aspect of the application with a lower number of taps recorded for standing and stepping. In the post-intervention interviews, office workers were positive about the device generally reporting that the application and prompts have increased their awareness of sedentary time. However, office workers disliked the prompt outside working hours and some experienced problems with the device including inaccurate representation of behaviour.

At baseline and during the fifth week, measurements were taken including activPAL deployment and the data collected were used to address thesis objective seven: *To gather preliminary data on the impact of the above intervention on sedentary time, physical activity, desk use, health- and work-related outcomes.* After four weeks, workday sedentary time was reduced by 4% of wear time and the amount of time spent in prolonged sedentary bouts over one hour was reduced by 3% (of sedentary time). Additionally, the majority of office workers increased standing and stepping time (3.3% and 1.1% of wear time respectively). Sedentary, standing and stepping times on a non-workday did not change as did daily sit-stand transitions and MVPA stepping time. Office workers reported that they sat less at their sit-stand desks (-22 minutes/workday) and reduced the time they did spend sitting before standing at their desks (-58 minutes/workday). The majority of office workers demonstrated improvements in body fat percentage, fat mass and blood pressure during the short intervention period, but a reduction in self-reported sleep time was observed (-25 minutes/night). Half of the sample reported improvements in work engagement (25% reduced, 25% maintained the same) and job performance (44% maintained, 6% reduced) with a mean positive change in work recovery, and presenteeism.

On a non-workday overall sedentary time did not increase by a meaningful amount (0.6% of wear time) but the majority of office workers increased the time spent prolonged sedentary bouts of over one hour by 4.8% of sedentary time with an associated reduction in bouts of 0-30 and 30-60 minutes. Furthermore, the LUMO data suggests that as sedentary and standing time during working hours improved in weeks three and four of the study, sedentary and standing time during non-working hours worsened. The post-intervention interviews revealed that sedentary time outside of working hours was seen as relaxing and justified due to the physical/social environment.

In summary, this study found that a self-monitoring and prompting device was a feasible way to reduce sedentary time in office workers with sit-stand desks on workdays in the short-term. Furthermore, the improvements in workday sedentary, standing and stepping time have the potential to improve certain health and work outcomes although this study was not powered or long enough to explore this statistically. However, caution is needed due to increases in prolonged sedentary time during non-workdays even though the intervention device targeted the whole day not just working hours. Sedentary time outside of work appears to be perceived differently thus, interventions need to adopt a different approach to target sedentary behaviour in this domain.

5.2. General discussion

Sedentary behaviour is independently linked to a number of adverse health outcomes[10–14,16,28,29,48] and due to advances in technology,[135] prevalence is increasing[145] making sedentary behaviour a worldwide health concern. This thesis found sedentary behaviour to be highly prevalent in office workers (n=7170) especially on a workday where an average of over 10 hours of sedentary time per day with six of these hours occurring at work. Less sedentary time was reported on non-workdays but over 8 hours were still accumulated with the majority taking place while viewing TV. Similar prevalence rates have been found in other UK studies. Kazi and colleagues[47] reported an average of 680 minutes and 570 minutes sitting time on a workday and non-workday respectively in a sample of employees (n=504 workday, 384 non-workday). Of these sitting times, 405 minutes were accumulated at work and

120 minutes whilst TV viewing on a workday. On a non-workday, 178 minutes were spent sitting whilst TV viewing and 173 minutes during leisure-time per day compared to 173 minutes and 115 minutes found in the current study. The higher average minutes/day during leisure-time on a non-workday found in the Kazi et al. study could be due to the smaller sample size and variety of organisational sector employees included compared to the large sample of employees from the same organisation surveyed in the current study.

High amounts of sedentary time accumulated in the workplace and whilst TV viewing are concerning due to the associated increase in odds of partaking in multiple other unhealthy behaviours, including physical inactivity, cigarette smoking, alcohol overconsumption and under consumption of fruit and vegetables, with high amounts of sitting in the work and TV viewing domains as found in study one (n=806). Additionally, over a two-year period, little change was observed in the amount of domain-specific sitting time or other health behaviours undertaken highlighting that these behaviours are maintained over time. This novel finding is supported by other studies where sedentary behaviour has been shown to be positively associated with physical inactivity,[250] an unhealthy diet,[173] smoking,[172] and alcohol overconsumption.[172] Additionally, sedentary behaviours have been shown to track over time[332] as have combinations of SNAP behaviours.[333] However, the relationship between sedentary behaviour and multiple health behaviours has yet to be established.[178]

Therefore, Study Two investigated the effects of a multicomponent workplace intervention on sedentary time over the short- and long-term. Office workers who received multiple intervention strategies developed using the COM-B model of behaviour change[72] which included sit-stand desk provision, reduced sedentary time at work (-7.9±25.1% per day) and on an overall workday (-4.6±13.8% per day) after 3 months which was maintained after 12-months (-18.4±12.4% per day at work, -8.0±8.3% per overall workday). This is supported by other multicomponent workplace interventions where occupational sedentary time has been reduced by 35 minutes[73] and 45 minutes[242] per day after 12-months compared to the control groups. No change in physical activity level or health measures were observed in the current study. Healy and colleagues[243] reported that minimal changes were observed in some cardiometabolic bio-markers 12-months post-baseline but suggested that longer-follow up durations could be needed to observe significant changes in healthy adults. Additionally, Edwardson and colleagues[73] found no change in ActiGraph-determined stepping time or MVPA 12-months post-baseline in the intervention group.

The main difference between the few previous long-term intervention studies and the current study is the sample size which was substantially smaller in the current study (3-month follow-up n=43, 12-month follow-up n=18). Thus, the trends observed could not be statistically analysed and could be limited by a biased sample. On the other hand, Study Two found that sedentary time during non-working hours and on a non-workday increased which is a novel finding which neither of the other long-term studies mentioned have explored. Additionally, the intervention was acceptable. However, problems with retro-fit sit-stand desks were highlighted which have also been found in other workplace intervention studies.[67,188] Finally, the use of a pedometer as an intervention strategy did not allow participants to self-monitor sedentary time thus could have attenuated the results as found in other pedometer intentions.[207,210,238]

Consequently, Study Three assessed the feasibility of a self-monitoring and prompting device aimed at reducing sedentary time in office workers with fully-adjustable sit-stand desks. The device (LUMO) was feasible and acceptable with the sedentary time element of the application showing high engagement. Conversely, Brakenridge and colleagues[190] found that step counts were most engaged with after a 12-month LUMO intervention. This could be due to the disparities in the form of the LUMO prompt as the current study set the device to vibrate every 30 minutes of prolonged sedentary time whereas the sample in Brakenridge et al. were prompted through a notification on the smart device which could be turned off.[312] Thus, 49% of office workers turned the prompt off which could have resulted in less engagement with the sedentary time element of the application. The preliminary data also suggests a reduction in workday sedentary time (-4.3% wear time, 40 minutes/workday wear time), and time spent in prolonged sedentary bouts. Conversely, Brakenridge and colleagues[76] found a non-significant reduction of 7 minutes in sedentary time and -3 minutes for prolonged sedentary time on a workday overall 3-months post-baseline. The difference in results is likely due to the office workers in the current study having sit-stand desks which were not available in the other LUMO study thus the participants did not have as much opportunity to reduce their sedentary time.

Additionally, Brakenridge and colleagues found no improvements in health and work-related outcomes whereas a trend towards improvement was found in the current study. This could also be potentially due to the lack of opportunity to reduce sedentary time whilst working and no observed change in behaviour thus no improvements would be expected. Furthermore, Brakenridge and colleagues measured the intervention effects after 3 and 12-months in a sample of 66 office workers compared to a sample of 19 office workers over 4 weeks in the current study. Therefore, comparisons are limited as the current study could have observed a 'novelty effect' as found in other wearable device studies.[334] Thus, LUMO-use could have declined during a longer follow-up period. Conversely, Brakenridge et al. did not analyse the change in non-workday/non-working hours sedentary time with a LUMO intervention thus the current finding of increased prolonged sedentary time outside of working hours is novel. The current study found that office workers reported a different perception of sedentary behaviour during non-working hours compared to at work and viewed it as acceptable. This is supported by previous studies have found that enjoyment of sedentary activities and not viewing oneself as problematically sedentary are barriers to reducing sedentary time.[335]

A discussion of the results, limitations and strengths of each study has been reported in the relevant chapters. Thus, this section will discuss the overall findings, limitations and strengths of the thesis as a whole. Furthermore, future directions of research will be proposed, and overall conclusions made.

5.2.1. Compensation

Compensation in the form of increasing sedentary behaviour during non-working hours was observed in Study Two where workday and working hours sedentary time was reduced. This is highlighting a potential important limitation of workplace interventions especially as shown in Study One, TV viewing is the most common sedentary behaviour during non-working hours and has the same association with partaking in multiple unhealthy behaviours as the work domain. Additionally, TV viewing has been found to have an association with increased snack consumption,[173,174] obesity,[336,337] clustered cardiometabolic risk score,[338] cancer mortality[339] and all-cause mortality.[340] Furthermore, large amounts of leisure-time sedentary behaviour have been found to be associated with unfavourable alcohol consumption, smoking, nutrition and physical activity[341] in addition to negative health outcomes[12,342].

Using the activPAL, Mansoubi and colleagues highlighted the potential problem of compensation with the implementation of sit-stand desks in a sample of office workers (n=40) when a reduction in sedentary time during working hours was found in addition to an increase in sedentary time during non-working hours.[308] This study found that compensation occurred at 6 weeks and 3 months after the provision of sit-stand desks thus supporting the finding of compensation in the short-term found in this thesis. Danquah et al.[240] implemented an intervention consisting of environmental changes, management support and education sessions in a sample of office workers who had sit-stand desks. ActiGraph (thigh-mounted) sedentary time was reduced by 71 minutes/day on a workday overall and by 48 minutes/8-hours at work after 3 months in the intervention group (n=173) compared to the control group (n=144). Additionally, leisure-time sedentary time on a workday showed a trend towards increasing after 1 month by 11 minutes/8-hours with a reduction in steps (62 steps/hour) and MVPA (5 minutes/8-hours). However, this was not observed at 3 months post-baseline and non-significant compared to the control group.

Conversely, MacEwen et al.[343] implemented sit-stand desks in a sample of obese office workers (n=25) and found a reduction in workday sedentary time and no compensation effects on non-workdays after 12-weeks. Additionally, Dutta and colleagues[66] found no difference in sedentary time during non-working hours, but observed a reduction in working hours and total sedentary time in office workers who received sit-stand desks (n = 28). However, these results should be interpreted with caution due to an accelerometer being used in both studies to determine sedentary time which does not distinguish between sitting and standing. Thus, sedentary time may have been overestimated at baseline during non-working hours/on a non-workday limiting the sensitivity to observe increases in sedentary time post-intervention.

Furthermore, De Cocker et al.[344] found that 3 months after a web-based computer-tailored intervention to reduce workplace sitting was implemented, sitting at work was reduced and sitting during leisure-time was also reduced. However, self-report measures of domain-specific sedentary time were used, and no significant differences were observed when compared to the wait-list control condition. This is supported by

Chau and colleagues[64] who also found that a sit-stand desk intervention reduced self-reported TV viewing time compared to the control condition. Interestingly, both of these studies also measured sedentary time objectively (activPAL) but did not analyse work and non-work sedentary time separately. Gao and colleagues[229] also observed a reduction in self-reported occupational sitting time (6.6%) but found no change in leisure-time sitting after 6 months of sit-stand desk provision in a sample of University office workers (n=24). However, leisure-time sitting was measured via one question asking participants to report the average amount of time spend sitting during free-time thus potentially lacked the sensitivity to detect sedentary behaviour changes.

On the other hand, some workplace sedentary time interventions report total daily and occupational sedentary time showing further evidence of compensation. Alkhajah and colleagues[67] support this finding where a 3-month sit-stand desk intervention reduced sedentary time at work by 125 minutes/day but only by 79 minutes/day for the overall workday. Thus, on average an extra 45 minutes of sedentary time occurred outside of working hours reducing the effect of the intervention. In the long-term, compensation evidence is mixed with the SMArT work study[73] observing similar reductions in sedentary time when averaged across the total day and during working hours at 3, 6 and 12-month follow-ups. Conversely, the Stand Up Victoria[242] study found a reduction of 99 minutes during working hours but only a 77 minute reduction for overall sedentary time for the intervention group compared to the control group. Therefore, there is some support for the finding of compensation with a long-term multicomponent sit-stand desk intervention found in this thesis, but more research is needed to confirm this concept.

Overall, the evidence for compensation of sedentary time in the short and long-term due to workplace interventions is mixed predominantly due to the lack of research in this area. Workplace interventions implementing sit-stand desks and measuring sedentary time using the activPAL have found evidence of compensation over the short (6 weeks – 3 months)[67,308] and long-term (12 months)[242]. Conversely, workplace interventions measuring sedentary time via accelerometery[66,343] and self-report questionnaires[64,229,344] have not found evidence of compensation during non-working hours. Thus, sedentary behaviour measures other than the activPAL may lack the sensitivity to identify changes in non-working hours sedentary behaviour especially in the small sample sizes reported previously.[66,343] Additionally, activPAL devices can be worn for 24 hours and generally have higher waking wear times compared to accelerometer which cannot be worn during water-based activities thus are more susceptible to non-wear potentially contributing to the difference in findings.[107] The ActiGraph has also been shown to lack the sensitivity to detect breaks in sedentary time.[345] Furthermore, self-report measures of sedentary time have limited sensitivity to detect changes and are susceptible to recall and social desirability biases limiting the potential to accurately detect compensation.[93,346]

The concept that reductions in sedentary time in one domain are replaced by increases in sedentary behaviour in another domain, is consistent with the ActivityStat hypothesis related to physical activity.[347] This hypothesis states that a compensatory change in physical activity will occur to maintain a stable level of EE over time thus is a homeostatic mechanism potentially under neurobiological control.[348,349] A review into the ActivityStat hypothesis revealed that evidence was mixed reporting that out of 15 adult studies, six supported (four in females only) and nine did not support the hypothesis (four in females and two in males only).[350] However, the review discussed that two studies explored a lower intervention load (<1.1 MET-h/day) and showed more support compared to higher loads but these were both in samples of children.[351,352] This concept has rarely been explored in terms of sedentary behaviour and the mechanisms behind compensation need to be researched further.

5.2.2 Barriers to reducing sedentary time

A trend towards reductions in the most prevalent domain of sedentary time (occupational) were apparent following the interventions in studies Two and Three. However, potential barriers to further reductions in occupational sedentary time were highlighted during the interviews by office workers and will be discussed in relation to the COM-B model of the BCW.[202] In Study Two, the retro-fit sit-stand desk provided reduced the opportunity to change behaviour during certain tasks as only the computer screen could be used standing thus during other tasks office workers were restricted to sitting. This was found in other studies which implemented retro-fit desks[61,71,188,353] and was reported by the few office workers who had retro-fit desks in Study Three. Opportunities were further reduced during working hours when office workers were not at their sit-stand desks. The majority of interventions implementing sit-stand desks have not measured the amount of time spent at the desks[64,65,242,66,67,69,187,188,229,234,237] but Study Three found that on average, office workers self-reported spending five hours per workday at their sit-stand desk. This is similar to a previous intervention which found university office workers were at their desk for 80% of their working day excluding breaks.[236] In Study Three, participants reported not responding to the prompts to stand whilst away from their desks during meetings and courses. Thus, the impact of sit-stand desks on sedentary behaviour are limited by the amount of time spent at them and should be considered in future interventions.

Furthermore, it was not just the lack of opportunity to reduce sedentary time but also the social acceptability aspect that was highlighted in participant interviews from study three. Office workers reported standing would have been inappropriate in certain instances for example during a meeting where one participant thought that colleagues would question where she was going. Participants thought attention would be drawn to them in these instances as others would not understand the change in behaviour thus reducing the motivation condition of behaviour change. This is an underlying barrier with sedentary behaviour change due to the relative novelty of it as a negative health behaviour.

Mansfield and colleagues[354] explored office workers' experiences of standing in meetings and found that in addition to the physical challenges of the sitting-conducive environment (e.g. no surface to write notes on), engagement, power and the psychological comfort were impacted. Participants reported a heighted awareness of self which was distracting, feeling isolated due to not being at eye-level, distracting others and being asked to sit down by others as standing was interpreted as unwillingness to engage. Furthermore, participants felt like the implicit norm of sitting was being broken and could be viewed as 'attention seeking' so felt the need to explain their behaviour. The final theme described the effect on power dynamics and that standing symbolised authority. This was perceived as empowering but generally if the participant was not leading the meeting, there were concerns that standing would be seen as challenging the authority of the leader. Previous interventions have included organisational support and found significant reductions in sedentary time at work.[73,187,188,242,245] Furthermore, Brakenridge and colleagues found that office workers who received management emails encouraging sedentary behaviour reductions at work, reduced sedentary time over 12 months to the same degree as those who received management emails and used the LUMO. Therefore, future interventions should consider this during the development phase and gain support from the organisation management.

The culture of sedentary behaviour extends beyond the workplace and was highlighted in Study Three where sedentary time was considered by employees as ‘acceptable’ during non-working hours. Office workers reported that sedentary behaviour whilst watching TV was ‘relaxing’ and that it was not ‘unreasonable’ to be sedentary for prolonged periods in this domain as TV programmes and films are often over 30 minutes in duration. Prompts to break-up prolonged sedentary time during non-working hours were ignored despite the provision of information on the danger of prolonged sedentary behaviour. Salmon and colleagues[81] found that enjoyment correlated to leisure-time sedentary behaviours including TV viewing, socialising and reading. This is a concern not only due to the negative associations of TV viewing found in Study One but also the health consequences of prolonged sedentary time which include an increased risk of premature cardiovascular and all-cause mortality.[26] Additionally, non-working hours provide the most opportunity for physical activity thus sedentary time in this domain could be displacing this opportunity.[175]

Conversely, breaking up prolonged periods of sedentary behaviour has been shown to improve postprandial glucose and insulin responses.[36] A recent review by Shrestha et al.[355] found that interventions have been effective at reducing sedentary behaviour during leisure-time and TV viewing by providing counselling, education and restrictions on TV viewing but not in the long-term. Conversely, interventions were ineffective at reducing sedentary time during leisure computer-use and transport domains. This is supported by participant feedback from Study Three where sedentary behaviour whilst travelling was seen as unavoidable due to car use and also whilst working at home due to the lack of a sit-stand desk.

The theory of planned behaviour (TPB)[356] suggests ‘that a person’s intention (i.e. summary decision and motivation to act) is the proximal determinant of behaviour that is in turn influenced by attitude (i.e. overall evaluation of the behaviour), subjective norm (i.e. perceived social approval to engage in behaviour), and perceived behavioural control (i.e. overall perceived ability to perform the behaviour when motivation is held constant).’[357] Additionally, perceived behavioural control may predict behaviour thus may represent actual control and attitude also may predict behaviour through less rational or more emotional evaluation of the behavioural outcome.[356,358] This theory has been validated for physical activity[359] and recognised as a useful model for understanding sedentary behaviours.[360] Rhodes and colleagues[360] found that attitude and subjective norm predicted intention which in turn was associated with behaviour when TV viewing was analysed in a community and a university student sample. Whereas, perceived behavioural control was not a significant predictor of behaviour of TV viewing in this sample. Therefore, this theory suggests that the in order to reduce sedentary behaviours during leisure-time like TV viewing, interventions need to focus on changing social norms, attitude and intention. For example, counselling participants specifically around the risks of excessive TV viewing rather than sedentary behaviour overall and setting a limit for TV viewing time per day.[360]

Finally, capability barriers were identified in this thesis where the interventions in studies Two and Three successfully increased office workers' awareness of sedentary time but a lack of information and/or understanding may have restricted behaviour change. For example the educational booklets given to office workers at the start of both interventions contained information on the health consequences of prolonged sedentary behaviour, tips to reduce sedentary time and increase physical activity, current sedentary behaviour[50] and physical activity guidelines[52] however, participants reported uncertainty about the frequency and duration of sedentary and standing time required for health benefits. This could be due to the lack of guidelines and focus on purely working hours in Study Two's educational booklet limiting the capability and motivation elements of behaviour change outside working hours. Conversely, the educational booklet used in Study Three detailed guidelines, suggested alternating between sitting and standing every 30 minutes and provided tips to reduce sedentary time during working and non-working hours. However, when participants were asked about the educational booklet, recall on the content was low with some reporting not looking at it. Additionally, the focus of the intervention was the feasibility of the LUMO device and the application did not feedback on participants' behaviour or include any guidance or targets regarding behaviour.

5.2.3 Sedentary behaviour guidelines

The lack of guidance around sedentary behaviour is common in interventions and this is due to the lack of defined policy. For example, the current UK guidelines[52] state that, 'adults should minimise the amount of time spent being sedentary (sitting) for extended periods'. Without specific guidance around the maximum duration of sedentary time associated with health risk, how often sedentary time should be broken up and what should replace sedentary behaviour, the motivation and capability for behaviour change may be compromised. Guidelines are available for office workers during working hours[50] which state, '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).' However, the guidelines lack specific detail on recommended duration and/or frequency of sedentary breaks and only address occupational sedentary behaviour. sitting. Furthermore, these guidelines were badly received due to confusion, misunderstanding, misapprehension and lack of declaration of potential conflicts of interest which lead to an amendment post-publication.[199,361]

The growing body of research suggests that breaking-up prolonged sedentary time is beneficial for health[42,362] but whether replacing sedentary time with standing is enough to elicit these benefits is under debate. This thesis was unable to establish the effects of reducing sedentary time on health markers due to the small sample sizes obtained but it was found that sitting time was replaced by standing rather than stepping or physical activity. A review of EE whilst standing compared to sitting[363] found that by substituting standing for 6 hours per day, a 65kg adult would expend an additional 54 kcal/day. Hill and colleagues[364] suggest that interventions reducing energy gain by 50 kcal/day could offset weight gain in approximately 90% of the population. Thus, replacing sitting with standing could stop weight gain over the long-term and reduce the risk of obesity and associated negative health outcomes.[365]

Thorp and colleagues,[40] found that alternating between sitting and standing every 30 minutes during an 8-hour workday, improved postprandial glucose responses in overweight and obese office workers. However, Bailey and Locke[41] found that standing breaks of 2 minutes after 20 minutes of prolonged sedentary time had no metabolic benefits, but 2 minutes light intensity walking was beneficial compared to uninterrupted sitting in non-obese adults. Furthermore, Hawari et al.[156] found that standing breaks of 15 minutes every 30 minutes increased daily EE but no beneficial metabolic consequences were observed. A review by Benatti and colleagues[34] concluded that replacing sitting with standing and light-intensity physical activity can produce favourable changes in postprandial metabolic parameters in the physically inactive and type 2 diabetics. However, higher intensities or volumes are more effective in physically active adults. Therefore, current research is ambiguous limiting the extent to which guidelines can state quantifiable thresholds for prolonged sedentary time and provide recommendations on replacement activities. However, findings from this thesis suggest that reductions in occupational sedentary behaviour are replaced by increased standing as a result of multicomponent and persuasive technology interventions. Thus, if light physical activity is needed to elicit metabolic benefits in already active adults, interventions need to target this specifically.

In regards to physically inactive adults, increasing light activity, such as replacing sedentary time with standing may be the first step in behaviour change for sedentary adults.[35,366,367] Focusing on decreasing sedentary behaviour but increasing light activity, such as standing, may prevent behavioural 'stalling' where physical activity interventions have attempted to go from reverse gear (inactive) to gear three (MVPA) ignoring gears one and two (standing and walking) and thus, have failed to change behaviour.[50,368] Furthermore, replacing sitting with standing is likely the most feasible option in most domains especially at work due to the limited impact and potential gains in work performance compared to stepping.[369] Similarly, standing whilst at work has been associated with improvements in fatigue, vigour, tension, confusion, depression and total mood disturbance.[65] However, the negative impacts of prolonged standing should also be highlighted including low back pain, physical fatigue, muscle pain, leg swelling, varicose veins, tiredness and body part discomfort.[370] Dutch ergonomic guidelines recommend no more than one hour of continuous standing and less than four hours total standing for the day.[371] A review by Karakolis and colleagues[372] concluded that there may not be a generic optimal ratio of sitting-to-standing and that it is likely to depend on the task performed and individual worker.

There is additional debate around whether MVPA has a protective role over the negative effects of sedentary behaviour.[373] There is some evidence that increasing high amounts of moderate physical activity may attenuate the risk of death associated with high sedentary time.[374] However, approximately 60 to 70 minutes of at least moderate intensity physical activity are needed to eliminate the effects of total sedentary time and only attenuate the risk of death associated with high TV viewing time.[374] Furthermore, many studies have found that sedentary behaviour is associated with negative health outcomes independently of physical activity.[9,10,32,48] Conversely, the association between sedentary time and mortality risk has been shown to be attenuated by physical activity in some instances.[32] Observational research has found that physically active adults had a better health profile even if high sedentary time was apparent (‘sedentary exercisers) compared to inactive, sedentary adults (‘couch potatoes’).[375] However, ‘light movers’ (physically inactive but low sedentary time) had significantly better health profiles compared to ‘couch potatoes’ but ‘busy bees’ (physically active and low sedentary time) had the most favourable health profiles. Thus, it is likely that adults who are both sedentary and inactive are at the highest risk of associated negative health consequences.[376] Therefore, workplace interventions should target this group in particular and tailor intervention strategies to individuals depending on their physical activity level. Furthermore, research is needed to ensure specific policy guidelines on reducing sedentary behaviour are produced.[377,378]

5.2.4 The future of wearable persuasive technology

The use of technology in sedentary behaviour interventions is rare but emerging.[75] A recent meta-analysis by Stephenson and colleagues[379] found that computer, mobile and wearable technology tools reduced sitting time on average by -41.28 minutes/day (95% CI -60.99, −21.58, I2 = 77%, n = 1402) but effectiveness appeared to lessen over time (≤ 3 months= −42.42 min/day, >3 to 6 months= −37.23 min/day, >6 months= −1.65 min/day). However, there is limited use of wearable sedentary behaviour monitors in workplace interventions. Study Three highlighted the feasibility and potential effectiveness of a wearable persuasive technology device (LUMO) for reducing sedentary behaviour in office workers. Unfortunately, the LUMO device has been discontinued by the manufacturer (Lumo Bodytech Inc., Mountain View, CA, USA) thus is no longer available to implement in interventions. However, problems were reported in Study Three including discomfort and significant impact on clothing choices due to the positioning of the waist-worn monitor. This was also reported by previous interventions implementing the LUMO.[112,312] A potential development suggested by some participants was in the form of a device similar to the activPAL monitor that gave feedback and vibrated. There is an activPAL device available (activPAL VT)[380] which provides haptic sedentary time feedback through the device in addition to being a research standard sedentary behaviour monitor. However, this device has not been utilised as an intervention tool[211] potentially due to the attachment method requiring adhesive to the skin thus reducing the feasibility of long-term wear.

To address this issue, the SitFIT was developed by PAL technologies[109] (see Chapter 1.2.2) but has not been deployed in a workplace intervention. The SitFIT is based on the activPAL monitor but is a pocket-worn device that provides real-time visual feedback on the monitor for step counts and upright time in addition to haptic prompts to reduce sedentary time. Furthermore, the data from the SitFIT can be downloaded to a smart device via Bluetooth and viewed in more detail allowing comparisons of behaviour over time. The feasibility of the SitFIT was assessed in a sample of men (n=40) over 4 and 12 weeks.[381] The device was found to be acceptable, usable and motivating in terms of sedentary time reductions. Participants in the intervention group (n=20) reduced activPAL-determined sedentary time by 8 minutes/day at both follow-up points with increases in standing (4 weeks: 23 minutes/day, 12 weeks: 16 minutes/day) and stepping time (4 weeks: 9 minutes/day, 12 weeks: 9 minutes/day) but not significantly compared to the control group (n=20).

Additionally, the SitFIT was used as an intervention tool as part of a lifestyle-change programme in the EuroFIT (European Fans in Training) study[382] which was a two-arm RCT that recruited men aged 30-65 years via European football clubs. After 12-months, step counts had increased in the intervention group (n=451) compared to the control group (470) but no change in activPAL-determined sedentary time was observed.[383] The main limitations of these studies are that the results are not generalisable to females and the opportunities available to reduce sedentary time were not measured. The SitFIT device is also limited as it requires participants to wear clothing with front pockets on the thighs thus could limit the wear time.[109] To address these issues, PAL technologies are currently developing the ‘Activator’ which is based on the same sensing platform as the SitFIT but can be attached to clothing, worn discretely on the thigh using an integrated elastic loop or worn in the pocket.[109] Similarly, the ‘VitaBit’ (VitaBit Software International B.V., Eindhoven, The

Netherlands) is a thigh worn monitor which can be attached to clothing via a magnetic strip and measures sitting, standing and stepping time (see Chapter 1.2.2).[110] The device also has an associated smart device application allowing the user to self-monitor sedentary time and prompting behaviour change via on-screen messages but has thus far not been utilised as an intervention tool.

Therefore, the development of wearable persuasive technology is progressing and this thesis has highlighted the feasibility and potential to reduce sedentary time in office workers. However, the use of persuasive technology alone may not be enough to elicit behaviour change[75] thus future studies should deploy these devices as part of multicomponent workplace intervention and measure the effects on working and non-working hours sedentary time.

5.3 Thesis strengths and limitations

The use of a large, secondary data sample of office workers in Study One allowed for a more representative investigation of the sedentary behaviour problem with a long-term follow-up confirming that these behaviours were maintained over time. Therefore, this confirms that UK office workers are highly sedentary[47] and interventions should focus on reducing occupational and TV viewing sedentary time. Furthermore, Study One had adequate statistical power for a novel investigation of the association with domain-specific sedentary time and multiple other health behaviours. This is the first study to provide a comprehensive investigation into the associations between sitting in a variety of domains and other health-related behaviours. Thus, highlighting the need to reduce sedentary time in addition to other health behaviours due to evidence of clustering. The use of a self-report measure allowed for analysis of individual domains of sedentary behaviour which is not possible with objective measures.[93] The DSSTQ used has been shown to be valid and reliable[263] but limited by the phenomenon of concurrent behaviours (i.e. home computer-use can occur whilst watching TV) and social desirability bias.[93] However, the study highlighted key domains of sedentary time and further separated workday and non-workday sedentary behaviour.

This is a key strength of the thesis as all three studies analysed workday and non-workday sedentary time separately thus observing the important consequence of compensation when reducing occupational sedentary time. This phenomenon has rarely been highlighted by previous workplace interventions but is supported by the few studies that have found evidence of compensation when measuring sedentary time using the activPAL.[67,188,308] Further research is needed to explore the extent of compensation as a result of workplace interventions and future studies should measure work and non-work sedentary behaviour separately. Additionally, interventions targeting reductions in occupational and leisure-time sedentary behaviour are needed to explore whether larger reductions can be elicited.

When sedentary behaviour was measured in studies Two and Three with smaller samples, an objective measure was utilised which is currently the gold standard for field-based research.[107] This allowed for unbiased assessments of sedentary behaviour and detailed data on sedentary, standing and stepping times to be obtained. This is a significant contribution to the literature around workplace interventions as a large number of previous studies have adopted self-report measures or accelerometers to determine sedentary time. Additionally, waterproofing of the device allowed for continuous wear thus maximising the number of valid days obtained. Conversely, reactivity bias has been observed with the use of wearable monitors which could potentially impact the accuracy of the results.[117,384,385] The use of a control group in Study Two attenuates this bias and allowed for other potential confounding variables to be accounted for (e.g. seasonal changes[386]). Furthermore, the LUMO device used in Study Three allowed for continuous monitoring of sedentary, standing and stepping over the 5-week period. Therefore, reactivity bias was minimised, and week-by-week changes were observed. The LUMO has been shown to be a valid measure of sitting[113] however, problems with the device were reported by participants and a large amount of data were lost due to an upload problem. Thus, the representativeness of these data are limited and only used as a descriptive comparison of working and non-working hours over the study period.

The lack of a control group is a limitation of Study Three, but the aim of the study was to assess the feasibility of the LUMO device which was achieved. Additionally, detailed qualitative data were obtained from individual participant interviews which allowed for an extensive picture of the intervention acceptability to be drawn. This study was the first to provide office-workers who had sit-stand desks with a wearable device allowing self-monitoring and haptic feedback on prolonged sedentary time. Previous studies have utilised this device but obtained limited findings due to the lack of sit-stand desks available[76,112] and feedback on the smart device only.[76] Thus, this thesis highlights the benefits of wearable monitors as intervention tools and suggests future improvements to this field.

Focus groups were also undertaken in Study Two to gain detailed feedback on the intervention and were also used to develop intervention strategies tailored to the participants increasing the chances of success. The long-term follow-up in Study Two is a strength as it allowed the long-term effects of a workplace intervention on sedentary time to be assessed which adds to the limited research available in UK samples.[246] The trend towards reductions in workplace and overall workday sedentary time 12-months post-intervention is a key finding that warrants further investigation due to majority of previous studies measuring the short-term (≤3 months).[53] Conversely, only a small sample could be analysed at 12 months due to unavailability of participants and contamination of the intervention. Thus, no statistically significant differences in sedentary time, activity or health outcomes could be evaluated. This was also the case for Study Three where the small sample limited the analyses and conclusions in terms of changes in behaviour, work and health outcomes. Additionally, only the short-term feasibility was assessed with a 4-week follow-up so the long-term feasibility of the LUMO device in office workers with sit-stand desks is unknown.

Study Three included a daily self-report measure of time spent at the participant's sit-stand desk. This is a strength because previous studies have not included this as a measure and desk time was found to be highly variable. Thus, desk time is potentially an important factor to be considered in future workplace interventions and should be explored in terms of intervention exposure. The current measure was limited by the self-report nature and could be open to recall bias. Technology has been developed and can be used to objectively measure the context of sedentary behaviours in the workplace as reviewed by Loveday et al.[387,388] Bluetooth low energy (BLE) proximity beacons have the potential to determine location and therefore context of sedentary time. For example, Loveday and colleagues[388] measured office dwell time as a proxy for sit-stand desk time by attaching ActiGraph GT9X beacons to the wall where the door was situated which recorded data from participants who wore a ActiGraph GT9X on their wrist. The pilot study found that activPAL-determined sedentary time at work was 200 minutes/day when work hours were self-reported compared to 163 minutes/day using the beacons. Thus, BLE beacons have the potential to objectively measure office dwell time but do not measure desk time specifically. Desk sensors are available (OfficeIQ, Humanscale, NY)[389] that attach to sit-stand desks and monitor sit-stand desk time using BLE. However, these have not been validated and do not provide information specific to an individual.[388] Loveday and colleagues concluded that the ideal tool to measure sedentary behaviour context does not currently exist but measuring the context is essential to determine intervention exposure especially when providing sit-stand desks.[387]

Finally, the generalisability of the thesis results is limited to UK office workers and the samples in studies Two and Three were predominantly highly educated, white British females. Therefore, the results should be interpreted with caution and further research is needed to confirm the thesis findings in other populations. The problem of non-representative samples is common in sedentary behaviour workplace interventions with studies recruiting university samples that are biased towards white, highly educated adults.[53,61,67,229] Additionally, the majority of research in this area is conducted in Australia, the UK and America thus reducing the generalisability to other countries. Nevertheless, significant and meaningful findings were observed in this thesis for sedentary behaviour prevalence, links to other health behaviours, a trend towards reductions in occupational sedentary with a multicomponent intervention in the long-term and the feasibility of technology to help reduce sedentary time in work and non-working hours.

5.4 Future directions

Although the area of sedentary behaviour research has gained considerable momentum over the last 10 years, there are still essential questions that remain unanswered and limited research in key areas. As highlighted in this thesis, a) sedentary behaviour is highly prevalent in office workers and linked to multiple other health behaviours, b) implementation of multicomponent interventions has the potential to reduce occupational sedentary behaviour over the long-term and c) the use of wearable technology as a sedentary behaviour intervention strategy shows promise in the short-term. The recommendations for future research in office workers as a result of this thesis are:

1. Longitudinal studies are needed to establish the causality of the relationship between partaking in multiple health behaviours and sedentary time at work and whilst TV viewing.
2. Interventions targeting improvements in multiple other unhealthy behaviours in addition to reducing sedentary time are needed.
3. Long-term RCT multicomponent interventions (>12 months) developed using theories of behaviour change, that target reductions in sedentary behaviour during both working and non-working hours should be conducted.
4. The separate analysis of sedentary time during working and non-working hours when investigating the effects of an intervention to further explore the concept of compensation should be undertaken in all future intervention work.
5. Recruitment of large representative samples to further explore the effects of multicomponent interventions to reduce sedentary behaviour in terms of physical activity, health and work-related outcomes should be conducted.
6. There is a need to further develop wearable technology focusing on reducing sedentary behaviour and the implementation of such devices should be evaluated in large intervention studies to measure their effects.
7. The further development, utilisation and evaluation of technology to objectively measure desk-time and workplace sedentary behaviour intervention exposure is needed.
8. The development of clear and quantifiable guidelines on prolonged sedentary behaviour are needed, including how best to combat the negative effects in order to inform national health policy and start to change the culture of sedentary behaviour.

5.5. Conclusions

This thesis has explored sedentary behaviour prevalence, links to other health behaviours and intervention strategies in UK office workers. It was found that the majority of sedentary time occurred during working hours and was associated with partaking in multiple unhealthy behaviours. TV viewing showed a similar association and was the most prevalent sedentary behaviour during non-working hours. A multicomponent intervention addressing deficits in the capability, opportunity and motivation elements of behaviour change resulted in a trend towards reductions in occupational sedentary behaviour over the short-term and preliminary evidence for potential long-term effects. However, there was evidence of compensation during non-working hours with increased sedentary time. The use of persuasive wearable technology is a promising avenue for future sedentary behaviour interventions with improved devices on the horizon which warrant further research. These findings contribute to the growing body of sedentary behaviour research and have highlighted the need for future research. It is important that sedentary behaviour research continues in order to inform public health guidelines and change the culture around sedentary behaviour.

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Appendices

Appendix 3.1

Study Two: Device instructions

How to wear the <u>thigh monitor</u>

- The thigh monitor or activPAL measures your posture – specifically your sitting, standing and sleeping time
- Wear it **continuously for 7 days.**
- Put it on your upper mid-thigh and that the **'man' on the device is standing upright** – head facing upwards (see picture below).
- The thigh monitor is **waterproof** so you can continue wearing it whilst bathing, showering etc…

Note: the monitor will be flashing every 6 seconds. This is an indication that it is working. If it stops flashing, contact us immediately and we will provide you with a new one.

How to wear the <u>hip monitor</u>

- The <u>hip monitor or Actigraph</u> measures the intensity of your physical activity (light, moderate or vigorous activity).
- It is to be worn **for 7 days**. However, it should be removed when bathing, showering and/or swimming. If you find it uncomfortable to sleep with, you can take it off but it is very important that you **<u>put it on as soon as you wake up in the morning.</u>**
- The monitor should be placed on, or as close to, your waistband as possible and rest on your hip bone, either side is OK.
- The monitor can be worn either underneath or on top of your clothing, just as long as it fits snugly around your waistband.
- The monitor will be **flashing** whilst recording data, if it stops flashing please contact Veronica Varela-Mato as it has stopped working and we will need to change it.

How to fill in the daily log

- The log is divided into 7 days. Please complete each day's questions as accurately as possible – record the exact times or to the nearest 5 minutes.

  1. Indicate the date.
  2. Record the time that you **woke up** and when you put the waist device on.
  3. Indicate if you have worn the waist device or not on that night by ticking the correspondent box.
  4. State if it a **work or non-work day**.
  5. If it was a work day, please record the time you **started and finish working** and if you had **breaks**.
  6. Record any times you **removed** any of both devices for more than 15 minutes during the day.
  7. Finally, if you take off the waist monitor to sleep, please **record the time that you removed** it and tick the corresponding box the following morning.

NOTES:

- Midnight = 12am; midday = 12pm
- **Sleep and awaking times are very important.**

Daily log (Remember to fill it in daily). Write your comments at the Thigh device

Waist device (ActiGraph)

Thigh device (ActivPAL)

Date: ___/___/___ Waking up time?	What time did you put the waist device on?	Is today a work or non-work day?	What time did you start working?	Did you have a lunch break?	What time did you finish working?	Did you go to sleep with the waist device on?	At what time did you go to bed?	Did you remove the thigh device?	Did you remove the waist device?
01/04/14 7:30 am/pm	7:35 am/pm	Work Non-work	8:30 am/pm	12:30am/pm 1:30 am/pm	5:00 am/pm	Yes / no	23:30 am / pm	____ am/pm ____ am/pm	20:20am/pm 20:50am/pm
Day 1 ___/___/___ ____ am/pm	____ am/pm	Work Non-work	____ am/pm	____ am/pm ____ am/pm	____ am/pm	Yes / no	____ am/pm	____ am/pm ____ am/pm	____ am/pm ____ am/pm
Day 2 ___/___/___ ____ am/pm	____ am/pm	Work Non-work	____ am/pm	____ am/pm ____ am/pm	____ am/pm	Yes / no	____ am/pm	____ am/pm ____ am/pm	____ am/pm ____ am/pm
Day 3 ___/___/___ ____ am/pm	____ am/pm	Work Non-work	____ am/pm	____ am/pm ____ am/pm	____ am/pm	Yes / no	____ am/pm	____ am/pm ____ am/pm	____ am/pm ____ am/pm

Date: ___/___/___ Waking up time?	What time did you put the waist device on?	Is today a work or non-work day?	What time did you start working?	Did you have a lunch break?	What time did you finish working?	Did you go to sleep with the waist device?	At what time did you go to bed?	Did you remove the thigh device?	Did you remove the waist device?
Day 4 ___/___/___ ____ am/pm	____ am/pm	Work Non-work	____ am/pm	____ am/pm ____ am/pm	____ am/pm	Yes / no	____ am/pm	____ am/pm ____ am/pm	____ am/pm ____ am/pm
Day 5 ___/___/___ ____ am/pm	____ am/pm	Work Non-work	____ am/pm	____ am/pm ____ am/pm	____ am/pm	Yes / no	____ am/pm	____ am/pm ____ am/pm	____ am/pm ____ am/pm
Day 6 ___/___/___ ____ am/pm	____ am/pm	Work Non-work	____ am/pm	____ am/pm ____ am/pm	____ am/pm	Yes / no	____ am/pm	____ am/pm ____ am/pm	____ am/pm ____ am/pm
Day 7 ___/___/___ ____ am/pm	____ am/pm	Work Non-work	____ am/pm	____ am/pm ____ am/pm	____ am/pm	Yes / no	____ am/pm	____ am/pm ____ am/pm	____ am/pm ____ am/pm

Do you have any comments about the daily log?

____

____

____

____

THANKS FOR FILLING IN THE QUESTIONNAIRE

Please, remember to return this log with the devices to us once you have finished the measurement period. The returning date is on your participant pack.

Leicester-Loughborough Diet, Lifestyle and Physical Activity Biomedical Research Unit
NHS National Institute for Health Research

Loughborough University

Appendix 3.2

FOCUS GROUP SCHEDULE

The SHIFT Study

COM-B / Theoretical Domains Framework Questions

Psychological capability

What does health mean to you? And how would you define a healthy lifestyle?

Would you say that being active is important for a healthy lifestyle?

What do you understand by the term "sedentary behaviour"?
Would you say that you have a sedentary lifestyle? What routines of your daily activity would you classified as sedentary?

Do you think there is a relationship between sitting for too long and health?
DO you think there is a relationship between sitting time and sleep? (prompt: quality of sleep)
Knowledge

Why do you think we sit at work?
Would you say that the time you spend sitting changes depending on the circumstances? (Prompt: for instance if we are stressed – so you don't take your lunch break)

Do you think you would be able to set a goal of reducing your sitting time by 60 min. a day? (Prompt: the health and work consequences?)

Since you started working here, have you noticed any organisational efforts to promote regular breaks from your desk? (Prompt: are you encouraged to deliver messages face-to-face rather than email? Are there central printers/waste bins?)
Memory, attention & decision processes
Behavioural regulation

Physical capability

Would you say you are physically capable of reducing your sitting time at work?
Physical skills

Physical opportunity

If you think about it, would you say you already break up your sitting time? Any reasons?

Can you spot any places within your working environment that would allow you to break up your sitting time?
(Prompt: meeting room for standing meetings)
Environmental context and resources

Reflective motivation

Would you say that being able to regularly break up sitting would have any impact in your workplace? (E.g. by having a height adjustable desk that allows you to switch between sitting and standing to work; or other work place policies and initiatives) (Prompt: health & work consequences)
Beliefs about consequences

If you were provided with a standing desk, how easy do you think it would be to stand and work? Would you stand to work in an office at a time when no one else is? Would other people's reactions affect your decision to stand? Why / why not?
Social Influences
Intentions (reflective motivation)

If you were provided with pedometers would you have active breaks? (Prompt: go to the furthest away printer, take the stairs instead of the lift)

Is there anything that you can think of that would encourage you to break up your sitting time more often? Prompt: What about organising team activities, reminders…
Beliefs about capabilities, Intentions

Behaviour change strategies

Environmental strategies

Can you think of any feasible strategy to help you to break up your sitting time in your working space? Do you have any personal strategies?

What would you change from your working environment to help you to break up your sitting time? Prompt: going to another printer, standing lunches, walking lunches.

Organisational strategies

What type of prompts would be effective to make you to stand for longer? Prompt: Poster around the office, regular reminders by email, a Facebook community, newsletters, and social pressure.

Has it happened in your office before?

Standing desk/ treadmill

Overall, what are your thoughts about using a standing desk to help you to break up your sitting time? What about a shared treadmill in the office? (Prompt: Belong to a social community where there will be challenges and regular newsletters)

Can you think about anything else that help you to reduce your sitting time during working hours?

What is sedentary behaviour?

- "Sedentary behavior refers to any waking activity characterized by an energy expenditure of ≤ 1.5METs and a sitting or reclining posture"[3]

Have you ever thought about your daily routine?

What are the effects of prolonged time sitting on health?[4,5]

- **147%** Increase risk of a cardiovascular event
- **112%** increase risk of developing diabetes
- **90%** increase risk of cardiovascular mortality
- **34-78%** increase risk of different cancers
- **5%** increase risk of being overweight/obese

every 2 hour of continuous sitting at work

What can I do to improve this?

Try to break up your sitting time as often as possible. check the leaflet for tips!

Try a 20 min lunchtime walk!

More ideas at: http://www.prevention.com/weight-loss/weight-loss-tips/100-easy-tricks-move-more-and-lose-weight?page=3
http://www.melbourne.vic.gov.au/ParksandActivities/ActiveMelbourne/100Ways/Pages/WhatAre.aspx

3. Sedentary Behaviour Research Network, 2012; 4.Clemes et al, 2014; 5. Wilmot et al, 2012)

The Shift Study

Sitting Time and Health

SHIFT

Loughborough University

Leicester-Loughborough Diet, Lifestyle and Physical Activity Biomedical Research Unit

NHS National Institute for Health Research

What is being Healthy?

- Being healthy is a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity[1]. It also defined as the ability to adapt and self manage physical, mental and socially[2].

How do I keep myself healthy?

Public Guidelines recommend accumulating:

- **≥150 minutes** of **moderate** physical activity a week, such as cycling or fast walking every week.

OR

- **≥75 minutes** of **vigorous** physical activity a week, such as running or a game of singles tennis every week.

AND

- **Muscle-strengthening** activities on **≥2 days** a week that work all major muscle groups (legs, hips, back, abdomen, chest, shoulders and arms).

Hence, 30 min of moderate to vigorous physical activity should be accumulated on ≥5 days a week.

Remember! You can accumulate this 30 min in 3 blocks of 10 min throughout the day. So you don't need to worry about time.

Ground breaking research also suggests that 20 min of brisk walking a day reduces risk of premature death by up to a third!

Did you know?

Being active protects you against coronary heart disease, stroke, high blood pressure, high cholesterol, obesity, type II diabetes, some cancers and improves muscle balance and strength, reducing the risk of falling and back pain.

1.World Health Organization, 1948.

2. British Medical Journal 2011.

Moderate Activities

- Walking fast
- Hoovering
- Painting
- Tennis-doubles
- Pushing a lawn mower

(Any activity that will raise your heart rate, make you breathe faster and feel warmer)

Vigorous Activities

- Jogging/running
- Swimming
- Carpentry
- Riding a bike fast
- Team Sports

(Any activity that means you won't be able to say more than a few words without pausing for breath)

Remember!

Any activity that raises your heart rate will have a beneficial health impact. Every little helps!

A good place to start is hitting your daily target of 10,000 steps. Why not getting a pedometer and challenge yourself!

However, what about the time I spend sitting?

...Recent research has shown that PROLONGED sedentary behaviour/sitting time has its own negative health implications INDEPENDENT of meeting the physical activity guidelines (Sedentary behaviour Research Network,2012)

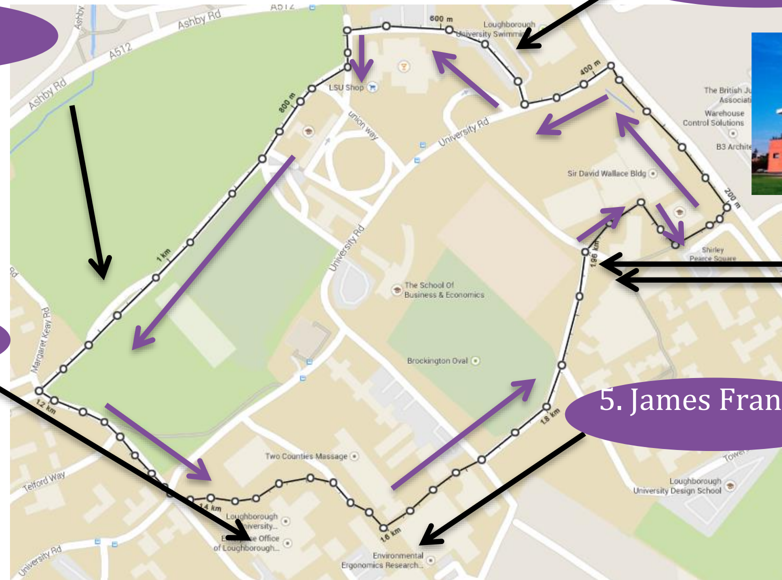
On average, office workers are sedentary for 65% of their working day (Clemes et al, 2014).

Appendix 3.4

Route 3:

3. Hockey Pitch

2. Swimming Pool



1. John Beckwith

4. Edward Herbert

5. James France

25 minutes;
200 calories

Route 4:

1.Edward Herbert

3. Wolfson Building

2. Library

4. Burleigh Court

25 minutes;
200 calories

*** Routes 3 and 4 challenge you with stairs and hills!**

The Shift Study

How to reduce sitting time at work

SHIFT

Loughborough University

Leicester-Loughborough Diet, Lifestyle and Physical Activity Biomedical Research Unit

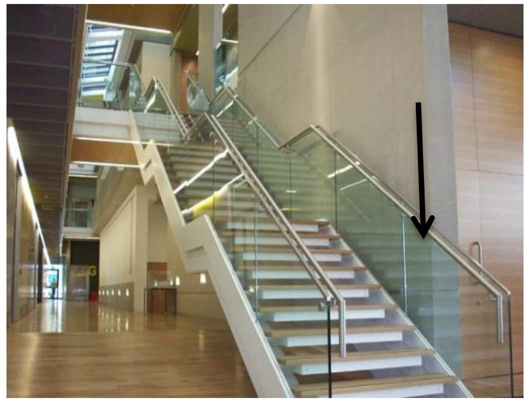
NHS National Institute for Health Research

Whilst working;

- Book meeting rooms that are on a different floor to your office.
- Move your bin from your desk to a different location.
- Print work to a different floor or building
- Put telephones at a higher level on your desks and stand whilst talking on the phone.
- Use the toilets on different levels of your building.
- Encourage people to have standing/walking meetings
- Encourage a colleague to have active breaks together

5 minute break;

- Make your own hot beverages
- Walk to colleagues desk and sort problems face to face to reduce sitting time and stress.
- Go outside for some fresh air to refresh your thoughts
- Have a walking tea break
- Fill your water glass every hour



10+ minute break;

- Why not take part in some scheduled exercise classes?
- Make sure you take your lunch break
- Go to your furthest away cafe in campus
- Use the gym whenever you can
- Go for a walk and get fresh air

Did you know?

Taking the stairs for **10 minutes** a day burns **92 calories**

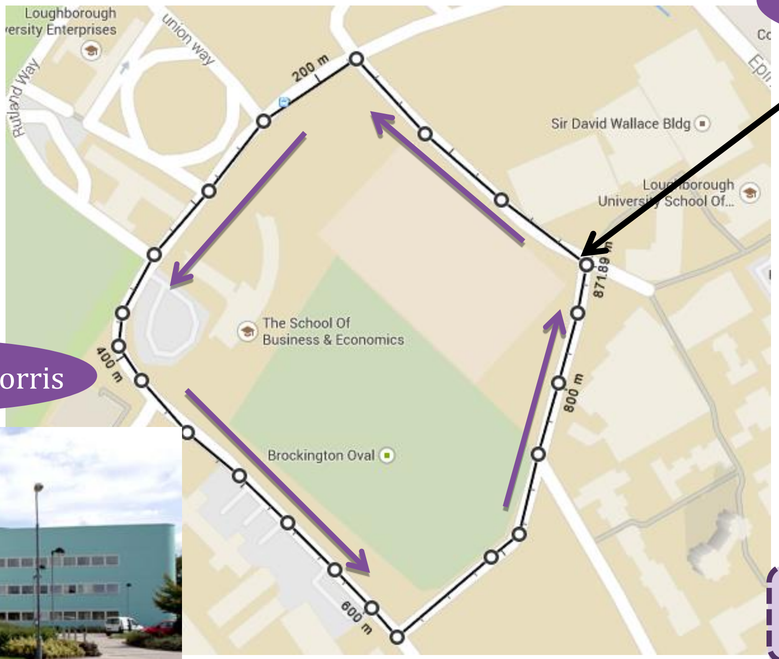
Reducing sitting by as little as an **hour** a day reduces the chance of cardiovascular disease, cancer and diabetes

Feel like the gym is too far away from your office to walk? **Well why you don't you ride your bike there giving you extra physical activity!**

Is it wet and cold outside and you don't fancy walking or biking to the gym? **Did you know that campus shuttle is free for staff too?**

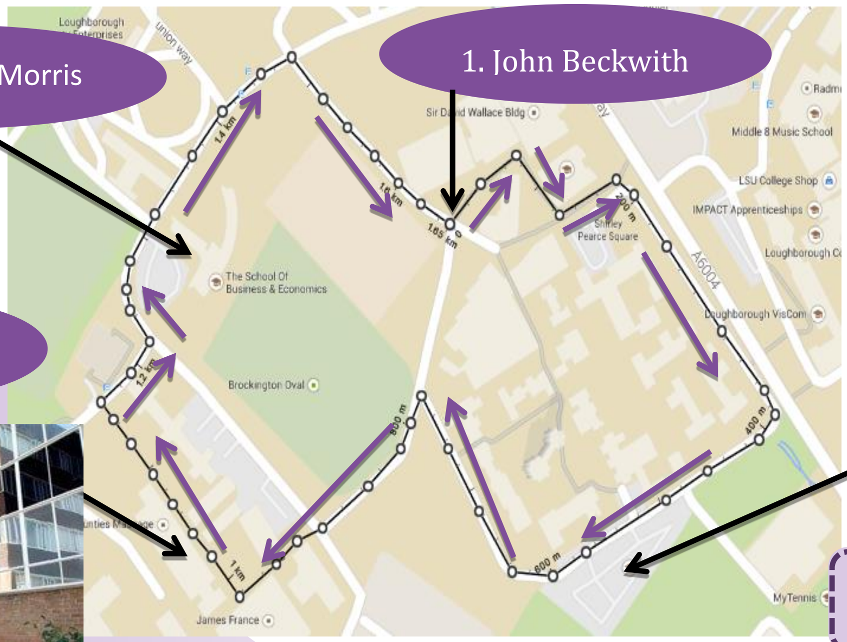
Walks around campus

Route 1:



10 minutes; 50 calories

Route 2:



20 minutes; 100 calories

- **Make sure you take your lunch breaks!**
- **Join the gym and pop in for 30 minutes light intensity cardio on your lunch break**
- **Take part in one of the activities on campus**

Appendix 3.5

Feedback sheet for health markers

1. Body Mass Index or BMI: This is the amount of kg per square metre in your body. It gives you an idea of whether your weight is appropriate for your height. It's useful to know because when your weight increases (or decreases) outside of the ideal range, your risk for certain medical problems also increases.

BMI

height (m)

weight (kg)	1.38	1.42	1.46	1.50	1.54	1.58	1.62	1.66	1.70	1.74	1.78	1.82	1.86	1.90	1.94	1.98	
150	79	74	70	67	63	60	57	54	52	50	47	45	43	42	40	38	23s 8
148	78	73	69	66	62	59	56	54	51	49	47	45	43	41	39	38	23s 3
146	77	72	68	65	62	58	56	53	51	48	46	44	42	40	39	37	22s 13
144	76	71	68	64	61	58	55	52	50	48	45	43	42	40	38	37	22s 9
142	75	70	67	63	60	57	54	52	49	47	45	43	41	39	38	36	22s 4
140	74	69	66	62	59	56	53	51	48	46	44	42	40	39	37	36	22s
138	72	68	65	61	58	55	53	50	48	46	44	42	40	38	37	35	21s 10
136	71	67	64	60	57	54	52	49	47	45	43	41	39	38	36	35	21s 5
134	70	66	63	60	57	54	51	49	46	44	42	40	39	37	36	34	21s 1
132	69	65	62	59	56	53	50	48	46	44	42	40	38	37	35	34	20s 10
130	68	64	61	58	55	52	50	47	45	43	41	39	38	36	35	33	20s 6
128	67	63	60	57	54	51	49	46	44	42	40	39	37	35	34	33	20s 2
126	66	62	59	56	53	50	48	46	44	42	40	38	36	35	33	32	19s 12
124	65	61	58	55	52	50	47	45	43	41	39	37	36	34	33	32	19s 7
122	64	61	57	54	51	49	46	44	42	40	39	37	35	34	32	31	19s 3
120	63	60	56	53	51	48	46	44	42	40	38	36	35	33	32	31	18s 13
118	62	59	55	52	50	47	45	43	41	39	37	36	34	33	31	30	18s 8
116	61	58	54	52	49	46	44	42	40	38	37	35	34	32	31	30	18s 4
114	60	57	53	51	48	46	43	41	39	38	36	34	33	32	30	29	17s 13
112	59	56	53	50	47	45	43	41	39	37	35	34	32	31	30	29	17s 9
110	58	55	52	49	46	44	42	40	38	36	35	33	32	30	29	28	17s 5
108	57	54	51	48	46	43	41	39	37	36	34	33	31	30	29	28	17s
106	56	53	50	47	45	42	40	38	37	35	33	32	31	29	28	27	16s 10
104	55	52	49	46	44	42	40	38	36	34	33	31	30	29	28	27	16s 5
102	54	51	48	45	43	41	39	37	35	34	32	31	29	28	27	26	16s 1
100	53	50	47	44	42	40	38	36	35	33	32	30	29	28	27	26	15s 10
98	51	49	46	44	41	39	37	36	34	32	31	30	28	27	26	25	15s 6
96	50	48	45	43	40	38	37	35	33	32	30	29	28	27	26	24	15s 2
94	49	47	44	42	40	38	36	34	33	31	30	28	27	26	25	24	14s 11
92	48	46	43	41	39	37	35	33	32	30	29	28	27	25	24	23	14s 7
90	47	45	42	40	38	36	34	33	31	30	28	27	26	25	24	23	14s 2
88	46	44	41	39	37	35	34	32	30	29	28	27	25	24	23	22	13s 12
86	45	43	40	38	36	34	33	31	30	28	27	26	25	24	23	22	13s 8
84	44	42	39	37	35	34	32	30	29	28	27	25	24	23	22	21	13s 3
82	43	41	38	36	35	33	31	30	28	27	26	25	24	23	22	21	12s 13
80	42	40	38	36	34	32	30	29	28	26	25	24	23	22	21	20	12s 8
78	41	39	37	35	33	31	30	28	27	26	25	24	23	22	21	20	12s 4
76	40	38	36	34	32	30	29	28	26	25	24	23	22	21	20	19	12s
74	39	37	35	33	31	30	28	27	26	24	23	22	21	20	20	19	11s 9
72	38	36	34	32	30	29	27	26	25	24	23	22	21	20	19	18	11s 5
70	37	35	33	31	30	28	27	25	24	23	22	21	20	19	19	18	11s
68	36	34	32	30	29	27	26	25	24	22	21	21	20	19	18	17	10s 10
66	35	33	31	29	28	26	25	24	23	22	21	20	19	18	18	17	10s 6
64	34	32	30	28	27	26	24	23	22	21	20	19	18	18	17	16	10s 1
62	33	31	29	28	26	25	24	22	21	20	20	19	18	17	16	16	9s 11
60	32	30	28	27	25	24	23	22	21	20	19	18	17	17	16	15	9s 6
58	30	29	27	26	24	23	22	21	20	19	18	18	17	16	15	15	9s 2
56	29	28	26	25	24	22	21	20	19	18	18	17	16	16	15	14	8s 11
54	28	27	25	24	23	22	21	20	19	17	17	16	16	15	14	14	8s 7
52	27	26	24	23	22	21	20	19	18	17	16	16	15	14	14	13	8s 3
50	26	25	23	22	21	20	19	18	17	17	16	15	14	14	13	13	7s 12
48	25	24	23	21	20	19	18	17	17	16	15	14	14	13	13	12	7s 8
46	24	23	22	20	19	18	18	17	16	15	15	14	13	13	12	12	7s 3
44	23	22	21	20	19	18	17	16	15	15	14	13	13	12	12	11	6s 13
42	22	21	20	19	18	17	16	15	15	14	13	13	12	12	11	11	6s 9
40	21	20	19	18	17	16	15	15	14	13	13	12	12	11	10	10	6s 4
38	20	19	18	17	16	15	14	14	13	13	12	11	11	11	10	10	6s
36	19	18	17	16	15	14	14	13	12	12	11	11	10	10	9	9	5s 9
	4'6½	4'8	4'9½	4'11	5'½	5'2	5'4	5'5½	5'7	5'8½	5'10	5'11½	6'1	6'3	6'4½	6'6	

Very overweight

BMI 30+

Overweight

BMI 25 - 30

Healthy

BMI 18.5 - 25

Underweight

BMI less than 18.5

2. Fat percentage: Our body is composed of two types of fat:

2.1. Essential body fat, which is needed for the correct function of our body and we cannot lose it, which for men is about 3% of body mass.

2.2. Storage fat, the fat that it is accumulated in our body due to an excess eating or lack of physical activity.

In general, the total body fat percentage for a male adult should be between 11% to 20% of body mass. Your fat percentage is ____ . Having excess body fat makes arteries stiffer, increasing the risk of cardiovascular diseases such as high blood pressure, heart attack or stroke.

Males	Females	Rating
5-10	8-15	Athletic
11-14	16-23	Good
15-20	24-30	Acceptable
21-24	31-36	Overweight
>24	>37	Obese

3. Waist circumference (WC): Waist circumference is an important indicator of how healthy we are. Having a larger waist circumference in comparison to your hips circumfrence, than the healthy range is an indicator of greater risk of developing coronary heart disease, high blood pressure and diabetes. Hip-waist ratio is a simple measure of fat distribution.

Your WC is_______ cm .

Your Hip Circumference: ________cm.

W-H ratio: _______(WC) : _______(HC)=_______ cm

W-H ratio results: ≥0.90cm (M); ≥0.85cm (F) = substantially increased risk.

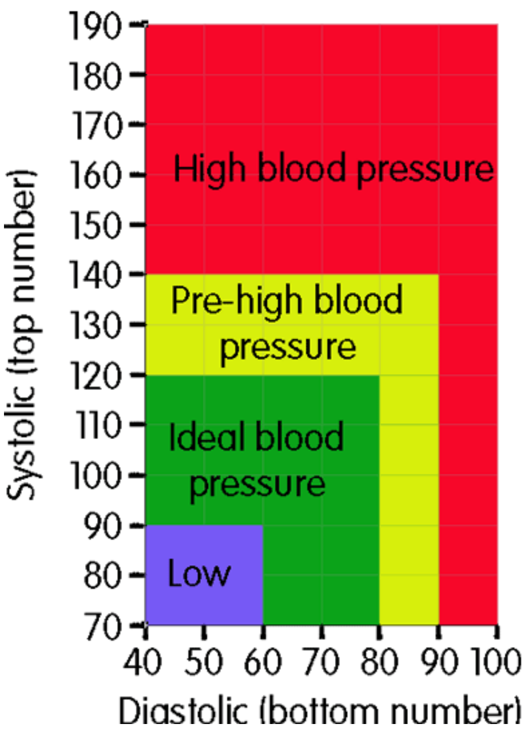
	Your health is at **risk** if you have a waist size of:	Your health is at **high risk** if you have a waist size of:
Men	Over 94cm (about 37 inches)	Over 102cm (about 40 inches)
Women	Over 80cm (about 31.5 inches)	Over 88cm (about 34.5 inches)
Asian men		Over 90cm (about 35.5 inches)
Asian women		Over 80cm (about 31.5 inches)

4. Blood pressure:

When measuring blood pressure we obtain 2 readings:

- The top number is your **systolic** blood pressure: when your heart is beating and pushing the blood around your body.
- The bottom one is your **diastolic** blood pressure: when your heart is relaxing and between beats.

In the chart below you can see what your values mean:



Systolic blood pressure	Diastolic blood pressure

Did you know that this factors below can contribute to have high blood pressure?

- Not doing enough physical activity
- Being overweight or obese
- Having too much salt in our diet
- Regularly drinking too much alcohol
- Having a family history of high blood pressure.

5. Finger prick test:

When analysing a sample of blood we obtain information to measure:

Blood glucose: This is the main sugar found in the blood and the body's main source of energy. Keeping this within the ideal ranges is very important to prevent future health complications.

Triglycerides: It is a type of fat (lipid) in blood. Having a high level of triglycerides can increase the risk of heart disease.

HDL Cholesterol: It is known as the good cholesterol as it picks up excess cholesterol in the bloodstream and take it back to the liver where it's broken down. Having low levels of HDL cholesterol increases the risk of cardiovascular diseases.

LDL Cholesterol: It is known as the bad type of cholesterol. LDL carries cholesterol from your liver to the cells that need it. Too much bad cholesterol (LDL) in your blood can cause fatty material to build up in your artery walls; increasing the risk of cardiovascular disease.

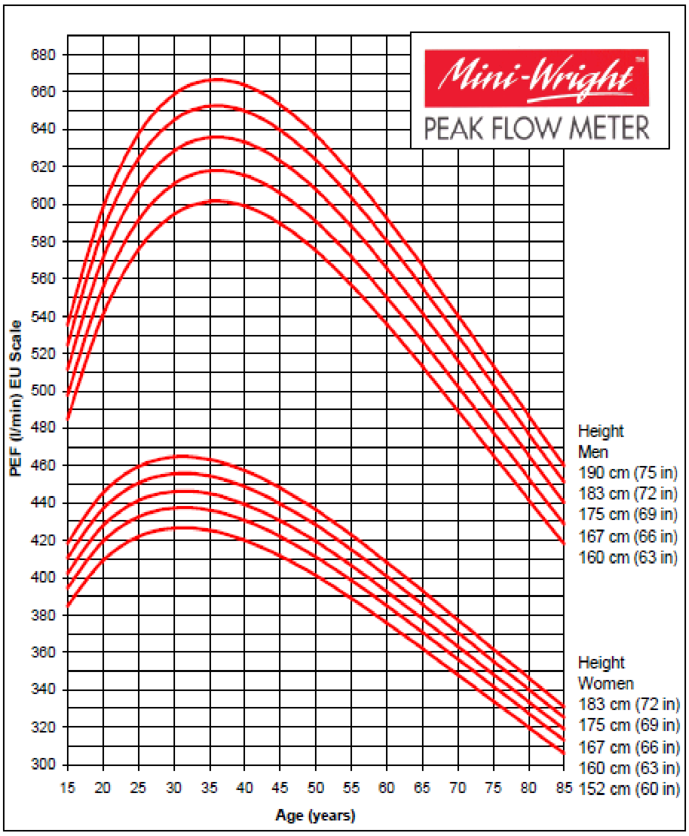
Total Cholesterol: It is the sum of both types of cholesterol.

In the table below you can see your results and compare them to the desirable ranges.

Blood components	mmol/litre	Desirable range
Glucose (sugar in blood)		3.9 - 5.5mmol/l
Triglycerides (fat in blood)		<1.7mmol/l
HDL Cholesterol (good cholesterol)		>1.6 mmol/l
LDL Cholesterol(bad cholesterol)		<2.0mmol/l
Total Cholesterol		<4.0mmol/l

6: Peak flow test:

This test measures the lung capacity by measuring how much air you can blow out of your lungs in one blast. This provides information about how open your lungs and airways are. Narrowing or obstruction to your airways can be caused by asthma, smoking and air pollutants.



L/minute

Appendix 3.6

Focus groups – post intervention questions

1. Have you noticed any health benefits of your participation on the study?
2. Have you seen any changes on your PA levels?
3. Have you seen any changes on the time you spend sedentary? Standing?
4. Has having a standing desk prompted you to move more during your working hours?
5. What's your opinion on the step challenges?
6. Have you noticed any changes on your working routine?
7. Has having the option of sitting or standing whilst working have any impact on your working routine?
8. How has it affected to your work performance?
9. Would you say that having a standing desk has have any impact on your colleagues which didn't have one?
10. What aspects of the intervention did you like the most?
11. Which ones did you dislike?
12. Would you change anything?
13. Ultimately, would you go back to a standard desk?
14. Overall how would you describe your experience of using a standing desk?

References and Useful Links

Appendix 4.1

- http://www.ergotron.com/en-gb/tools/workspace-planner - **use the workstation planner to measure the required adjustment from sitting to standing.**
- http://www.juststand.org/tabid/816/language/en-US/default.aspx - **more information on sitting vs standing**
- Clemes SA, et al. Sitting time and step counts in office workers. Occup Med. 2014;64(3):188-192.
- Hamilton MT et al. Exercise physiology versus inactivity physiology: An essential concept for understanding lipoprotein lipase regulation. Exerc Sport Sci Rev. 2004;32(4):161-166.
- https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/213740/dh_128145.pdf
- Buckley JP et al. The sedentary office: An expert statement on the growing case for change towards better health and productivity. Br J Sports Med. 2015.

The Dangers of Sitting and How to Reduce Them

Why is Sitting Bad for you?

Sitting for long-periods of time increases your risk of:

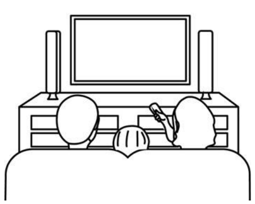
- Type II diabetes
- Obesity
- Cardiovascular disease
- Some forms of cancer

This is due to **'inactivity physiology'** which is a process where your metabolism changes whilst sitting. For example, there is a decrease in plasma HDL-Cholesterol (good cholesterol)

Even if you are physically active, sitting for too long is still bad for your health.

The average UK adult sits for **over 8.5 hours on a workday** and **over 5.5 hours on a non-workday.**

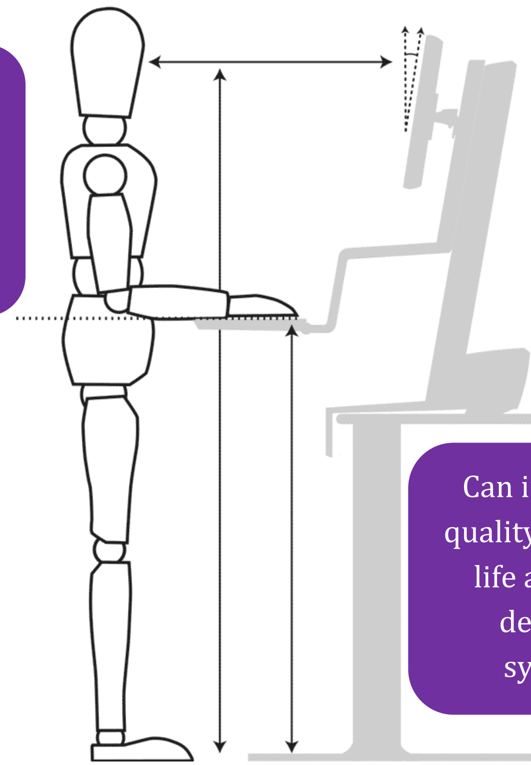
How long do you sit for?



Benefits of Standing vs Sitting

Burns 30-60 more calories in an hour

Feel more energized, comfortable, focused and productive



Can improve the quality of everyday life and reduce depression symptoms

Can help to reduce joint stiffness and pain

How to use your sit-stand desk

The position of your computer equipment in relation to your body should remain the same when seated and standing. If you're unsure, visit: http://www.ergotron.com/en-gb/tools/workspace-assessment-tool and take the workspace assessment.

1. Aim to alternate between sitting and standing every **30 minutes**
2. If this is uncomfortable, start with shorter standing times (e.g. 10 minutes) and increase over time
3. **Don't** sit or stand for extended periods – **alternate** between the two.
4. Always **listen to your body** and change posture if you are uncomfortable.
5. Wear **comfortable shoes** when standing
6. The **top of the screen** should be at or just below **eye level** and roughly an **arm's length away** (depending on screen size).
7. Your **head should be directly over shoulders** without straining forward or backward. The maximum forward tilt of your head should never go past 20° when scanning your screen.
8. Your **wrists should remain flat** when typing, creating a straight line from elbows to knuckles.
9. Your **upper arms** should be roughly **parallel** with your **torso** and your **elbows** should stay **relaxed** with a 90° to 120° angle.

What are the Physical Activity Guidelines for Adults?

≥150 minutes of **moderate** physical activity a week, such as cycling or fast walking every week.

OR

≥75 minutes of **vigorous** physical activity a week, such as running or a game of singles tennis every week.

AND

Muscle-strengthening activities on **≥2 days** a week that work all major muscle groups (legs, hips, back, abdomen, chest, shoulders and arms).

AND

All adults should minimise the amount of time spent being sedentary (sitting) for extended periods.

New Workplace Guidelines:

Predominantly desk-based workers should progress towards accumulating at **least 2 hours per day** of **standing and light activity** at work and aim to eventually increase this to **4 hours per day.**

Seated-work should be **regularly broken up with standing**-based work and vice versa

Prolonged static standing postures should be **avoided** and that movement should be checked and corrected on a regular basis especially in the presence of musculoskeletal symptoms.

Tips to Reduce Your Sitting Time

In the Workplace:

- Alternate from sitting to standing every 30 minutes using your sit-stand desk
- Leave your sit-stand desk in the 'standing' position to encourage a period of standing when you return
- Stand after lunch to help your metabolism and increase alertness.
- Use the bin/printer further away from you
- Use facilities on a different floor (e.g. toilets, kitchen, meeting rooms)

Whilst Travelling:

- Walk, run or cycle at least part of your way to work
- Park further away from your office
- Take public transport so you can walk to and from the stops/stations
- Stand-up on public transport and get on/off one stop/station early
- Take regular breaks during long journeys

- Take active breaks (e.g. a 5 minute walk,)
- Fill your water glass every hour
- Have lunch away from your desk and go for a walk before or after
- Stand when doing specific tasks (e.g. talking on the phone)
- Use the stairs instead of the lift

At home:

- Stand or walk around during TV advert breaks, whilst using your phone/tablet or reading
- Do house-work whilst watching TV
- Wash your car by hand

ID: _______________

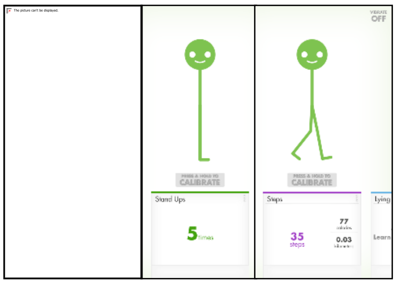
LUMO #: ___________________

Appendix 4.2

The feasibility of reducing workplace sitting time using behavioural feedback, prompts and sit-stand desks in a sample of office workers: The Ctrl Alt Del Study

Weeks 2-5 Intervention Instructions & Daily Log

Please read this document carefully for instructions on what we would like you to do during the 2nd- 5th week of the study.



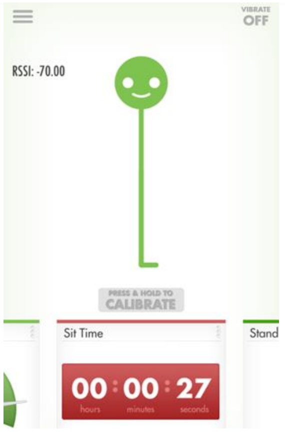
Please keep this booklet in a safe place

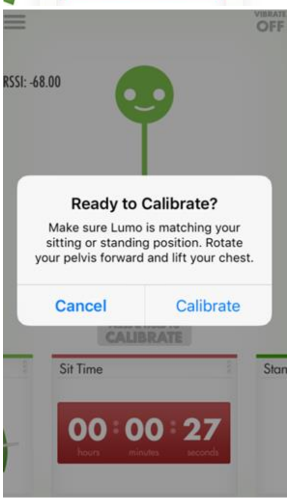
If you have any questions or concerns, please contact:
Tory Bullock (V.Bullock@lboro.ac.uk)

1. How to wear the lower-back monitor (LUMO)

- The lower-back monitor or **LUMO** also measures your **posture** (including sitting, standing and walking).
- Place the LUMO in the **centre of your lower back** with the logo the right way up and facing-outwards. It can be worn directly in contact with skin or over a **thin** piece of clothing.
- Use the elastic straps secure the LUMO around your lower back and use the Velcro to adjust the tightness.

- It is to be worn during **waking-hours** only **for 4 weeks**.
- When removing the LUMO at night please take it off immediately before you go to sleep and place it on charge using the charging plug and cord provided in your pack. It is best to place this on your bed side table as a reminder to put it on when you wake up in the morning
- It is important that you place the device on charge **every night** in order to log the removal time in the data.
- The device is **not** waterproof so it should be removed for water-based activities - making sure to place the device horizontal on a flat surface with the LUMO logo facing upwards.
- **IMPORTANT:** The LUMO must be recalibrated when it is put back on after a period of non-wear. This can be performed by:
    1. Opening the app on your Apple device
    2. Pressing the 'press & hold to calibrate' button on the home-screen
    3. Follow the on-screen instructions





Be careful NOT to press the touch button whilst putting the LUMO on or taking it off as this can turn it off (red light)

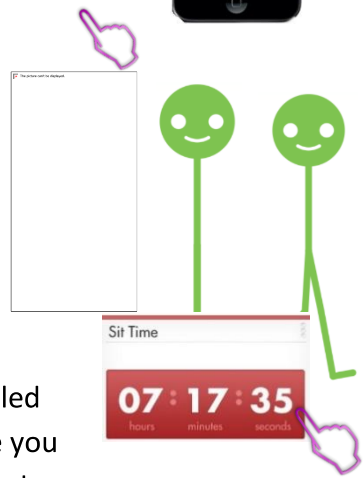
Summary:
1. **Wake up** – put LUMO on and calibrate using the app
2. **Wear LUMO all day** and remove only for showering, swimming or bathing (place flat facing up and recalibrate when put back on)
3. **Sleep** – take LUMO off, put on charge and place down flat with LUMO logo facing up in a place where you will remember to put it on when you wake up

2. Using the LUMO application

1. How do I open the app?

- Press either the ‘Home’ button or the ‘On/Off’ button to open the menu on your iOS device.
- Touch the ‘LU COPD’ app to open it
- You will then be able to navigate the app to look at the different feedback options

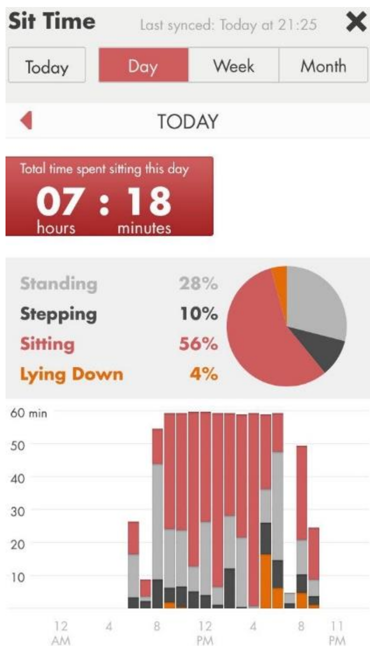
2. How do I interpret the avatar?

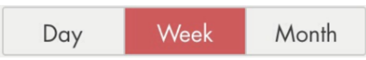


- The avatar represents your current posture (sitting, standing or walking)
- The avatar does not provide any other function than showing you your posture

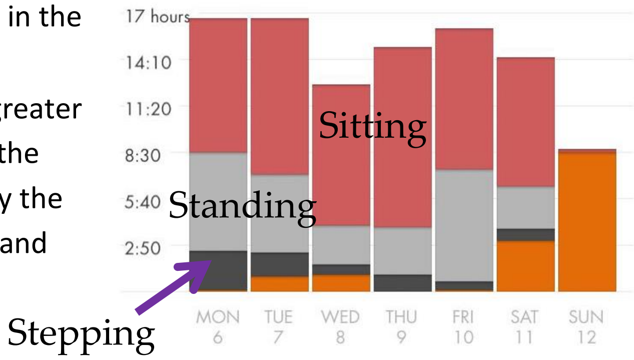
3. How do I find out about my sitting time?

- On the panel across the bottom of the screen, there is a slide titled “Sit Time”. This provides you with a count-up of how much time you have been sitting for on that day. For example, in the picture on the right, this would mean you have sat for over 7 hours.
- By touching the slide, you will be provided with more detailed information. It will look something like this.
- The red box provides the same information as above
- The pie chart shows the proportion time spent in different postures [standing, stepping, and sitting (including lying down)] and the percentages are given next to the posture names. The higher the percentage, the more time you have spent in that posture.
- The bar chart shows the amount of time per hour spent in each posture.
- When you have been wearing the LUMO for at least a few days, you can also start to see how you are getting on a day-to-day basis



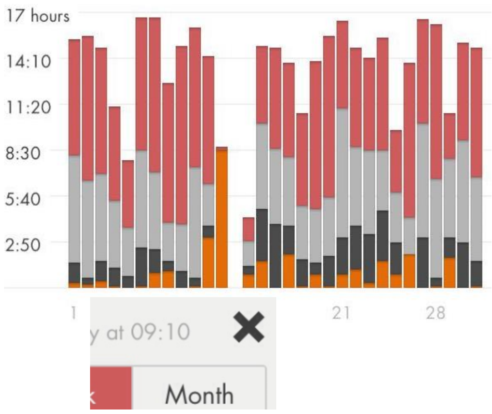


- In the top right of the screen, press the “week” icon to see the percentages of the postures across multiple days in the form of a bar & pie chart
- The more time spent in a posture each day, the greater amount of colour for that posture. For example, the picture on the right shows Thursday to be the day the wearer sat the most, Friday they stood the most and Monday they spend the most time stepping.

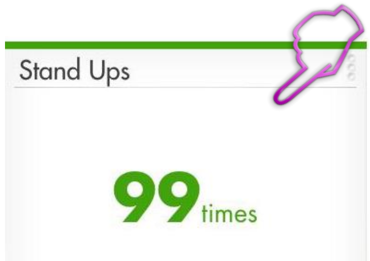


- You can move between weeks by touching the left and right arrows 
- To view information from the last month, touch the "month" icon in the top right of the screen.
- To go back to today's information, touch the "Today" icon 

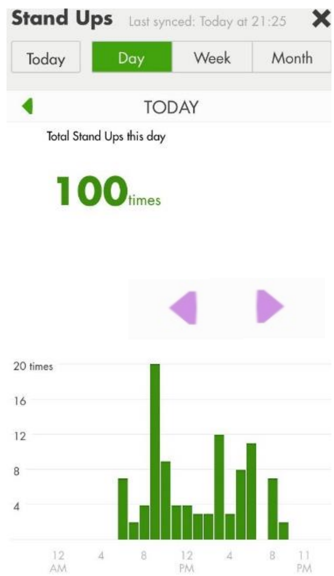
- To close the screen and return to the panel view, touch the cross in the top right corner

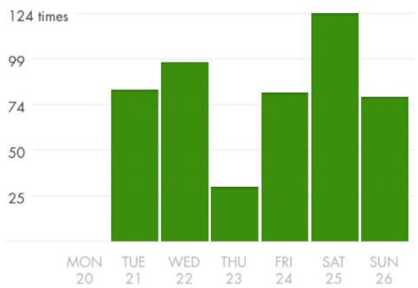


4. How do I find out about the number of stand-ups I have done?

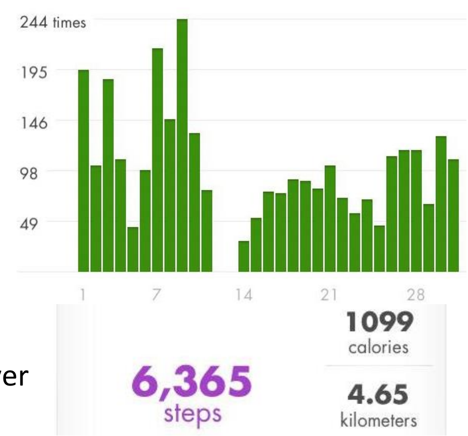


- On the panel across the bottom of the screen, there is a slide titled "Stand Ups". This provides you with how many times you have stood up from a seated position. For example, in the picture on the right, this would mean you have stood up 99 times
- By pressing the slide, you will be provided with more detailed information. It will look something like this
- You can choose whether to see information on a day-to-day basis by touching the "Day" icon at the top of the screen
- On the day view, the bar chart shows the number of times you have stood up each hour. The higher the bar, the more times you have stood. The left side of the graph shows the number of stand-ups each hour.
- You can move between days by touching the left and right arrows
- When you have been wearing the LUMO for at least a few days, you can also start to see how you are getting on, on a day-to-day basis
- In the top right of the screen, press the "week" icon to see the number of stand-ups on multiple days in the form of a bar chart
- The more times you have stood up each day, the taller the bar.
- In the top right of the screen, press the "month" icon to see the number of stand-ups over a month.
- To go back to today's information, touch the "Today" icon





- To close the screen and return to the panel view, touch the cross in the top right corner

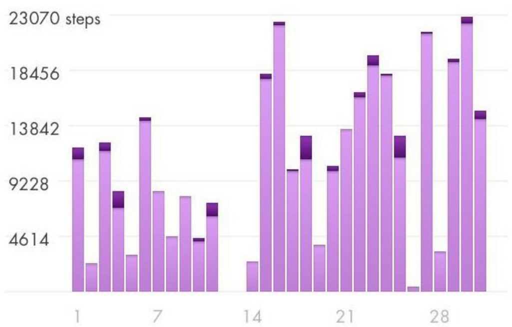


How do I find out about my steps?

- On the panel across the bottom of the screen, there is a slide titled “Steps”. This provides you with how many steps you have taken for that day. For example, in the picture on the right, this would mean you have taken over 6,000 steps for that day
- The slide also converts the number of steps into an estimation of calories burned and distance walked (in kilometres)
- By pressing the slide, you will be provided with more detailed information. It will look something like this

- You can choose whether to see information on a day-to-day basis by touching the “Day” icon at the top of the screen
- On the day view, the bar chart shows the number of steps taken each hour. The higher the bar, the more steps you have taken. The left side of the graph shows the number of steps taken each hour.
- When you have been wearing the LUMO for at least a few days, you can also start to see how you are getting on, on a day-to-day basis
- You can move between days by touching the left and right arrows
- In the top right of the screen, press the “week” icon to see the number of steps taken on multiple days in the form of a bar chart

- The more steps taken each day, the taller the bar.
- In the top right of the screen, press the “month” icon to see the number of stand-ups over a month.
- To go back to today’s information, touch the “Today” icon
- To close the screen and return to the panel view, touch the cross in the top right corner



<u>LUMO FAQ's</u>

How do I check if the LUMO is charged?

Gently press the **Touch Button** to view charge level:

Green - The LUMO has more than one day of charge remaining.

Orange - The LUMO has one day or less of charge remaining.

Red – You have turned the LUMO off – Press and hold the button again to turn it back on. You should see a green light appear when you do this.

Alternatively – touch the three horizontal bars on the top left corner of the app which will display the side menu will display the battery charge next to the LUMO tab.

The LUMO will stay on for the full 2 weeks unless you turn it off.

How do I clean my LUMO? Is it water resistant?

You can simply take a damp cloth or a wipe and wipe the sensor down. Also, if needed you can remove the Velcro straps from the actual sensor moulding and you can hand wash the belt straps and line dry.

LUMO is not completely water resistant. While it is ok to have moisture and sweat from normal use and activities, you can NOT submerge the LUMO sensor in water or shower with it, etc. It has a Lithium battery and other hardware components that can be damaged if it gets wet.

Connectivity issues. What do I do?

Please try the following:

1. Turn the Bluetooth on your iOS device off and then on again through the iOS Settings icon. Go to Settings>Bluetooth>On/Off in your iOS device.
2. Kill the app: first double-click on the home screen of your iOS device, then scroll through the open apps by swiping right until you find the LUMO app. Swipe upwards to close the app.
3. Restart the LUMO app.
4. If this doesn't work, try turning off your iOS device completely, and then turn it back on.
5. Alternatively – try turning the LUMO on and off again – this can be achieved by touching the button on the device for a period of 5 seconds until the red light flashes. Perform the same action again to turn it back on. A green light should flash to let you know it is turned on again.

Please make sure your battery is charged as the app works best when it is charged.

The LUMO will still be collecting data during this time even if it isn't connected to the app.

Any other problems please contact me using the details on the front page

3. Daily log (Remember to fill it in daily). Write your comments in the space provided

Date: ___/___/___	Is today a work or non-work day?	What time did you start working?	What time did you finish working?	How long was spent at your sit-stand desk?
Day example: 01/04/17	(Work) Non-work	Start Work: 8:30 (am)/pm	Finish Work: 5:00 am/(pm)	7 hrs 30 mins
Day 1: ___/___/___	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 2: ___/___/___	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 3: ___/___/___	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 4: ___/___/___	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 5: ___/___/___	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 6: ___/___/___	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 7: ___/___/___	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 8: ___/___/___	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 9: ___/___/___	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 10: ___/___/___	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 11: ___/___/___	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 12: ___/___/___	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 13: ___/___/___	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 14: ___/___/___	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 15: ___/___/___	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 16: ___/___/___	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 17: ___/___/___	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins

Day 18: _____/_____/_____	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Date: ___/___/___	**Is today a work or non-work day?**	**What time did you start working?**	**What time did you finish working?**	**How long was spent at your sit-stand desk?**
Day 19: _____/_____/_____	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 20: _____/_____/_____	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 21: _____/_____/_____	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 22: _____/_____/_____	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 23: _____/_____/_____	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 24: _____/_____/_____	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 25: _____/_____/_____	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 26: _____/_____/_____	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 27: _____/_____/_____	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 28: _____/_____/_____	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 29: _____/_____/_____	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins
Day 30: _____/_____/_____	Work Non-work	Start Work: ______am/pm	Finish Work: _____am/pm	____hrs____mins

Do you have any comments about the daily log?

____
____
____
____
____
____
____

THANKS FOR FILLING IN THE DAILY LOG

Please, remember to return this log to us once you have finished the measurement period. The return date is on your participant pack

Appendix 4.3

ID: ______________

The feasibility of reducing workplace sitting time using behavioural feedback, prompts and sit-stand desks in a sample of office workers: The Ctrl Alt Del Study

Week 5 Questionnaire booklet

Please FULLY COMPLETE this questionnaire booklet and then keep it in a safe place so you can return it to us in your participant pack at the end of the 7 days

If you have any questions or concerns, please contact: Tory Bullock (V.Bullock@lboro.ac.uk)

Section 1) Intervention evaluation

Usefulness: Please indicate how useful you think the intervention elements were for helping you to alter your behaviour in each of the domains by circling the number corresponding to the statement that best describes your feelings. **1 = not useful, 2 = somewhat useful, 3 = not sure, 4 = useful, 5 = extremely useful**

1. How useful was the intervention overall for helping you to:	**At work**					**Whilst traveling**					**During leisure-time**				
a) Reduce your sitting time	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
b) Increase the number of times you stood-up	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
c) Increase your standing time	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
d) Increase your step count	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
e) Increase your incidental activity	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
f) Increase your moderate to vigorous activity	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
g) Increase your sit-stand desk use	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
2. How useful was the <u>vibration prompt</u> for helping you to:	**At work**					**Whilst traveling**					**During leisure-time**				
a) Reduce your sitting time	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
b) Increase the number of times you stood-up	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
c) Increase your standing time	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
d) Increase your step count	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
e) Increase your incidental activity	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
f) Increase your moderate to vigorous activity	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
g) Increase your sit-stand desk use	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
3. How useful was the <u>Lumo application</u> for helping you to:	**At work**					**Whilst traveling**					**During leisure-time**				

a) Reduce your sitting time	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
b) Increase the number of times you stood-up	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
c) Increase your standing time	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
d) Increase your step count	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
e) Increase your incidental activity	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
f) Increase your moderate to vigorous activity	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
g) Increase your sit-stand desk use	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5

Ease of use: Please indicate the extent to which you agree with the following statements by circling the number corresponding to statement that best describes your feelings. *Note: 'Lumo' refers to the device and the application (app).*

1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = completely agree

1. It was easy to understand the features of the Lumo	1	2	3	4	5
2. It was easy to use the Lumo	1	2	3	4	5
3. It did not require a lot of effort to use the Lumo	1	2	3	4	5
4. It was clear and understandable how to use the Lumo	1	2	3	4	5
5. It was easy to learn how to use the Lumo	1	2	3	4	5
6. It was easy to calibrate the Lumo device using the app	1	2	3	4	5
7. Without help from anyone else, I trust myself to use the Lumo	1	2	3	4	5

Satisfaction: Please indicate the how satisfied you were with the intervention elements by circling the number corresponding to the statement that best describes your feelings.

1 = not satisfied, 2 = somewhat satisfied, 3 = not sure, 4 = satisfied, 5 = extremely satisfied

a) The intervention overall	1	2	3	4	5
b) The vibration prompts	1	2	3	4	5
c) The Lumo app	1	2	3	4	5
d) Would you continue with the intervention if possible?	Yes / No				
e) Would you recommend the intervention to a friend?	Yes / No				

Comfort: (please circle one answer)

a) How comfortable was the Lumo to wear on a scale of 1 to 5?

(Not at all comfortable) 1 2 3 4 5 (Very comfortable)

b) Did you experience any adverse events as a result of the intervention? Yes / No

If yes, please provide details: ____

Compliance: (please circle one answer)

a) How often did you wear the Lumo during the intervention period?

Never Once/Twice Once per week Most days Everyday

b) How often did you check the Lumo app on average during the intervention?

Never < once per day Once per day 2-5 times per day 5 times per day

c) How often did you re-calibrate your Lumo device after putting it back on?

Never rarely sometimes most times every time

Future: (please circle an answer)

a) Would you wear the Lumo with the vibration prompts but without the app? Yes / No

b) Do you think the above would be as effective as the current intervention? Yes / No

c) Would you wear the Lumo without the vibration prompts but with the app? Yes / No

d) Do you think the above would be as effective as the current intervention? Yes / No

Section 2) Workplace activity

Please answer the following questions based on the last 3-4 weeks (intervention period):

1. On a normal workday, how much time do you spend at your desk?
   _______ hours ______ minutes

2. Of this time spent at your desk on a normal workday, how much time is spent sitting?
   ______ hours ______ minutes

3. Which of the following positions do you use your desk in: (tick 1 box only)
   ☐ Sitting ONLY → Go to Section 3
   ☐ Standing ONLY → Go to Section 3
   ☐ BOTH sitting and standing → Go to Question 4

4. On average, how long would you:
   a) Stand at your desk before alternating to sitting? _______ hours _______ minutes
   b) Sit at your desk before alternating to standing? _______ hours _______ minutes

Section 3) Physical activity

In the past week on how many days have you done a total of 30 minutes or more of physical activity, which was enough to raise your breathing rate? (This may include sport, exercise, and brisk walking or cycling for recreation or to get to and from places, but should not include housework or physical activity that may be part of your job).

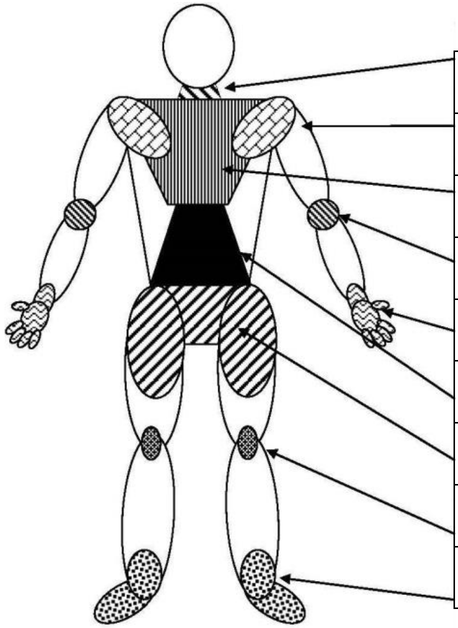
_________ days

Section 4) Sitting time questionnaire:

Based on the last 3-4 weeks (intervention period), please estimate how many hours you spend sitting each day in the following situations. If you don't spend any time in some of the situations, please write '0' or 'n/a'.

Activity	On a WEEK day	On a WEEKEND day
While traveling to and from places	________ hours ________ minutes	________ hours ________ minutes
While at work	________ hours ________ minutes	________ hours ________ minutes
While watching television	________ hours ________ minutes	________ hours ________ minutes
While using a computer at home	________ hours ________ minutes	________ hours ________ minutes
In your leisure time, NOT including television (e.g., visiting friends, movies, dining out, etc.)	________ hours ________ minutes	________ hours ________ minutes

Section 5) Musculoskeletal Problems: The following questions refer to trouble experienced in muscles and joints which have progressively come about. Please answer every question even if you have never had trouble in any parts of your body. This picture shows how the body has been divided. You should decide for yourself which part (if any) is or has been affected.



	Have you at any time during the last <u>3 weeks</u> had trouble (such as ache, pain, discomfort, numbness) in:	On a scale of 0 to 10, how much pain did you experience? (0 is no pain, 10 is the most pain you can imagine)	During the last <u>3 weeks</u> have you been prevented from carrying out normal activities (e.g. job, housework, hobbies) because of this trouble in:	During the last <u>3 weeks</u> have you seen a physician for this condition:	During the last 7 days have you had trouble in:
NECK	YES NO		YES NO	YES NO	YES NO
SHOULDER	YES NO		YES NO	YES NO	YES NO
UPPER BACK	YES NO		YES NO	YES NO	YES NO
ELBOW	YES NO		YES NO	YES NO	YES NO
WRIST/HAND	YES NO		YES NO	YES NO	YES NO
LOWER BACK	YES NO		YES NO	YES NO	YES NO
HIP/THIGH	YES NO		YES NO	YES NO	YES NO
KNEE	YES NO		YES NO	YES NO	YES NO
ANKLE/FEET	YES NO		YES NO	YES NO	YES NO

Please answer the following questions based on the last 3-4 weeks (intervention period)

Section 6) Work feelings

Work engagement

The following 9 statements are about how you feel at work**.** Please read each statement carefully and decide if you ever feel this way about your job. If you have never had this feeling, **circle** the “0” (zero) in the space after the statement. If you have had this feeling, indicate how often you feel it by **circling** the number (from 1 to 6) that best describes how frequently you feel that way.

0=never
1=Almost never (a few times a year or less)
2=rarely (once a month or less)
3=sometimes (a few times a month)
4=often (once a week)
5= very often (a few times a week)
6= Always (every day)

At my work I feel bursting with energy						
0	1	2	3	4	5	6
At my job, I feel strong and vigorous						
0	1	2	3	4	5	6
I am enthusiastic about my job						
0	1	2	3	4	5	6
My job inspires me						
0	1	2	3	4	5	6
When I get up in the morning, I feel like going to work						
0	1	2	3	4	5	6
I feel happy when I am working intensely						
0	1	2	3	4	5	6
I am proud of the work that I do						
0	1	2	3	4	5	6
I am immersed in my work						
0	1	2	3	4	5	6
I get carried away when I am working						
0	1	2	3	4	5	6

How many whole days have you been off work because of a health problem?

_______________days

How many whole days have you attended work while suffering from health problems?

Please answer the following questions based on the last 3-4 weeks (intervention period)

_______________days

Work Recovery

The following 11statements are about how you feel once you have completed a working day. Please read each statement and answer **YES** or **NO** depending on which answer is most appropriate.

I find it hard to relax at the end of a working day	YES	NO
At the end of a working day I am really feeling worn out	YES	NO
My job causes me to feel rather exhausted at the end of a working day	YES	NO
Generally speaking, I'm still feeling fresh after supper	YES	NO
Generally speaking, I am able to relax only on a second day off	YES	NO
I have trouble concentrating in the hours off after my working day	YES	NO
I find it hard to show interest in other people when I just come home from work	YES	NO
In general, it takes me over an hour to feel fully recovered after work	YES	NO
When I get home, people should leave me alone for some time	YES	NO
After a working day I am often too tired to start other activities	YES	NO
During the last part of the working day I cannot optimally perform my job because of fatigue sometimes	YES	NO

Job Satisfaction

Please circle the answer (from 1 to 7) where 1 = extremely dissatisfied and 7 = extremely satisfied.

How satisfied are you with your job in general?						
1	2	3	4	5	6	7

Job Performance

Please circle the answer (from 1 to 7) where 1 = very poorly and 7 = extremely well.

How well do you think you have performed in your job over the last 4 weeks?						
1	2	3	4	5	6	7

Section 7) Sleep

During the past 4 weeks, typically how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.) ___________ hours per night

THANKS FOR FILLING IN THE QUESTIONNAIRE

Please, remember to return this booklet with the devices to us once you have finished the measurement period. The returning date is on your participant pack.

National Centre for Sport & Exercise Medicine
Working for Health & Wellbeing

Take Ctrl Of Your Work Behaviour

Alternate Between Sitting & Standing

Delete The Sedentary Habit

Loughborough University

Appendix 4.4

Ctrl Alt Del Study – Post-Intervention Interview Schedule

Before the interview explain the following:

- Purpose of the interview – *gain insight into your experience of the intervention for PhD study contributing to thesis.*
- Clarification of topic under discussion – *initial thoughts before the study, experience of the intervention as a whole and each component individually*
- Format of the interview – *semi structured so I will ask some open-ended questions and probe for more detail if needed.*
- Approximate length of interview – *30-45 minutes*
- Assurance of confidentiality – *anything you say will be confidential*
- Purpose of digital recorder – *ask permission to use it. Explain that I will be the only person to listen to the recording*
- Assure participant that he or she may seek clarification of questions.
- Assure participant that he or she can decline to answer a question.
- Assure participant that there will be opportunity during the interview to ask questions.

1) Introduction:

- Tell me about the last month, what have you been up to?

2) Sitting attitude:

- **Before the intervention, what did the word sitting mean to you?**

- Can you tell me a little bit about this – what do you think when I say sitting?
- Why do you sit?
- Typical times or situations when you sit for a long while during the day?
- **What makes you sit?**
- How does sitting make you feel?
- Has this changed as a result of the intervention? (at work/outside of work)

3) Study motivation:

- **What influenced your decision to take part in this study?**
  - Why did you decide to take part?
- **What did you hope to get from it?**
    - Was it what you expected?
- **This study tried to encourage people to sit less. What were your initial thoughts on this before the study started?**
  - Do you think targeting your sitting is appropriate for you? Why/not?

- **How did you think it would impact your normal life?**
- **Did you feel it was worthwhile to find out about your sitting/inactivity levels?**

4) <u>**General experience with intervention**</u>

- **Can you tell me about your sitting, standing and activity over the study period?**
  - Tell me about ways you tried sit less
  - Can you give me any examples of this?
  - When did you sit? Why? Did you do this before?
  - **Did you sit less at particular times or on particular occasions?**
  - How did this make you feel?
  - Did you experience any problems/benefits?
  - Can you tell me if you changed your everyday life as a result of this study?
  - **If they didn't change anything**: Why might this be?

5) <u>**Experience with educational advice**</u>

- **You were given an information booklet about sitting, do you remember this?**
  - What do you remember from it? What did you use? How did you use it?
  - How did you get on with it?
  - Did you find any of it useful? Which bits?

6) <u>**Experience with technology**</u>

- **Can you tell me about how you use technology (computers/internet/mobile phones/wearable devices)**
  - What do you use? How? What for? How often?
  - Used for health e.g. to track steps or diet or anything?
  - Describe to me how it has helped you?
  - Has it changed anything for you? Influenced your behaviour in any way? (to do things in a different way e.g. shopping)
  - Difficulties experienced? Stress, annoying, novelty?
    - **None used:** What do you think the reasons are for you not using them continuously/everyday?
    - How would you feel about using them?

A. Device wear:

- **When you knew that the intervention involved wearing a waist device, what were your initial thoughts?**
  - Any concerns?
  - How did you think it would fit in with your everyday life?

- **How did you get on with it?**
  - What did you think of it?
  - How did you find wearing it?
  - When did you wear it/take it off? Why?
  - How often did you charge it? Calibrate it?
  - How could it be improved?

B. Vibration prompts:

- **When you knew that the intervention involved vibration prompts, what were your initial thoughts?**
  - Any concerns?
  - How did you think it would fit in with your everyday life?
- **How did you get on with the prompts?**
  - What did you do when the belt vibrated to tell you to stand?
  - Why was this? Can me about that. What was going on at this time/in your life?/that day?
  - What do you think of this timing of the prompts
  - Can you expand on this
  - Do you think it had an effect on your behaviour? Increased PA/standing, decreased sitting? How? Why? Can you give me an example

C. App:

- **When you knew that the intervention involved using an Apple application, what were your initial thoughts?**
  - Any concerns?
  - How did you think it would fit in with your everyday life?
- **How did you get on with it?**
  - When did you look at it? How often?
  - Why is this?
  - Did you find anything on it interesting? What in particular? How come? What did you make of it?
  - Do you want to show me?
  - Do you think it had an effect on your behaviour? Increased PA/standing, decreased sitting? How? Why? Can you give me any examples
  - How could it be improved?

7) <u>Sit-stand desk use (/outside of work depending on what has been discussed)</u>

- **Did the intervention affect your sit-stand desk use?**
  - In what way? Can you give me examples

- How long would you stand for before sitting?
- Did your behaviour have any effect on those around you?
- How did you feel standing whilst working? Why?
- Did you notice any effects on your wellbeing/work?
- **No:** why not? What would increase sit-stand desk use?

8) <u>**Overall study experience**</u>
   - **How do you feel as a result of the intervention?**
     - Have you noticed any change in your health or wellbeing? Tell me more about this
     - Productivity?
   - **What did you think of the intervention as a whole?**
     - How did it make you feel?
     - Do you think it was beneficial? Why? Why not?
     - Did you prefer one component over another? Why?
     - Would you use the app without the buzz or vice-versa?
     - dDo you think it is something you would like to do/ use long term? Why? Not?
     - Did you mention the study or show any of the components to friends/family? What did they think?
     - Would you recommend it to a friend?

     - What would you change? Why?
     - What would help you to reduce your sitting? Anything else/instead? Why?

- **What do you think you will take away from the study?**
  - What will you do? How will you do this? What will help you with this? Will you continue to use the technology/educational tools? How?
  - If nothing, why is this?

<u>**Ask if they have anything else they want to say**</u>

ID: _______________

Appendix 4.5

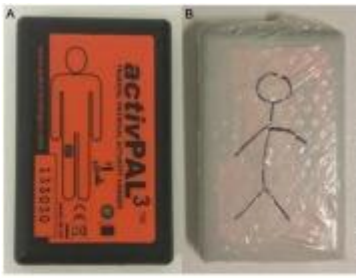
LUMO #: ___________________

activPAL #: ________________________

The feasibility of reducing workplace sitting time using behavioural feedback, prompts and sit-stand desks in a sample of office workers: The Ctrl Alt Del Study

Week 1 Activity Monitor Instructions & Daily Log

Please read this document carefully for instructions on what we would like you to do during the 1st week of the study.



Please keep this booklet in a safe place so you can return it to us at the end of the 7 days

If you have any questions or concerns, please contact:
Tory Bullock (V.Bullock@lboro.ac.uk)

1. How to wear the <u>lower-back monitor (LUMO)</u>

- The lower-back monitor or **LUMO** also measures your **posture** (including sitting, standing and walking).
- Place the LUMO in the **centre of your lower back** with the logo the right way up and facing-outwards. It can be worn directly in contact with skin or over a **thin** piece of clothing.

- Use the elastic straps secure the LUMO around your lower back and use the Velcro to adjust the tightness.
- It is to be worn during **waking-hours** only **for 7 full days**.
- When removing the LUMO at night please take it off immediately before you go to sleep and place it on charge using the charging plug and cord provided in your pack. It is best to place this on your bed side table as a reminder to put it on when you wake up in the morning

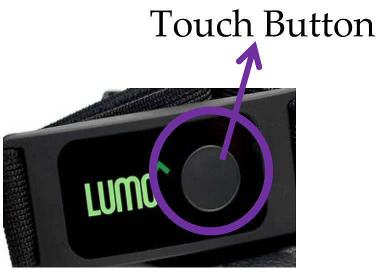
- It is important that you place the device on charge **every night** in order to log the removal time in the data.
- The device is **not** waterproof so it should be removed for water-based activities - making sure to place the device horizontal on a flat surface with the LUMO logo facing upwards.

Be careful NOT to press the touch button whilst putting the LUMO on or taking it off as this can turn it off (red light)

Summary:
1. **Wake up** – put LUMO on
2. **Wear LUMO all day** and remove only for showering, swimming or bathing (place flat facing up)
3. **Sleep** – take LUMO off, put on charge and place down flat with LUMO logo facing up in a place where you will remember to put it on when you wake up

LUMO FAQ's

How do I check if the LUMO is charged?



Gently press the **Touch Button** to view charge level:

Green - The LUMO has more than one day of charge remaining.

Orange - The LUMO has one day or less of charge remaining.

Red – You have turned the LUMO off – Press and hold the button again to turn it back on. You should see a green light appear when you do this.

The LUMO will stay on for the full week unless you turn it off.

How do I clean my Lumo? Is it water resistant?

You can simply take a damp cloth or a wipe and wipe the sensor down. Also, if needed you can remove the Velcro straps from the actual sensor moulding and you can hand wash the belt straps and line dry.

Lumo Back is not completely water resistant. While it is ok to have moisture and sweat from normal use and activities, you can NOT submerge the Lumo Back sensor in water or shower with it, etc. It has a Lithium battery and other hardware components that can be damaged if it gets wet.

Any other problems please contact me using the details on the front page

2. How to wear the thigh monitor (activPAL)

- The thigh monitor or activPAL measures your posture – specifically your sitting, standing and sleeping time
- Wear it **continuously (24 hours/day) for 7 full days.**
- Use the patches provided to attach the device (email if you need additional patches using the details on the 1st page)
- Put it on your upper mid-thigh with the **'man' on the device facing outwards & standing upright**.
- The thigh monitor is **waterproof** so you can continue wearing it whilst bathing, showering etc.

Note: the monitor will be flashing every 6 seconds. This is an indication that it is working. If it stops flashing, contact us immediately and we will provide you with a new one.

3. How to fill in the daily log

- The log is divided into 8 days. Please complete each day's questions as accurately as possible – record the exact times or to the nearest 5 minutes.
    1. Indicate the date.
    2. Record the time that you **woke up** and when you put the lower-back device on.
    3. State if it was **work or non-work day**.
    4. If it was a workday, please record the times you **started and finished working,** if you had a **lunch break** and how many hours/minutes you were **at your sit-stand desk** for during the workday.
    5. Record any times you **removed** either of the devices for more than 15 minutes during the day.
    6. Finally, record the time that you removed the lower-back device and **went to sleep**.

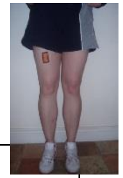
NOTES:

- Midnight = 12am; midday = 12pm
- **Sleep and waking times are very important.**

Daily log (Remember to fill it in daily). Write your comments in the space provided

Lower back- device (LUMO)

Thigh device (activPAL)



Date: ___/___/___ Waking up time?	What time did you put the lower-back device on?	Is today a work or non-work day?	What time did you start working?	Did you have a lunch break?	What time did you finish working?	How long did you spend at your sit-stand desk?	What time did you take the lower-back device off?	At what time did you go to sleep?	Did you remove the thigh device?	Did you remove the lower-back device?
01/04/17 **7:30** am/pm	**7:35** am/pm	Work Non-work	**8:30** am/pm	**12:30** am/pm **1:30** am/pm	**5:00** am/pm	**8** hours **0** minutes	**11:25** am/pm	**11:30** am/pm	___ am/pm ____ am/pm	**8:20** am/pm **8:50** am/pm
Day 1 ____/____/___ _______am/pm	_________ am/pm	Work Non-work	________ am/pm	______am/pm ______am/pm	________ am/pm	______hours _______mins	_________ am/pm	________ am/pm	_______am/pm _______am/pm	_______am/pm _______am/pm
Day 2 ____/____/___ _______am/pm	_________ am/pm	Work Non-work	________ am/pm	______am/pm ______am/pm	________ am/pm	______hours _______mins	_________ am/pm	________ am/pm	_______am/pm _______am/pm	_______am/pm _______am/pm
Day 3 ____/____/___ _______am/pm	_________ am/pm	Work Non-work	________ am/pm	______am/pm ______am/pm	________ am/pm	______hours _______mins	_________ am/pm	________ am/pm	_______am/pm _______am/pm	_______am/pm _______am/pm

Date: ___/___/___ Waking up time?	What time did you put the lower-back device on?	Is today a work or non-work day?	What time did you start working?	Did you have a lunch break?	What time did you finish working?	How long did you spend at your sit-stand desk?	What time did you take the lower-back device off?	At what time did you go to sleep?	Did you remove the thigh device?	Did you remove the lower-back device?
Day 4 ____/____/___ _______am/pm	_________ am/pm	Work Non-work	________ am/pm	______am/pm ______am/pm	________ am/pm	______hours _______mins	_________ am/pm	________ am/pm	_______am/pm _______am/pm	_______am/pm _______am/pm
Day 5 ____/____/___ _______am/pm	_________ am/pm	Work Non-work	________ am/pm	______am/pm ______am/pm	________ am/pm	______hours _______mins	_________ am/pm	________ am/pm	_______am/pm _______am/pm	_______am/pm _______am/pm
Day 6 ____/____/___ _______am/pm	_________ am/pm	Work Non-work	________ am/pm	______am/pm ______am/pm	________ am/pm	______hours _______mins	_________ am/pm	________ am/pm	_______am/pm _______am/pm	_______am/pm _______am/pm
Day 7 ____/____/___ _______am/pm	_________ am/pm	Work Non-work	________ am/pm	______am/pm ______am/pm	________ am/pm	______hours _______mins	_________ am/pm	________ am/pm	_______am/pm _______am/pm	_______am/pm _______am/pm
Day 8 ____/____/___ _______am/pm	_________ am/pm	Work Non-work	________ am/pm	______am/pm ______am/pm	________ am/pm	______hours _______mins	_________ am/pm	________ am/pm	_______am/pm _______am/pm	_______am/pm _______am/pm

Do you have any comments about the daily log?

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THANKS FOR FILLING IN THE DAILY LOG

Please, remember to return this log with the devices to us once you have finished the measurement period. The return date is on your participant pack.