Physical Capability & Sedentary Behaviour in UK Office Workers

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Abbreviations

Activity permissive work stations (APWs)

Average Power (AvP)

Fast walk speed (FWS)

International physical activity questionnaire (IPAQ)

Light intensity physical activity (LIPA)

Moderate-to-vigorous physical activity (MVPA)

Peak anaerobic power (PAP)

Physical activity (PA)

Quality of life (QoL)

Sedentary behaviour (SB)

Sedentary time (ST)

Sit to stand workstations (STSWs)

Usual walk speed (UWS)

1.0 Chapter 1: Abstract

Spending too much time in sedentary behaviour (SB), has been identified as a risk factor for chronic disease and mortality. Most of the research into SB has focused on cardiometabolic outcomes. Other components of optimal health and fitness have been considered less, which are important for quality of life and may indicate risk for future disease. In older populations time spent in SB and breaks in SB, have been associated with markers of improved physical capability (PC); research is needed to determine if similar associations exist in younger adults.

The modern workplace provides an environment which exposes individuals to extremely high levels of sitting and there is a need for interventions to reduce this. Calisthenics exercises may provide a method to break up prolonged inactivity, requiring little space and no equipment and offering important benefits to health.

This thesis investigates into SB and PC, in UK office workers, who are below retirement age. The first study (n=42) considers associations between SB and components of PC, measured using balance, grip strength and walk speed. The second study (n=19) trials a two-week calisthenics exercise intervention, within the workplace, to determine if this improves PC.

In these extremely sedentary office workers, SB was not associated ($p>0.05$) with impairing grip strength or walk speed, however was impairing the balance of males ($\beta = -0.98$, $p<0.05$). The grip strength and walk speed of individuals were relatively reduced compared to norms and may highlight impaired PC due to the sedentary occupation. A calisthenics exercise intervention resulted in considerable reductions in workplace sitting (-35 mins.day^{-1}) and provided improvements to balance (composite: +1.3%, $p>0.05$; anterior: +2.6%, $p<0.05$). The intervention is therefore an effective mode by which occupational sitting could be reduced, without impairing work performance and providing health benefits associated with breaking up SB. Future work should further investigate associations across more diverse populations and trial multi-component interventions, over longer durations.

Keywords: Sedentary behaviour, physical capability, office workers, calisthenics exercises, workplace intervention.

2.0 Chapter 2: Literature Review

2.1 Sedentary Behaviour

In modern society people are spending an increasing proportion of their time being inactive, leading to lifestyles being more sedentary. This increase in inactivity is due to spending more time conducting screen based activities, changes in the ways we communicate and an increased use of automated transportation (Owen et al., 2010a). This rise in sedentary behaviour (SB) has reduced the amount of time people are spending being physically active. SB relates to any waking behavior which requires an energy expenditure of less than 1.5 METs, while in a sitting or reclining posture (Sedentary Behaviour Research, 2012). It has been suggested adults spend 51-68% of their time being sedentary (Dunstan et al., 2012a). Adults in England were reported to spend on average 10 hours per day being sedentary; when objectively measured during a national health survey in 2008 (Nhs, 2008). At weekends, the amount of time spent sedentary was slightly higher than during the weekdays. Overall men were more sedentary than women, during both weekdays and weekends. In 2012, when subjectively measured, the average time adults spent being sedentary was slightly reduced compared to in 2008; this reduction may be due to differences between objective and subjective measures. (Nhs, 2012). This large proportion of time which adults are spending sedentary has led to the concern that it may be having a negative impact upon health. As early as the 1950’s it was suggested that bus drivers and mail sorters were at an increased risk of cardiovascular disease (CVD) compared to their physically active working counterparts, bus conductors and postmen, who were required to stand (Morris et al., 1953). In recent years evidence has emerged identifying SB as a novel risk factor for disease and all-cause mortality, requiring research to better understand the underlying mechanisms and dose-response relationship associated with it (Owen et al., 2010b). Current physical activity (PA) guidelines recommend adults aim to be active daily, complete at least 150 minutes of moderate-to-vigorous physical activity (MVPA) per week and include at least two days where activities are undertaken to improve muscular strength. Additionally all adults should attempt to minimise the amount of time they spend sitting. (Doh, 2011). Research is needed to better inform these guidelines, to enable more detailed and specific information to be provided, on how and when individuals should be accumulating their SB.

2.2 Sedentary Behaviour and Health

Prolonged SB is as a risk factor for several chronic diseases such as obesity, metabolic syndrome, diabetes, cardiovascular disease and certain types of cancer (Ekblom-Bak et al., 2010, Owen et al., 2010b, Levine, 2015). A meta-analysis concluded that sedentary time (ST) is associated with a 112% increased risk for diabetes, a 147% increased risk for a cardiac event, a 90% increased risk for cardiovascular mortality and a 49% increased risk for all-cause mortality. There was a stronger association between SB and diabetes than for other mortality outcomes (Wilmot et al., 2012). Independent of time spent in PA, prolonged SB is also associated with all-cause mortality, cardiovascular disease, diabetes and certain types of cancer (Biswas et al., 2015). To better understand the associations between SB and chronic disease and mortality, research has investigated the underlying physiological mechanisms that are affected in response.

Associations have mainly been investigated in cross-sectional research and there has been less investigation into the longitudinal effects of SB. A systematic review was conducted on longitudinal studies between 1996 and 2011 (Thorp et al., 2011). The majority of studies included used self-reported measures of SB: total sitting time, TV viewing time and other screen-time behaviour and TV viewing time plus other SB. There was a consistent association between self-reported SB and mortality and weight gain, from childhood into adult years. There were mixed associations for the incidence of disease and markers of cardiometabolic health. More longitudinal research is required using more objective measures of SB, to better understand the impact of SB on health outcomes.

Heart attacks and strokes are the leading cause of mortality in the western world, caused by atherosclerosis and the predisposing endothelial dysfunction. Endothelial dysfunction is a systemic disorder due a reduction in the bioavailability of vasodilators, specifically nitric oxide

(Bonetti et al., 2003). Reduced nitric oxide availability due to endothelial dysfunction is associated with atherosclerosis, which is predictive of future cardiac events (Davignon and Ganz, 2004). A better understanding into how prolonged SB may be impacting upon vascular health, is therefore of vital importance. SB is associated with a number of haemodynamic changes, which lead to changes in shear stress and predispose the lower limbs to oxidative stress, a risk factor for atherosclerosis (Thosar et al., 2012). In response to three hours of prolonged sitting, flow mediated dilation (FMD) was shown to be significantly impaired in the femoral artery (Thosar et al., 2014b). FMD is the standard method used for non-invasive assessment of endothelial dysfunction (Stoner and Sabatier, 2012). A reduction in shear rate was also observed in the brachial artery, highlighting how the effects on the vasculature in response to prolonged sitting are not limited to the lower extremities (Thosar et al., 2014b). This suggests even short periods of SB are sufficient to impair vascular function, interrupting SB therefore appears to be of vital importance for the maintenance of vascular health.

Research has investigated the acute changes that occur in response to SB by exposing individuals to increased periods of physical inactivity. Healthy volunteers were subjected to five days of bed rest; this was associated with insulin resistance, dyslipidemia, increased blood pressure and an impairment of microvascular function. This highlights how even short-term SB can have detrimental metabolic and vascular implications (Hamburg et al., 2007). Early studies using bed rest may lack real world applicability, as this from of SB is extreme and may not represent the changes which occur during real world SB. Recreationally active adults were requested to reduce their step count to below 5000 steps per day and refrain from structured activity. After five days FMD was reduced in the popliteal artery but not the brachial artery and there was a significant reduction in circulating endothelial micro-particles (EMPs) (Boyle et al., 2013). EMPs are small circulating vesicles which are released when endothelial cells are disturbed and are associated with cardiac risk factors (Horstman et al., 2004). The reduction in FMD observed only in the legs suggests the arteries that perfuse the limbs receiving the reduction in activity, are those most affected. This indicates that extreme SB such as bed rest may not be required to impair vascular function (Boyle et al., 2013). Even in individuals who are usually recreationally active, the vasculature may therefore be vulnerable to the negative effects of a sedentary lifestyle.

2.3 Sedentary Behaviour and Physical Capability

Due to the detrimental associations between SB and cardiometabolic outcomes, it is of interest to consider other components of optimal health and fitness that may be affected by exposure to SB. Sedentary lifestyles may also affect components of physical capability, such as strength, agility, flexibility and balance. Physical capability relates to an individual's ability to complete the physical tasks of daily living (Kuh and New Dynamics of Ageing Preparatory, 2007). A meta-analysis of older community dwelling populations found associations between mortality and grip strength, walk speed, standing balance and chair rise time. Grip strength was the only measure associated with mortality at a younger age and it was suggested a 1kg reduction in grip strength was associated with a 3% change in mortality (Cooper et al., 2010). Grip strength has therefore been suggested as a simple, inexpensive method risk stratifying for all-cause mortality, cardiovascular mortality and cardiovascular disease (Leong et al., 2015). A 13-year follow-up of adults aged 53-66 years concluded that lower levels of physical capability, assessed using grip strength, chair rise time and standing balance, were associated with higher rates of mortality; it was suggested that standing balance may be more strongly associated with mortality than the other measures (Cooper et al., 2014). Balance measures therefore provide another inexpensive method, by which reductions in physical capability can be identified, associated with increased mortality. These associations highlight how even in individuals below retirement age, these simple measures were able to identify those less likely to live a long and healthy life. Detecting impairments in physical capability at a younger age, may therefore provide a method to identify individuals at risk for future adverse health outcomes.

Research investigating the effect of SB on physical capability is limited, with current work being confined to older populations, where impairments in physical capability can impact upon activities of daily living and in turn reduce quality of life (QoL). The television viewing time of older adults was compared with their physical capability, measured using handgrip strength and walk speed (Keevil et al., 2015). Those who spent the least amount time viewing television, walked at a faster usual pace than those who watched the most television. Strong and consistent observations were not observed between TV viewing time and grip strength. Muscular strength reductions in response to SB may therefore be better reflected in the legs due to the large periods of inactivity the muscles are exposed to; more research into these associations is required. The observed associations between SB and walk speed likely represent a meaningful difference in the functional health of the elderly, as walking speed has been proposed as the sixth vital sign of health (Fritz and Lusardi, 2009). In community dwelling adults, it was suggested that an increase of 0.1 $m.s^{-1}$ in walk speed was associated with an 8% reduction in mortality (Studenski et al., 2011), In British adults (average age of 61 years), slower walk speed was associated with increased mortality, over a 6.4 year up follow-up (Elbaz et al., 2013). This relationship was observed for both cardiovascular disease and cancer. It was suggested that walk speed may provide a simple and inexpensive indicator of health in later midlife.

The current evidence appears to suggest that maintaining or improving physical capability in older populations, is of vital concern for reducing mortality and improving QoL. Simple inexpensive measures such as grip strength, walk speed and balance tests provide a method by which physical capability can be easily assessed. Research is needed to determine if the physical capability of younger adults may be impaired in response to high exposure to SB. If so it may be possible to detect impairments in physical capability before they put individuals at risk for disease or adverse health outcomes. This could be vital for maintaining optimal health and fitness, improving QoL and promoting healthy ageing.

2.4 Sedentary Behaviour and Physical Activity – “The Active Couch Potato”

To better understand the detrimental effects SB may pose for health, it is important to consider how this may interact with the associated health benefits of participating in PA. Individuals who meet current PA guidelines but who still spend large proportions of their time being sedentary, may still be detrimentally affecting their health. This phenomenon has been termed “the active couch potato” (Owen et al., 2010a). Adults who were meeting PA guidelines, were used to investigate the dose-response relationship between television viewing time and metabolic risk factors. Significant detrimental associations were found between television viewing time and waist circumference, systolic blood pressure and plasma glucose (Healy et al., 2008b). Associations for mortality were investigated when considering the independent and combined effects of television viewing time and MVPA. MVPA relates to physical activities requiring an energy expenditure of >3 METs (Ainsworth et al., 2011). After adjusting for MVPA, individuals with the most television viewing time were at a greater risk for all-cause, cardiovascular and cancer mortality. Adults who participated in large quantities of MVPA (>7h/week) but who reported high levels of television viewing (>7h/day), were still associated with an increased risk for all-cause and cardiovascular mortality, compared to those who reported low television viewing (<1h/d) (Matthews et al., 2012). This suggests even participating in large amounts of MVPA, much greater than recommended in current PA guidelines, did not mitigate the health risks associated with prolonged SB.

It appears that too much time spent in SB and too little time spent in MVPA, are separate and distinct risk factors for chronic disease (Sedentary Behaviour Research, 2012). Research is required to investigate the independent effects of SB on health outcomes and how this fits with the current knowledge base on the benefits of participating in PA (Boyington et al., 2015). Therefore SB should not be considered in isolation but along with the effects of light intensity physical activity (LIPA) and MVPA (Thyfault et al., 2015). LIPA relates to PA requiring an energy expenditure of 1.6-2.9 METs (Ainsworth et al., 2011). To achieve this there is a need for research to monitor SB and PA of all intensities, under free living conditions, to better understand the combined effect this has upon health.

2.5 Interrupting Sedentary Behaviour

Due to the negative associations that have been observed between prolonged SB and health, it is of interest to consider how ST may be interrupted. There is a need to better understand how breaks of different frequency and duration may provide potential health benefits, vital for consideration when informing public health guidelines. The effect of breaks in SB independent of total ST and time spent in MVPA, were investigated over a seven-day period. Breaks in SB were beneficially associated with adiposity, lipids, BMI and waist circumference (Healy et al., 2008a). A meta-analysis by Chastin et al. (2015) concluded independent of total ST, breaks were associated with beneficial obesity metrics. Breaks of at least light intensity may also have a positive effect upon glycaemia but it was unclear if this was independent of total ST. This supports how interrupting periods of SB by using LIPA, may help in controlling adiposity and postprandial glycaemia. Further investigation is required to support this, with more accurate monitoring of SB accumulation. Cross-sectional analysis was conducted using the US National Health and Nutrition Examination Survey (NHANES) from 2003-2006. This was the first time a large, multi-ethnic population sample was used to examine objectively measured total ST, breaks in ST and associations with cardio-metabolic health and inflammatory risk markers. Breaks independent of total ST were beneficially associated with waist circumference, C-reactive protein and fasting plasma glucose. C-reactive protein is an inflammatory marker associated with increased risk for several diseases, including CVD and vascular mortality (Healy et al., 2011). The beneficial cardiometabolic associations observed when interrupting SB, highlight the importance of not just considering the overall time spent in SB but also the pattern by which it is accumulated.

To try and better understand the dose-response relationship between SB and health, research has investigated the effect of breaks of varying modality and duration. Buckley et al. (2013) compared office workers on two days, one spent sitting and one spent standing. When standing compared to sitting, postprandial glucose levels were attenuated by 43%. Standing compared to sitting increased energy expenditure by 174 Kcal, equating to a significant difference of 0.83 Kcal per minute. Accelerometer counts were similar on both days, suggesting the observed increases were due to standing and not from performing additional PA. Replacing periods of workplace SB with standing may therefore offer a method by which metabolic health can be improved. For example, two-minute walking breaks, every twenty minutes, led to significant reductions in postprandial glucose and serum insulin levels, in overweight/obese adults (Dunstan et al., 2012b). The reductions were said to be at least comparable with those observed during an acute bout of MVPA, suggesting brief interruptions of at least LIPA can attenuate the acute postprandial glucose and insulin level increases associated with SB. These breaks were of short duration (two minutes) and would not have counted towards aerobic activity guidelines. This suggests that PA which would currently count towards guidelines may not be required to improve metabolic function and highlights how these guidelines may not currently be sufficient. Swartz et al (2011) showed that interrupting a thirty-minute bout of SB using one, two or five-minute walking breaks, at a self-selected pace, resulted in a significant increase in energy expenditure compared to remaining sedentary. This suggests if an individual interrupted their SB once per hour, with a one, two or five-minute self-paced walk over an 8-hour day, they would expend an additional 24, 59 or 132 Kcal respectively. These small changes could have large implications in assisting in the maintenance of weight control or weight loss (Swartz et al., 2011).

In healthy normal weight adults, the effect of a continuous PA bout (30 minutes) or a regular activity break (1m40s per hour), was compared over a nine-hour period (Peddie et al., 2013). The regular activity breaks were more effective in reducing postprandial glycaemia and insulinaemia. It was suggested this was due to increased carbohydrate oxidation ratio and clearance of glucose from the blood stream, due to the maintenance of type 4 glucose transporters, increasing muscle glucose uptake. This suggests small but frequent bouts of PA used to interrupt SB, may be more beneficial to metabolic health than one prolonged period of activity. Standing and walking interventions may therefore provide a simple but effective mode by which SB can be broken up. Interrupting sitting with two minutes of standing or walking, every twenty minutes, was compared in healthy adults (Bailey and Locke, 2015). There was a significant reduction in postprandial glycaemia (16%) when interrupting sitting with walking but not when interrupting with standing. Standing, therefore, may not be of sufficient intensity to provide metabolic health benefits, when used in short durations. In individuals with type 2 diabetes, sitting was interrupted every 30 minutes, for 3 minutes, with light intensity walking or simple resistance activities (half squats, calf raises, knee raises) (Grace et al., 2017). The use of these regular activity interruptions, to interrupt SB, appear to promote the reduction of post prandial pro-inflammatory lipids and increase concentrations of lipids with antioxidant capacity. Interrupting SB with short bouts of LIPA may therefore provide an effective method by which metabolic health can be improved within the workplace. Energy expenditure and heart rate responses were compared when interrupting sitting with two minutes of standing, walking or a set of calisthenics exercises (Carter et al., 2015). Calisthenics exercises provided a greater total energy expenditure and heart rate response compared to standing or walking. Calisthenics may therefore offer a more efficient method by which SB can be broken up within the workplace, providing beneficial cardiometabolic changes, while requiring little space and no equipment to perform.

There has been less research investigating the vascular responses that occur in response to breaking up prolonged SB. Endothelial function was examined in response to three hours of uninterrupted sitting and breaking up this sitting period at hourly intervals, with five minutes of walking (Thosar et al., 2014a). Femoral artery shear rate and FMD were significantly impaired in response to the three hours of continuous sitting, when this period was interrupted with walking, the decline in FMD was prevented. Interrupting prolonged sitting with short bouts of walking was able to negate the declines observed in endothelial function. Using two minutes of calisthenics to break up prolonged sitting, at 20 minute intervals, increased brachial artery SR and FMD (Carter and Gladwell, 2016). The increase was significant following the third set of calisthenics, suggesting there may be an accumulative effect of exercise. Twenty minutes post intervention levels returned to baseline; breaks in SB may need to be frequent to continue providing improvements to vascular function. This provides further support to how calisthenics may be an effective mode by which SB can be interrupted, providing important cardiovascular health benefits.

Most of the research investigating the effect of breaking up SB has focused on cardiometabolic health and there has been less research which has considered other outcomes of optimal health and fitness. Prolonged SB often exposes the legs to large periods of inactivity and this reduces muscle activity. Electromyography (EMG) was measured in the quadriceps and hamstrings under free living conditions (Tikkanen et al., 2013). On average during daily life the locomotor muscles are inactive for 7.5 hours per day and only a fraction (4%) of the muscles maximum capacity is used. Standing considerably increases muscle capacity compared to sitting and stair climbing increases muscle activity more than brisk walking. More frequent interruption of SB may therefore increase muscle activity, especially in the lower extremities, this may improve muscular function and provide associated health benefits; more research is required.

Breaks in SB were significantly associated with improved physical capability in older adults, after adjusting for total ST and MVPA (Sardinha et al., 2015). Similarly breaks independent of total ST and MVPA, were associated with lower extremity function in older adults (Davis et al., 2014). This suggests more frequent interruption of SB may enhance physical capability without the need to reduce overall ST. Conversely in older men but not women, lower leg power and muscle quality was said to be increased in the more sedentary individuals, who interrupted SB less frequently (Chastin et al., 2012). It was suggested this may be due to these individuals being highly active and walking over an hour per day, where additional body fat associated with increased SB, acted as training stimulus for the lower extremities. Research is needed to determine if interrupting SB may provide improvements to physical capability in younger adults. This could assist in improving overall health, reduce the risk for associated disease and mortality and improve QoL.

2.6 Patterns of Physical Activity, Sedentary Behaviour and Health

Subjective and objective measurements have been used to examine how patterns of free living SB and PA combine, to influence health. The free living behaviour of young adults meeting current PA guidelines, was objectively monitored for seven days (Lyden et al., 2015). The participants were requested to remain as sedentary as possible, which resulted in a significant reduction in insulin activity. This decrease was associated with less time spent in LIPA and more time spent in prolonged sedentary bouts (>30 mins). Metabolic function appears to decline due to the reduced LIPA, therefore using LIPA to break up SB may offer important metabolic health benefits. Objectively monitoring free-living in individuals at risk of diabetes, it was determined that time in SB may be a more important indicator of cardiometabolic health than time in MVPA (Henson et al., 2013). Increasing breaks in SB was associated with improved weight maintenance and therefore interventions should encourage individuals to sit less and move more regardless of the intensity of activity. A large cross-sectional analysis was conducted, investigating associations between objectively measured patterns of SB, glucose metabolism and metabolic syndrome (Van Der Berg et al., 2016). Each extra hour of SB was associated with a 22% increased risk for diabetes and 39% increased risk for metabolic syndrome, independent of time spent in high intensity PA. This indicates how reducing time in SB may play a vital public health role in the development and prevention of Type 2 Diabetes, even in individuals conducting high intensity PA. Replacing SB with LIPA, which currently does not contribute towards PA guidelines, may be an effective intervention for improving cardiometabolic health.

Several studies have examined objectively measured SB and PA activity data from the US NHANES, to determine possible associations with health and mortality. Independent of MVPA participants aged over 50 in the highest quartile of SB, were said to have a five times greater risk of death compared to those in the lowest quartile. MVPA was also associated with a reduced risk for mortality, highlighting the importance of promoting both reduced SB and participation in MVPA, to reduce the risk for all-cause mortality (Koster et al., 2012, Schmid et al., 2015). It was not possible to determine if greater time in MVPA was able to compensate for the increased all-cause mortality risk associated with SB and this requires further investigation (Schmid et al., 2015). Examining with a longer follow-up of five to seven years a greater total volume of PA was associated with reduced mortality; independent of MVPA a greater amount of LIPA was also associated with reduced mortality (Fishman et al., 2016). Using theoretical models, it was predicted that replacing SB with LIPA and MVPA reduced the risk for mortality, the reduction being greater for MVPA. It may be easier and more practical to get individuals to replace periods of SB with LIPA instead of MVPA, while still offering a reduced risk for all-cause mortality. Interventions to reduce SB may therefore be more successful if they target increasing LIPA, which may be easier to incorporate into normal daily living and working environments.

In contrast, it has been suggested (using NHANES data) there were only weak associations between SB and cardiometabolic health after adjusting for MVPA. (Maher et al., 2014). When adjusting for total PA the associations were said to disappear, except for those with C-reactive protein. It was suggested associations seen in previous research may be due to residual confounding and the crude ability of accelerometry to measure PA. Further research is required using other cross-sectional data sets and other research designs to support these findings; to determine if overall activity levels are the underlying factor or if SB does expose individuals to negative health effects, independent of PA. Understanding this relationship is very important when determining if health guidelines need to advise people to sit less or conduct more activity overall or both should be equally advised.

Activity patterns were objectively monitored during a twelve-week intervention with inactive over 60s, to compare being more active against sitting less (Barone Gibbs et al., 2016). The more active group increased their time in MVPA without decreasing time in SB. The group who sat less did not increase their objectively measured MVPA but subjectively it increased. Measures of physical function and QoL were only improved for the group who sat less. This suggests that the sitting less was more effective at improving physical function than conducting more PA, important for consideration when designing interventions to reduce SB.

Using activity monitors research has attempted to categorise individuals based on if they are meeting PA guidelines and additionally the amount of time they spend conducting SB, under free living conditions. English adults who met PA guidelines, while still reporting high levels of SB, had a favorable cardiometabolic profile compared to those who did not meet PA guidelines (Bakrania et al., 2016). Individuals with lower levels of SB and lower PA, still had some associations with beneficial cholesterol levels, suggesting reducing SB despite remaining inactive, offered some benefits to health. Using the NHANES data set, a similar approach was used to group individuals based on their time spent in MVPA and the ratio between their LIPA and SB, to examine the risk for a ten-year atherosclerotic cardiovascular event (Loprinzi and Davis, 2015). Those who did not meet PA guidelines and spent more time in SB than LIPA, had the greatest increased risk. There was no difference in the risk for both groups who met PA guidelines, suggesting the amount of SB and LIPA they conducted was less important, if completing more higher intensity PA. Research is required to determine if enough MVPA can counteract the potential consequences of an imbalance in the ratio between LIPA and SB. Using more accurate objective measures, it may be possible to better understand the pooled relationship between SB and PA and how this impacts health.

2.7 Workplace Activity Levels

The modern chair based office provides an environment which fosters sitting and may provide a prime location for interventions aimed at reducing SB (Levine, 2015). To determine where interventions may be most effective it is of interest to consider different work environments and their activity levels. SB and PA were objectively measured in Australian office, customer service and call centre employees. ST comprised more than three quarters (77%) of this time, with around half of this spent in prolonged bouts (>20 mins) (Thorp et al., 2012). Work hours were consistently more sedentary and involved less LIPA than non-work hours. Call centre employees were the most sedentary and least active during work hours and spent more time in prolonged sedentary bouts. In contrast customer service employees had the lowest levels of prolonged ST. This likely reflects the available opportunities to interrupt SB under the different work settings; interventions may be most effective if targeted at workplaces of extreme SB.

Office workers in Perth were also shown to spend almost 82% of their time sedentary, during work hours. Those who were more sedentary during work, were also more sedentary and conducted less LIPA outside of work (Parry and Straker, 2013, Clemes et al., 2014) Office workers in the United Kingdom were shown to spend 71% of working hours being sedentary. Given this major contribution to daily SB, it was suggested there is an urgent need for workplace interventions to reduce this. The inverse relationship observed between SB and LIPA further supports how breaks of LIPA could be effective in reducing workplace SB (Clemes et al., 2014). Office based workers in England were monitored to measure the time they spent sitting, standing and stepping (Smith et al., 2015). Total sitting and standing time and step counts were similar across weekdays and weekends. The highest PA levels on workdays were shown to be between 7-9am, 12-14pm and 17-19pm; these individuals were still extremely sedentary sitting for over 10 hours a day. This likely reflects activity conducted during commutes and lunch breaks, interventions aimed at reducing workplace SB, may therefore be most effective if implemented during work hours associated with periods of low activity.

In contrast bus drivers were shown to spend less time sedentary and more time conducting LIPA, during work hours compared to non-work hours (Wong et al., 2014). This challenges the idea that occupations characterized by sedentary tasks automatically preclude movement opportunities. The Australian transport company involved in this study were highly proactive in their approach to providing workplace PA opportunities, potentially explaining the reduced SB seen during work hours. Further research is required across different sedentary work environments with different populations, to identify the most optimal times and locations to target with interventions aimed at reducing occupational SB.

2.8 Workplace Interventions

The increasing evidence for associations between prolonged SB and detrimental health effects, mean it is of interest to consider current workplace interventions aimed at reducing SB and promoting activity. There is a need for cities and workplaces to adapt to enable people to become more upwardly mobile and improve health (Levine, 2015). One intervention that has received considerable interest is the use of sit to stand workstations (STSWs). A four-week intervention was conducted trialing STSWs (Pronk, 2012). Time spent sitting was reduced by 66 minutes per day, reduced upper back and neck pain by 54% and improved mood; two weeks post intervention these effects had been largely negated. Outcomes were self-reported and there was an imbalance between participant numbers in the control and intervention groups; further research is required using objective measures to support these findings. When activity was objectively measured STSWs were shown to reduce sitting time by 33 min per day, a multi-component intervention reduced this by 89 min per day (Neuhaus et al., 2014b). The multi component intervention included management consultation, staff education, email reminders and coaching. Interventions may therefore be more effective if supported with components aimed at behavioural change. In overweight/obese adults STSWs were used to transition between standing and sitting at 30-minute intervals in a simulated work environment (Thorp et al., 2014). Compared to sitting, standing significantly reduced fatigue levels and lower back discomfort, while maintaining productivity. Research is required to determine if prolonged use of STSWs promotes concentration and productivity. Associations were examined between long term use of STSWs (>6 months) and patterns of activity and cardiometabolic health (Carr et al., 2016b). STSWs were associated with a significant reduction in ST and increases in standing time at work. Significant inverse associations were found between workplace PA and markers for cardiometabolic risk, supporting the importance of increasing PA levels during work hours. Research is required to investigate the long-term use of STSWs and the effect on clinically significant health outcomes.

Seated activity permissive workstations (APWs) provide another mode by which SB can be reduced and PA increased within the workplace. These activity workstations allow individuals to remain in a normal working position, while conducting LIPA, such as cycling at desk. Significant associations were observed between seated APWs and improved cardiometabolic biomarkers and work productivity (Carr et al., 2016a). A meta-analysis concluded APWs lead to substantial reductions in SB without having a negative impact upon work productivity (Neuhaus et al., 2014b). Larger scale long term randomized controlled trials are required to determine if reductions in SB and the impact upon health related and work-based outcomes is sustainable.

Research is needed to trial more cost effective and scalable interventions, that are effective at reducing workplace SB, increasing PA and providing clinically meaningful health benefits. Interventions should be designed to test solutions without the need to first demonstrate the underlying problem. These should not be limited to cardiometabolic health outcomes and need to consider musculoskeletal, physiological function and QoL related measures (Manini et al., 2015).

2.9 Conclusion

Prolonged SB has been identified as a risk factor for chronic disease and increased all-cause mortality. Research into the underlying causes has identified prolonged SB as being detrimental to cardiovascular and metabolic health. There is a lack of research that has investigated how other components of optimal health and fitness may be associated with SB. Too much time spent in SB and too little spent in MVPA have been identified as separate and distinct risk factors for chronic disease. Research should therefore not consider SB in isolation but along with the combined effects of all intensities of PA. Interrupting prolonged periods of SB, independent of the total ST has been shown to be beneficial for health. It therefore appears there is an accumulative effect to interrupting SB, where breaks need to be frequent to continue providing benefits to health. Monitoring free-living activity patterns research can consider the pooled relationship between SB and PA and the effect this has upon health. More research is required to determine if overall PA levels are more important or if SB is the underlying factor exposing individuals to negative health effects. This is vital to assist in better informing public health guidelines and workplace practices, regarding the amount of time that should be spent being sedentary. The modern desk based workplace provides an environment where individuals are exposed to extreme periods of sedentary behaviour. More research is required across different work settings and populations, to determine where best to target interventions aimed at reducing this. Interventions aimed at altering posture and increasing activity levels within the workplace have been shown to be successful at reducing the amount of time spent in prolonged sedentary periods. There is a need for cost effective interventions which can be applied on a large scale, to promote less time being sedentary and more time being active within the workplace, to improve health and QoL.

2.10 Research Questions

The review of the literature led to the following research questions:

1. Is sedentary behaviour associated with physical capability, in younger adults?
2. Does a calisthenics workplace exercise intervention improve the physical capability of younger adults, who work in a predominately sedentary occupation?

3.0 Chapter 3: Sedentary Behaviour and Physical Capability

3.1 Abstract

Background: Physical capability (PC) is important for conducting tasks of daily living and is associated with improved quality of life, in older populations. Detecting reductions in PC in younger adults, may highlight those at risk for future adverse health outcomes. Research into associations between PC and sedentary behaviour (SB) is limited and has been confined to older populations. The purpose of this research was to investigate associations between PC and SB, in adults below retirement age, working in a sedentary occupation.

Methods: Forty-two healthy adult volunteers (19 male), wore an accelerometer to assess their SB over a six-day period. Physical capability was assessed using balance, grip strength and walk speed tests. Regression analyses were run to determine if time spent in overall daily or workplace SB, was associated with PC; the effect of prolonged periods of SB was also considered.

Results: Overall daily and prolonged daily SB were independently associated ($p<0.05$) with balance in males but not females ($p>0.05$). For males, overall daily SB explained 40% and prolonged SB 42% of the variance in balance scores. There were no independent associations ($p>0.05$) between workplace SB and balance. Grip strength and walk speed were not independently associated ($p>0.05$) with any measures of SB.

Conclusions: Spending more time in SB was associated with impairing the balance of males, which may be due to inactivity during leisure time. Grip strength and fast walk speed were not associated with time spent in SB, however, they were already reduced in all individuals, compared to population norms. Together these findings may highlight how working in an extremely sedentary environment, is impairing physical capability. Providing more opportunities to reduce SB and increase PA, may assist in improving PC in younger adults, who work in sedentary occupations.

3.2 Introduction

3.2.1 Sedentary Behaviour

As discussed in section 2.1 & 2.2, the amount of time people are spending sedentary has increased, leading to the concern that this is having a negative impact upon health. Prolonged SB has been identified as a risk factor for obesity, diabetes, cardiovascular disease, cancer and all-cause mortality (Ekblom-Bak et al., 2010, Owen et al., 2010b, Wilmot et al., 2012, Levine, 2015). SB is defined as any waking behaviour requiring an energy expenditure of less than 1.5 METs, conducted while in a sitting or reclining posture (Sedentary Behaviour Research, 2012). The increase seen in SB is due to changes in transportation and more time spent conducting screen based activities (Owen et al., 2010a). The modern workplace provides an environment which fosters sitting, aimed at increasing productivity, reducing the opportunities for movement. High sedentary work environments such as desk based office occupations, may be exposing individuals to increased health risks associated with prolonged SB. Research is required to better understand the underlying physiological mechanisms and dose-response relationships associated with SB. This would enable public health guidelines to provide more specific information regarding how individuals should accumulate their SB.

3.2.2 Workplace Activity Levels

In section 2.7 activity levels within different work environments were discussed in more detail. Research has reported that office workers spend between 71-82% of their time sedentary during work hours (Thorp et al., 2012, Parry and Straker, 2013, Clemes et al., 2014). In Australian call centre employees, half of this ST was accumulated in prolonged periods (>20 minutes) (Thorp et al., 2012). Sedentary occupations therefore expose individuals to extremely high amounts of ST, this may be leading individuals in these occupations, to be at an increased risk for adverse health outcomes. Research is needed to further investigate sedentary behaviour within the workplace and the possible detrimental effect this may pose for health. Individuals who are more sedentary at work, have also been shown to be more sedentary during leisure time (Clemes et al., 2014). This suggests there may be a knock-on effect in response to workplace SB, causing individuals to engage in additional sedentary behaviours outside of work hours, further increasing the risk to their health.

3.2.3 Sedentary Behaviour and Cardiometabolic Outcomes

Most research into the detrimental health associations of SB has been conducted into cardiometabolic outcomes, as heart attacks and strokes are the leading causes of mortality within the western world (see section 2.2). Exposing healthy individuals to SB using bed rest, was associated with insulin resistance, dyslipidaemia, increased blood pressure and impaired microvascular function (Hamburg et al., 2007). Less extreme SB has also been shown to be associated with detrimental cardiovascular responses. Following five days of reduced step count, endothelial function was reduced in the popliteal artery (Boyle et al., 2013). In response to three hours of prolonged sitting, vascular function was also shown to be impaired in the femoral and brachial arteries (Thosar et al., 2014b). Highlighting how negative effects in response to prolonged SB, are not just confined the limbs exposed to periods of inactivity.

The pattern by which SB is accumulated may also be very important when considering how it affects health (see section 2.5). Beneficial associations have been shown between breaks in SB and adiposity, lipids, BMI and waist circumference (Healy et al., 2008a). Analysis of a large multi-ethnic population sample revealed independent of total SB, breaks were positively associated with cardiometabolic health outcomes (Healy et al., 2011). This suggests that breaking up prolonged periods of SB may be of importance, when trying to avoid detrimental cardiometabolic associations with prolonged inactivity. Sedentary work environments may be exposing individuals to even greater risk, due to requiring prolonged periods of inactivity, without providing opportunities for interruption. Research should further investigate if prolonged periods of inactivity in the workplace are associated with negative health outcomes.

3.2.4 Sedentary Behaviour and Physical Capability

There has been less research investigating other components of health and fitness that may be negatively affected in response to SB (see section 2.3). Physical capability relates to an individual's ability to conduct the physical tasks of daily living and is comprised of components such as strength, agility, flexibility and balance (Kuh and New Dynamics of Ageing Preparatory, 2007). Research in older populations has investigated associations between physical capability and health, due to the affect this has upon quality of life. A meta-analysis of older community dwelling adults, found mortality was associated with grip strength, balance, walk speed and chair rise time (Cooper et al., 2010). Associations between grip strength and mortality were even found in individuals aged under 60 years; it was suggested a 1kg reduction in grip strength was associated with 3% increased mortality. In British adults (average age of 61 years), walk speed was associated with increased risk for cardiovascular disease, cancer and mortality (Elbaz et al., 2013). In adults aged 53-66 years, reduced physical capability was associated with increased mortality (Cooper et al., 2014). It was suggested that balance may be more strongly associated with mortality, than the other components of physical capability, measured in this population. This suggests it may be possible to detect impairments in physical capabilities in adults below retirement age, where reductions may increase the risk for disease and mortality. The ability to detect and maintain physical capability as adults age may facilitate more healthy ageing and improve quality of life. Grip strength, balance and walk speed tests may provide easy, inexpensive and quick measures, associated with mortality, which can be used to assess the physical capability in younger adult populations.

Current research (see section 2.3) investigating associations between SB and measures of physical capability is limited, with the current work being confined to older populations. Associations were investigated between the television viewing time of older adults and grip strength and walk speed (Keevil et al., 2015). Less television viewing time was associated with walking at a faster usual pace; there were no strong associations between handgrip strength and television viewing time. Muscular strength reductions due to SB may be reflected better in the legs, where the muscles are exposed to periods of inactivity. More research is required to investigate associations between SB and outcomes of physical capability. If SB does have a detrimental effect on physical capability, it may be possible to detect these declines and identify individuals before they are possibly at risk for more adverse health outcomes.

Aims of Research

The workplace exposes individuals to large periods of inactivity, investigating associations during this period will provide more understanding into how workplace SB may be impairing physical capability.

The current study aimed to investigate if there were associations between SB and components of physical capability, in younger adults, below retirement age. The effect of prolonged periods of SB were also investigated, to determine if breaking up periods of prolonged inactivity may be important for physical capability, as has been shown with cardiometabolic outcomes.

3.2.4.i Research Questions

1. Is time spent in SB associated with components of physical capability?
    a. Balance
    b. Handgrip strength
    c. Walk speed
2. Is time spent in prolonged SB associated with components of physical capability?
3. Is time spent sedentary within the workplace associated with physical capability?

3.3 Methods

3.3.1 Participants

Participants were forty-two informed and consenting healthy adult volunteers, who worked in an occupation which required them to spend large periods of time sitting. Ethical approval to perform the research was granted by the University of Essex ethics committee and conformed to the declaration of Helsinki. Twenty-four participants were recruited from an engineering consultancy firm in Ipswich and participated in the research during January 2016. Nine participants were recruited from the University of Essex, comprised of employees and research students, who participated between May-July 2016. Nine participants were recruited from a local council call centre and were recruited and participated during September 2016. Demographic statistics of age, stature, mass and BMI, for males and females, are presented in Table 3-1.

Table 3-1. Demographic statistics (Mean ±SD) for males and females

	n	Age (years)	Stature (m)	Mass (kg)	Body Mass Index ($kg.m^2$)
Male	19	38.6 ±11.7	1.73 ±0.10	83.6 ±16.6	28.0 ±4.5
Female	23	43.3 ±12.6	1.65 ±0.10	69.3 ±12.8	25.7 ±5.6

3.3.2 Study Protocol

Participants completed written informed consent and completed a Par-Q General Health Questionnaire prior to participation in the research. Participants were provided with an accelerometer and requested to wear this during all waking hours; they were instructed to remove the device to conduct water based activities (e.g. bathing / swimming). The device was worn for a six-day period, positioned on the right hip and attached by a waist band. A log book was provided to record the time the device was attached and removed each day, along with any other periods of non-wear (see 7.1). On the seventh day of participation, participants attended a short testing session to assess outcomes of physical capability in the following order: 1. Handgrip strength 2. Dynamic balance 3. Walk speed. A diagram of the experimental protocol used is provided in Figure 3-1.

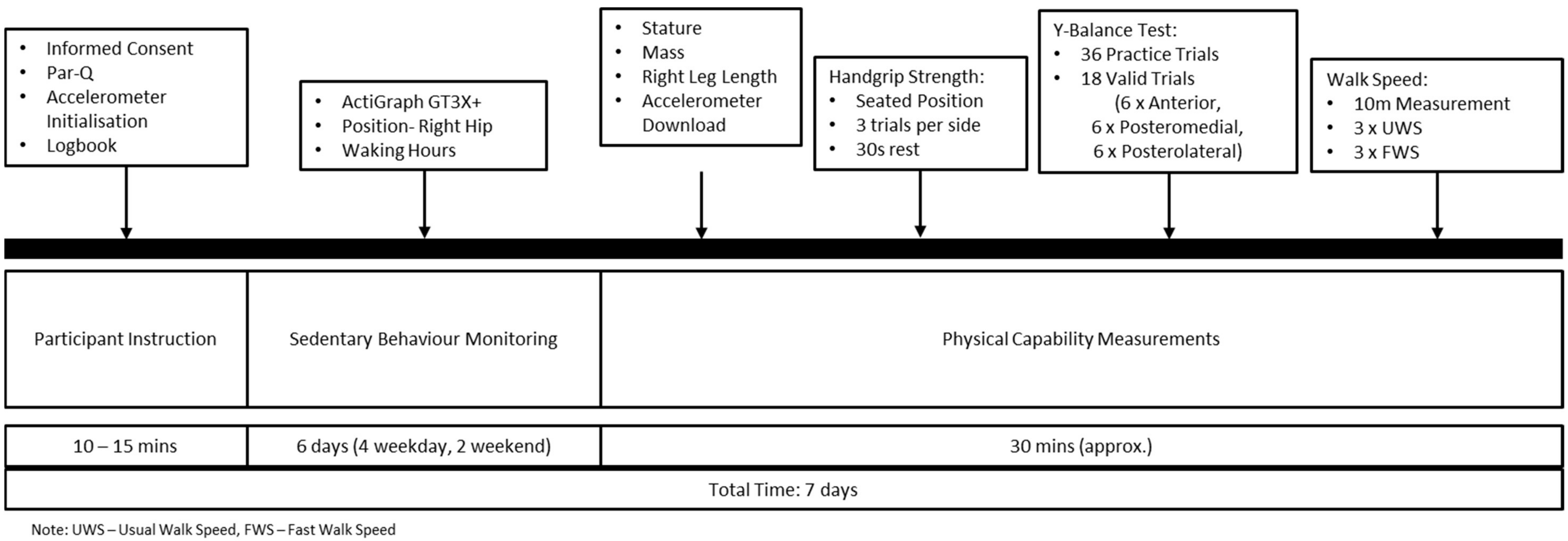


Figure 3-1. Seven-day experimental protocol to monitor sedentary behaviour and assess physical capability

3.3.3 Physical Capability Measures

3.3.3.i Handgrip strength

Handgrip strength was assessed using a dynamometer (TK5001, Takai & Co Ltd, Tokyo, Japan). The handgrip measurement protocol was performed as suggested for a standardised approach (Roberts et al., 2011). Three measures were completed with each hand; a 30 second rest period was taken between trials. Participants were encouraged to give maximal effort on each attempt. Handgrip strength was recorded to the nearest 0.5kg. Handgrip was calculated absolute (kg) and relative to body mass ($kg.kg^{-1}$). A mean handgrip score was calculated using the maximum recorded attempt from the right and left hand trials.

3.3.3.ii Balance

Balance was assessed using the Y-balance testing kit (Functional Movement Systems, USA). Participants were provided with instruction on how to complete the test and allowed six practice trials on each leg, in each direction, to avoid learning effects as has been previously suggested (Plisky et al., 2006, Hertel et al., 2010). The test protocol was then conducted as previously discussed (Plisky et al., 2009). Three valid trials were obtained for each stance leg in each of the three reach directions, measured to the nearest 5 mm. Right limb length was measured whilst standing, from the most inferior distal surface of the anterior superior iliac spine, to the inferior distal surface of the medial malleolus. Y-balance anterior and composite scores relative to limb length, were calculated for each limb using the following equations:

Anterior (%) = (Anterior reach ÷ limb length) x 100

Composite (%) = (Sum of three reach directions ÷ 3 x limb length) x 100

A mean value was calculated for both anterior and composite reach, using the scores from both the left and right legs.

3.3.3.iii Walk Speed

Walk speed analysis was only conducted with the twenty-four participants who took part in Ipswich in January 2016. It was not possible to measure walk speed with the participants in other locations, due to limited space and adhering to onsite health and safety regulations. Walk speed was measured over 10m course, with timing gates placed 6m apart, with an additional 2m at the start and end, to allow for acceleration and deceleration. Timing gates (Brower, USA) measured time to the nearest 0.01s. Participants completed three trials at both a usual walk speed (UWS) and a fast walk speed (FWS). For UWS participants were instructed to walk at a comfortable pace which they considered normal. For FWS participants were instructed to walk at a brisk pace, as if they were trying to catch a bus, without being allowed to run. UWS and FWS were calculated for all trials ($m.s^{-1}$).

3.3.4 Accelerometer Assessed Sedentary behaviour

Accelerometer data was collected using an ActiGraph GT3X+ (ActiGraph, Pensacola, Florida, USA). The devices were initialised using Actilife v6 (ActiGraph, Pensacola, Florida, USA) and set to record at 30hz. Actilife was used to download raw data from the devices and integrated into 60 second epochs. Wear time was validated as previously recommended and non-wear time was removed from analysis (Choi et al., 2011). Wear time was checked against participant log books and corrected if wear time was falsely removed. For a day to be valid participants were required to wear the accelerometer for at least 10 hours, as has been previously suggested as being sufficient to represent a valid day (Troiano et al., 2008, Keadle et al., 2014). It has been suggested previously, at least 4-5 days of valid wear is required to accurately represent SB (Hart et al., 2011, Keadle et al., 2014). However, despite asking participants to wear accelerometers for 6 days, taking these two criteria into account, 3 days (two weekday & one weekend) of valid wear was used for analysis, which has been previously used in research into associations between SB and physical capability (Sardinha et al., 2015). Four participants did not meet these criteria and these data were excluded from analysis. ST was calculated using cut points of <100 activity counts per minute (CPM) from the vertical (y) axis (Sasaki et al., 2011). Sedentary behaviour was assessed using the following sedentary parameters, extracted from periods of valid wear time as follows:

1. Daily ST – Sum of all minutes, where activity counts <100 CPM.
2. Workplace ST – Sum of all minutes on weekdays between 9am-5pm, where activity counts <100 CPM.
3. Daily Prolonged ST – Sum of all prolonged sedentary bouts. A prolonged sedentary bout comprised of at least 15 minutes of consecutive epochs, where activity counts <100 CPM. It has been suggested prolonged periods of SB should be considered of at least 10 minutes to detect detrimental associations with prolonged sitting (Kim et al., 2015b). Previous research has also investigated prolonged SB using periods of >20 minutes and bouts of prolonged duration (>15 minutes) were suggested to lead to less inaccurate classification of SB (Lyden et al., 2015). These findings led to prolonged SB being considered in bouts of at least 15 minutes in duration.
4. Prolonged workplace ST – Sum of all prolonged sedentary bouts on weekdays between 9am-5pm.

Sedentary measures were regressed on wear time to account for differences in individual wear times, as previously described (Healy et al., 2011, Kim et al., 2015b). Sedentary parameters were calculated across valid days, and reported in mean hours per day. Mean bout duration was calculated for each of the sedentary parameters.

3.3.5 Accelerometer Assessed Physical Activity

Physical activity was assessed using cut points at previously described for MVPA (Sasaki et al., 2011). The following parameters of physical activity were extracted from valid periods of wear time as follows:

1. Daily MVPA – Sum of all minutes, where activity counts were between 2690–6166 CPM.

2. Workplace MVPA - Sum of all minutes on weekdays between 9am-5pm, where activity counts were between 2690–6166 CPM.

3.3.6 Data analysis

Statistical analysis was conducted using statistical software (SPSS v19, IBM Corporation, Somers, NY, USE), with an accepted significance level of $p<0.05$. Mean ± standard deviation (SD) were calculated for all data, for males and females and presented in tables and figures. All statistical analysis was conducted with data split by sex. Pearson's product-moment correlation coefficients were used to investigate associations between sedentary parameters. Preliminary analyses were conducted to ensure no violation of the assumptions of normality, linearity, multicollinearity, and homoscedasticity. Physical capability outcomes were standardised using z-scores to address skewness. Multiple hierarchical regression was used to assess if ST predicts components of physical capability, after controlling for demographic variables. Bivariate correlations were used to assess collinearity and associations between parameters of ST. Due to collinearity between daily ST and prolonged ST, it was not possible to add these to the same regression model and analysis was conducted separately. Visual examination of residual scatterplots was used to identify outliers. Due to an insufficient sample size, no regression analysis was conducted for the walk speed of females.

3.4 Results

3.4.1 Physical Capability

Physical capability outcomes for males and females, are presented in Table 3-2.

Table 3-2. Measures of physical capability for males and females (Mean ± SD)

	n	Y-Balance Composite Score (%)	Anterior Balance (%)	Handgrip Strength (kg)	Relative Handgrip ($kg.kg^{-1}$)	Usual Walk Speed ($m.s^{-1}$)	Fast Walk Speed ($m.s^{-1}$)
Male	19	88.6 ±8.9	65.5 ±7.3	47.3 ±8.3	0.586 ±0.141	1.56 ±0.27	1.99 ±0.27
Female	23	80.1 ±11.1	59.4 ±7.3	27.0 ±4.5	0.402 ±0.100	1.35 ±0.16	1.92 ±0.23

Note: For usual and fast walk speed n=24 (16 male, 8 female)

3.4.2 Sedentary Behaviour

Daily ST was 9.9 ± 0.7 hours.day^{-1} for males and 9.7 ± 0.7 hours.day^{-1} for females (Figure 3-2). Workplace ST was 6.1 ± 0.4 hours.day^{-1} for males and 6.0 ± 0.8 hours.day^{-1} for females, out of an 8-hour work day.

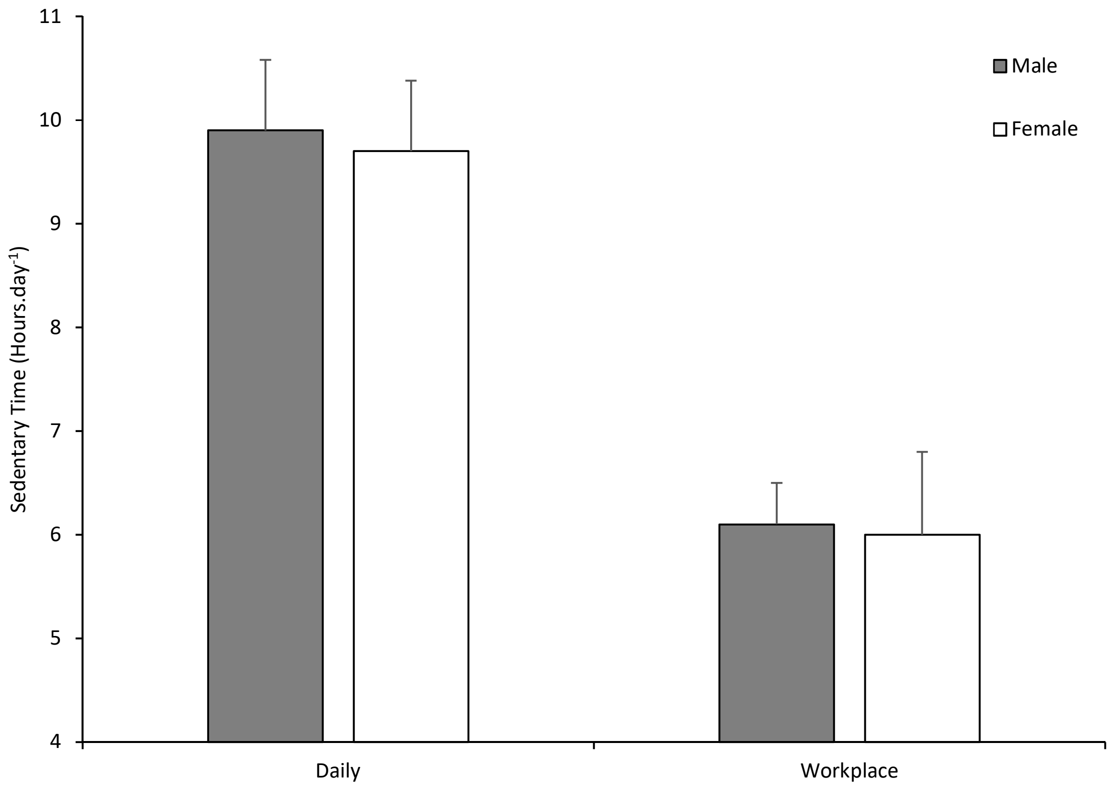


Figure 3-2. Daily and workplace sedentary time for males (n=19) and females (n=23) (Mean ± SD)

Daily prolonged (>15 minutes) ST was 5.8 ± 0.6 hours.day^{-1} for males and 5.7 ± 0.6 hours.day^{-1} for females (Figure 3-3). Workplace prolonged ST was 3.6 ± 1.1 hours.day^{-1} for males and 3.9 ± 1.5 hours.day^{-1} for females, out of an 8-hour work day.

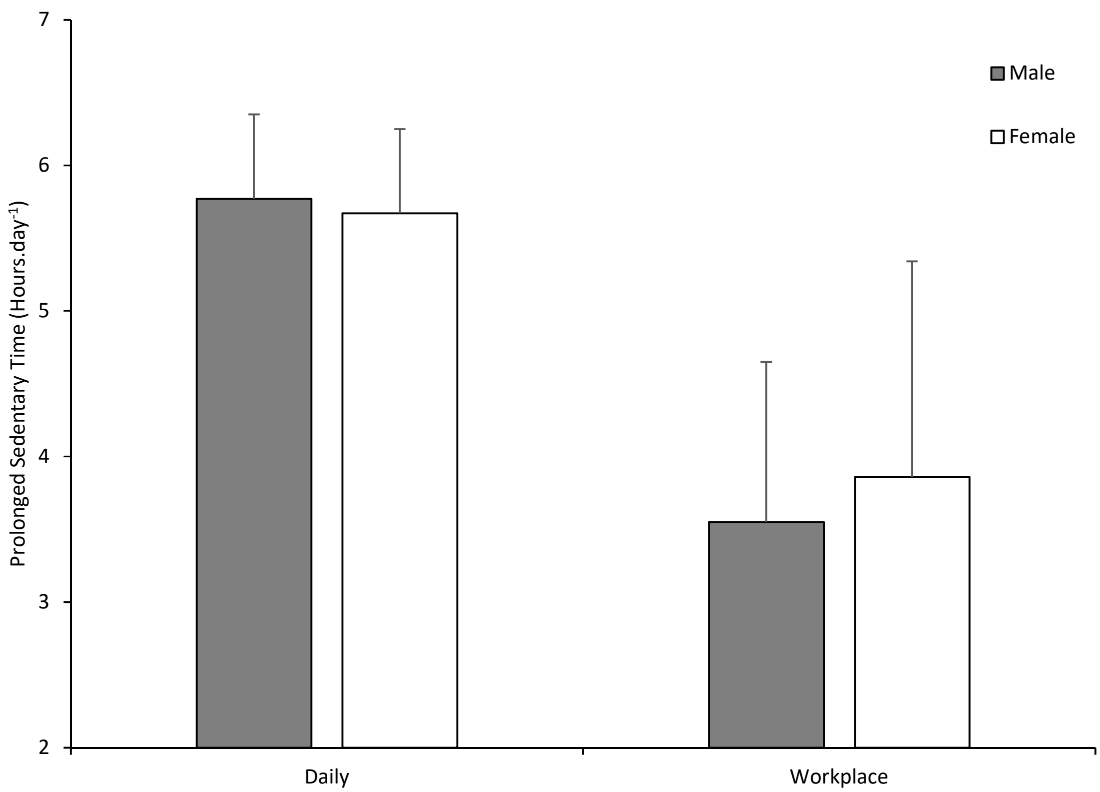


Figure 3-3. Daily and workplace prolonged (>15 minutes) sedentary time for males (n=19) and females (n=23) (Mean ± SD)

The average bout duration of SB during daily ST was 7.9 mins ± 2 for males and 7.8 mins ± 2.2 for females (Figure 3-4). The average bout duration of SB during workplace ST was 9.6 mins ± 3.3 for males and 10.5 mins ± 4.7 for females.

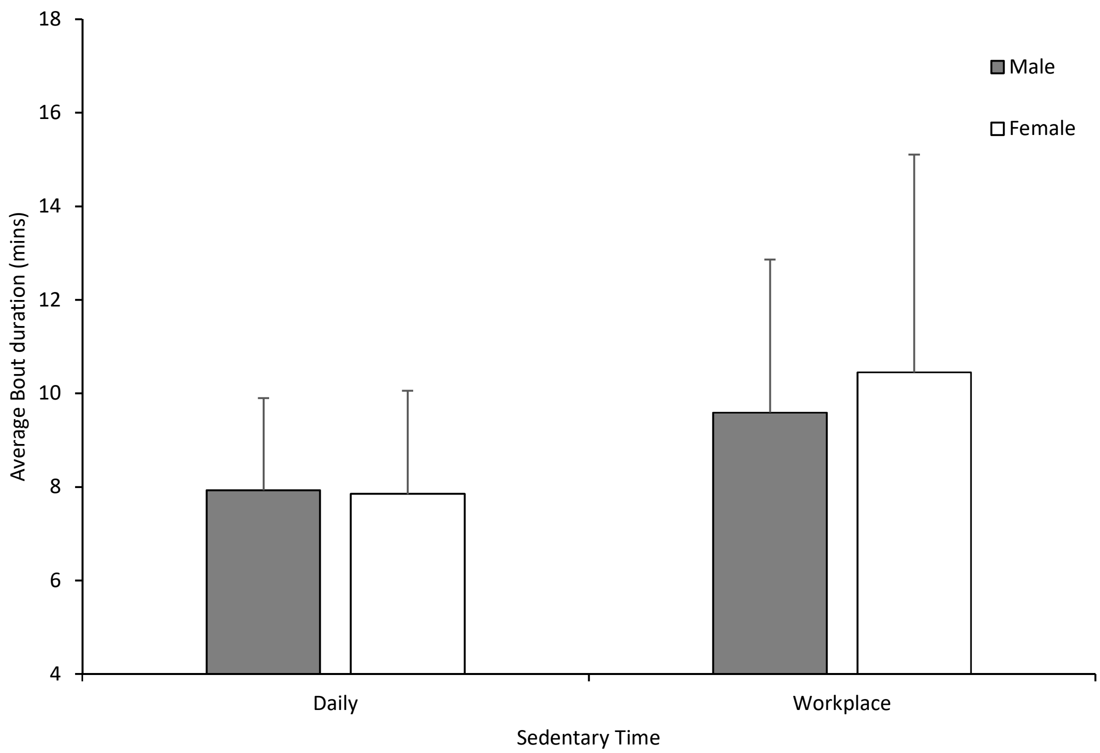


Figure 3-4. Average bout duration during daily and workplace sedentary time for males (n=19) and females (n=23) (Mean ± SD)

The average bout duration during daily prolonged ST was 29.2 mins ± 4.4 for males and 30.9 mins ± 4.5 for females (Figure 3-5). The average bout duration during prolonged workplace ST was 28 mins ± 5.7 for males and 31.6 mins ± 6.9 for females.

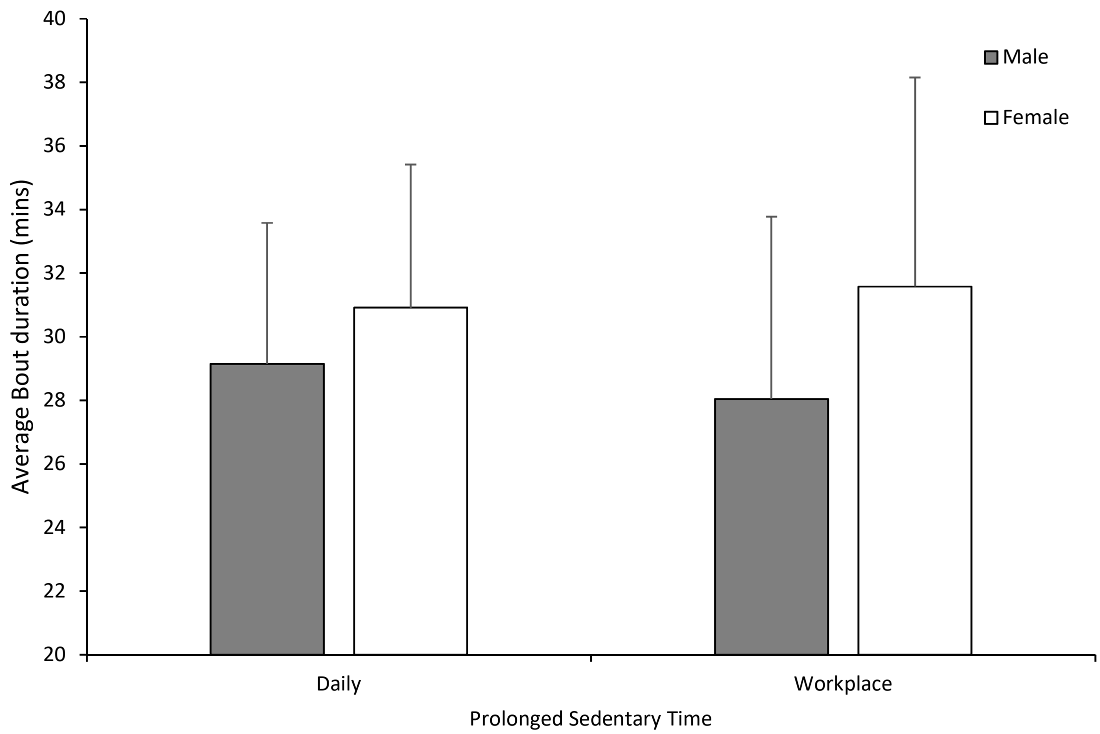


Figure 3-5. Average bout duration during daily and workplace prolonged (>15 minutes) sedentary time for males (n=19) and females (n-23) (Mean ± SD)

3.4.3 Sedentary Behaviour Associations

Bivariate correlations were used to investigate associations between parameters of sedentary behaviour; details of all correlations for males and females are provided in Table 3-3.

3.4.3.i Daily

Daily ST and daily prolonged ST were strongly and statistically correlated for males ($r = 0.996$, $p<0.001$) and for females ($r = 0.942$, $p<0.001$). Daily ST accounted for 99% of the variance in daily prolonged ST for males and 89% for females.

3.4.3.ii Workplace

Workplace ST and prolonged workplace ST were strongly and statistically correlated for males ($r = 0.768$, $p<0.001$) and for females ($r = 0.939$, $p<0.001$). Workplace ST accounted for 59% of the variance in prolonged workplace ST for males and 88% for females.

3.4.3.iii Daily vs Workplace

Daily ST was not statistically correlated with workplace ST for males ($r = 0.168$, $p>0.05$) or females ($r = 0.328$, $p>0.05$). Daily ST accounted for 3% of the variance in workplace ST for males and 11% for females. Daily prolonged ST was not statistically correlated with workplace prolonged ST for males ($r = -0.008$, $p>0.05$) or females ($r = 0.136$, $p>0.05$). Daily prolonged ST accounted for 0% of the variance in workplace prolonged ST for males and 2% for females.

Table 3-3. Bivariate correlations of measures of sedentary behaviour for males and females

	1	2	3	4
Male				
1. Daily Sedentary Time	-	0.168	0.996*	0.114
2. Workplace Sedentary Time		-	0.097	0.768*
3. Daily Prolonged Sedentary Time			-	-0.008
4. Prolonged Workplace Sedentary Time			-	-
Female				
1. Daily Sedentary Time	-	0.328	0.942*	0.293
2. Workplace Sedentary Time		-	0.228	0.939*
3. Daily Prolonged Sedentary Time			-	0.136
4. Prolonged Workplace Sedentary Time				-

***- p<0.05**

3.4.4 Moderate-to-Vigorous Physical Activity

Daily MVPA was 37.2 ± 15.5 $mins.day^{-1}$ for males and 34.7 ± 26.3 $mins.day^{-1}$ for females. Workplace MVPA was 18.2 ± 8.5 $mins.day^{-1}$ for males and 17.1 ± 16.7 $mins.day^{-1}$ for females, out of an 8-hour work day.

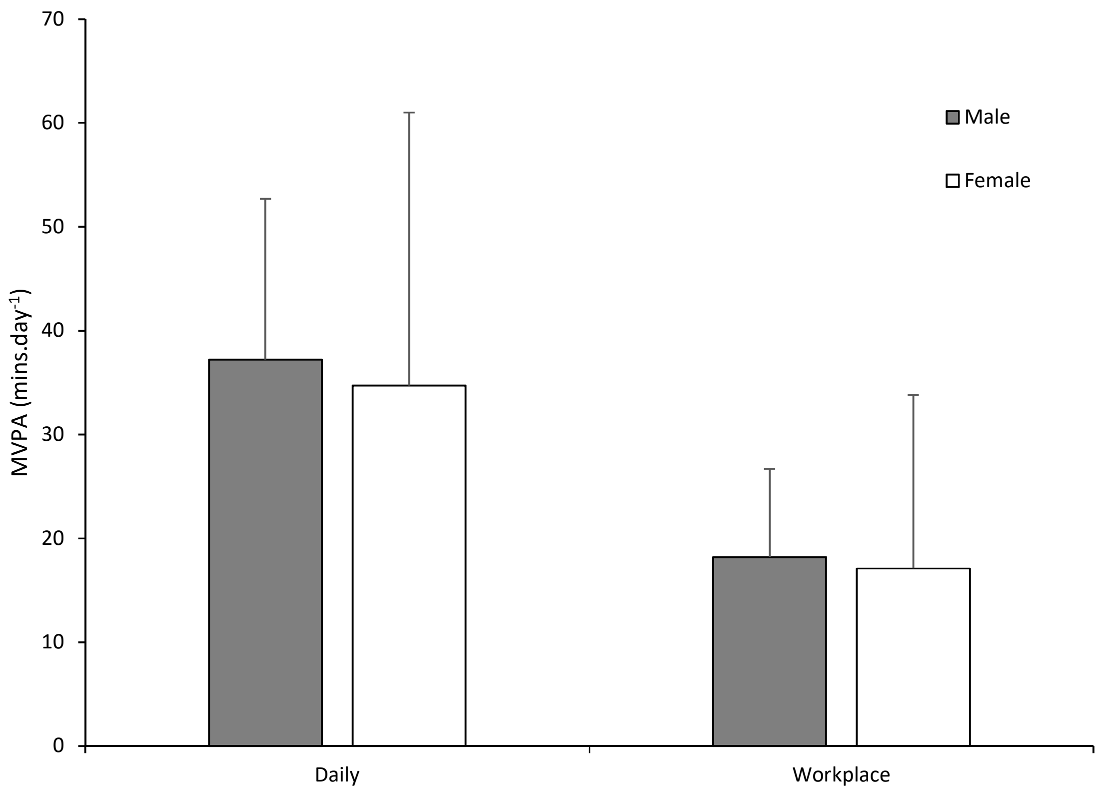


Figure 3-6. Daily and workplace moderate-to-vigorous physical activity (MVPA) for males (n=19) and females (n=23)

3.4.5 Sedentary Behaviour & Physical Capability

3.4.5.i Sedentary Time

Regression was undertaken to determine if daily and workplace ST predicted components of physical capability; see Table 3-4 for full details on each regression model.

Demographic variables explained 8% of the variance in composite balance for males and 20% for females. When daily and workplace ST were included, an additional 40% of the variance was explained for males and 4% for females. In the final model, daily ST was independently associated with composite balance for males (β = -0.98), accounting for 40% of the variance; reduced daily ST was associated with improved balance.

Demographic variables explained 32% for the variance in anterior balance for males and 21% for females. When daily and workplace ST were included, an additional 27% of the variance was explained for males and 6% for females. In the final model, daily ST was independently associated with anterior balance for males (β = -0.75), accounting for 25% of the variance; reduced daily ST was associated with improved balance.

Demographic variables explained 65% of the variance in handgrip strength for males and 55% for females. Including daily and workplace ST did not contribute further to the model for males or females.

Demographic variables explained 5% of the variance in usual walk speed for males. When daily and workplace ST were included, an additional 13% of the variance was explained.

Demographic variables explained 50% of the variance in fast walk speed for males. When daily and workplace ST were included, an additional 10% of the variance was explained.

Table 3-4. Hierarchical multiple regression models to predict balance, handgrip strength and walk speed from daily and workplace sedentary time (ST)

	Y-balance Composite *z*-score			**Y-Balance Anterior *z*-score**			**Handgrip *z*-score**			**Usual Walk Speed *z*-score**			**Fast Walk Speed *z*-score**		
	Total R^2	B	β	Total R^2	B	β	Total R^2	B	β	Total R^2	B	β	Total R^2	B	β
Male															
Step 2[a]	0.478			0.589*			0.650*			0.178			0.602		
Age (years)		0.020	0.355		0.012	0.157		-0.019	-0.233		0.031	0.480		-0.017	-0.272
Stature (cm)		0.066*	0.997*		0.064*	0.742*		-0.029	-0.321		0.021	0.300		0.032	0.465
Mass (kg)		-0.019	-0.494		-0.042*	-0.818*		-0.032*	-0.565*		-0.012	-0.231		-0.027	-0.554
Daily ST		-0.951*	-0.982*		-0.947*	-0.746*		0.005	0.003		-0.570	-0.489		-0.394	-0.351
Workplace ST		0.147	0.092		0.523	0.250		0.126	0.054		-0.046	-0.029		-0.243	-0.159
Female															
Step 2[a]	0.245			0.266			0.578*			-			-		
Age (years)		-0.030	-0.455		-0.037	-0.460		-0.014	-0.259		-	-		-	-
Stature (cm)		-0.012	-0.140		0.028	0.240		-0.004	-0.060		-	-		-	-
Mass (kg)		-0.008	-0.114		0.007	0.098		-0.034*	-0.659*		-	-		-	-
Daily ST		0.002	0.002		0.394	0.287		-0.170	-0.174		-	-		-	-
Workplace ST		-0.181	-0.175		-0.216	-0.185		0.062	0.074		-	-		-	-

Note: a: Demographic variables of age, stature and mass added in step 1, B = beta coefficients, β = standerdised beta coefficients, * $p<0.05$, Daily/Workplace ST (hours.day^{-1})

3.4.5.ii Prolonged Sedentary Time

Regression was undertaken to determine if daily and workplace prolonged ST predicted components of physical capability; see Table 3-5 for full details on each regression model.

Demographic variables explained 21% of the variance in composite balance for males and 20% for females. When daily and workplace prolonged ST were included, an additional 42% of the variance was explained for males but did not contribute further for females. In the final model, daily prolonged ST was independently associated with composite balance for males (β = -0.81), accounting for 42% of the variance; reduced daily prolonged ST was associated with improved balance.

Demographic variables explained 40% for the variance in anterior balance for males and 21% for females. When daily and workplace prolonged sedentary behaviour were included, an additional 23% of the variance was explained for males but did not contribute further for females. In the final model, daily prolonged ST was independently associated with anterior balance for males (β = -0.59), accounting for 23% of the variance; reduced daily prolonged ST was associated with improved balance.

Demographic variables explained 65% of the variance in handgrip strength for males and 55% for females. When daily and prolonged workplace ST were included, an additional 5% of the variance was explained for males and 3% for females.

Demographic variables explained 5% of the variance in usual walk speed for males. When daily and workplace prolonged ST were included, an additional 11% of the variance was explained.

Demographic variables explained 50% of the variance in fast walk speed for males. When daily and workplace prolonged ST were included, an additional 5% of the variance was explained.

Table 3-5. Hierarchical multiple regression models to predict balance, handgrip strength and walk speed from daily and workplace prolonged sedentary time (PST)

	Y-balance Composite *z*-score			**Y-Balance Anterior *z*-score**			**Handgrip *z*-score**			**Usual Walk Speed *z*-score**			**Fast Walk Speed *z*-score**		
	Total R^2	B	β	Total R^2	B	β	Total R^2	B	β	Total R^2	B	β	Total R^2	B	β
Male															
Step 2[a]	0.631*			0.627*			0.702*			0.160			0.578		
Age (years)		0.012	0.188		0.003	0.035		-0.014	-0.169		0.020	0.306		-0.020	-0.327
Stature (cm)		0.062*	0.851*		0.057	0.628*		-0.026	-0.286		0.013	0.184		0.028	0.404
Mass (kg)		-0.017	-0.391*		-0.038*	-0.681*		-0.036*	-0.633*		-0.008	-0.148		-0.027	-0.543
Daily PST		-1.038*	-0.808*		-0.940*	-0.587*		-0.103	-0.064		-0.318	-0.220		-0.395	-0.288
Workplace PST		-0.051	-0.076		0.027	0.032		0.204	0.240		-0.179	-0.279		-0.078	-0.125
Female															
Step 2[a]	0.248			0.198			0.585*			-			-		
Age (years)		-0.029	-0.439		-0.033	-0.446		-0.015	-0.288		-	-		-	-
Stature (cm)		-0.011	-0.136		0.003	0.030		-0.005	-0.078		-	-		-	-
Mass (kg)		-0.008	-0.125		0.002	0.021		-0.034*	-0.652*		-	-		-	-
Daily PST		-0.009	-0.006		0.142	0.088		-0.206	-0.178		-	-		-	-
Workplace PST		-0.104	-0.183		0.028	0.045		0.033	0.073		-	-		-	-

Note: a: Demographic variables of age, stature and mass added in step 1, B = beta coefficients, β = standerdised beta coefficients, * p<0.05, Daily/Workplace PST (hours.day^{-1})

3.5 Discussion

The major findings of this study are that in extremely sedentary office workers, time spent in SB is associated with independently impairing the balance of males but not females. SB was not associated with grip strength and walk speed; however, all individuals appear to be weaker and walk slower compared to UK norms. This may provide support to how sedentary occupations are impairing the physical capability of these individuals.

3.5.1 Sedentary Behaviour

Participants in this study spent almost ten hours per day sedentary, with almost six hours of this in prolonged sedentary periods. Highlighting how the individuals who participated are extremely sedentary, spending a large proportion of their waking hours in SB. This amount of SB is similar to adults that were objectively measured in a national health survey (Nhs, 2008). Therefore, associations between SB and physical capability if present, would be expected to be observed in these individuals. During work hours, individuals were spending almost six hours sedentary per day, with almost 4 hours of this in prolonged periods of at least 15 minutes. Participants were therefore spending around 70-75% of their work hours inactive, which is similar to levels observed in other extremely sedentary occupations, such as customer call centres (Thorp et al., 2012).

Interestingly and unexpectedly in these individuals, those who were more sedentary at work were not more sedentary during leisure hours. This is in contrast to previous research in UK office workers, where those more sedentary during work hours, were also reported to be more sedentary and conducted less PA outside of work time (Clemes et al., 2014). It was suggested this highlighted, how individuals who are more sedentary at work do not compensate and do more PA outside of work, so interventions to reduce SB should target both worktime and leisure periods. In this study, it appears some individuals who were highly sedentary during work hours, were not during leisure periods and may have been conducting PA to reduce this sedentary time.

Interventions addressing prolonged periods of inactivity during work hours, may assist in targeting periods when all individuals would benefit from reducing SB.

During overall daily SB, on average individuals were spending eight minutes in a sedentary bout, at work this was increasing to around 10 minutes a bout. During prolonged sedentary periods, the average sedentary bout was 30 minutes, during work hours the prolonged bout duration was similar.

3.5.2 Balance and Sedentary Behaviour

The first aim of this study was to investigate if balance is associated with time spent in SB. Total time spent in SB and prolonged SB, were both independently associated with composite and anterior balance, for males but not for females. These associations for males were strong, with total SB explaining 40% and prolonged SB explaining 42% of the variance in balance scores. For males, an extra hour per day spent sedentary was associated with a reduction in composite balance of 7% and a reduction in anterior balance of 6.6%. Similarly spending an extra hour per day in prolonged ST, was associated with a reduction in composite balance of 8.6% and anterior balance of 6.8%. In football players, an imbalance between limbs of 3.4% measured in the posteromedial direction, was associated with four times greater risk for injury (Gonell et al., 2015). In basketball players, an imbalance of 4.8% between limbs measured in the anterior direction, was associated a 2.5 times greater risk of injury (Plisky et al., 2006). Therefore, it appears spending more time in overall sedentary or prolonged sedentary behaviours, is associated with a meaningful detrimental balance reduction in males. There were strong statistically significant associations between the time individuals spent in sedentary and prolonged sedentary periods. Due to this collinearity, it was not possible to add these parameters into the same regression model, so it is not possible to determine if reducing SB or prolonged SB, is more strongly associated with the balance of males. Individuals who spent large amounts of time sedentary, were also spending large periods of time in prolonged SB. It would therefore be expected that associations between SB and balance, would also be observed between prolonged SB and balance. Research should investigate this further to determine if the overall amount of time spent sedentary or the amount SB is interrupted, is more strongly associated with balance ability. As previously discussed in relation to cardiometabolic outcomes (section 2.5), interrupting SB more frequently may be more important for health, independent of total sitting time.

Conversely, it is interesting that in females spending more time in overall sedentary or in prolonged sedentary periods, was associated with almost no change in composite or anterior balance. Work in older adults found associations between physical function and overall time spent SB, in men but not in women (Gennuso et al., 2016). This suggests that the way in which SB is impairing components of physical capability, may differ between the sexes. If there are sex specific differences in association between SB and balance, it may be that separate guidelines are required, regarding how SB should be accumulated. Research is needed to further investigate sex specific relationships and determine if independent recommendations are required.

Time spent sedentary or in prolonged sedentary periods during workplace hours was not associated with composite or anterior balance, in both males and females. This appears to suggest that the negative association observed in males, between overall SB and balance ability, was likely due to time spent sedentary outside of work hours. During workplace hours, the ability to reduce SB and conduct PA may be limited due to the constraints of the occupation. Outside of work hours those who are less sedentary, are likely replacing these sedentary periods by conducting PA. This may explain why less sedentary males were associated with increased balance, due to improvements attained from conducting additional PA, compared to those who are more sedentary. This additional PA was providing a training stimulus which was enabling balance to be maintained or even improved. This idea is supported by stronger associations recently found, where associations with physical capability were stronger for PA than SB, suggesting engaging in PA is important for maintaining physical capability (Van Der Velde et al., 2017). It is unexpected that this association was not be observed in females, as it would be expected they would also receive training benefits associated with conducting increased PA during leisure hours. There is also a need to better understand if the observed balance associations are in response to reduced SB or increased participation in leisure time PA; further research should investigate this.

3.5.3 Handgrip Strength and Sedentary Behaviour

Compared to published UK normative data, participants in this study had a reduced grip strength of 3kg relative to their age group; this was observed for both males and females (Dodds et al., 2014). It may be that even though no associations were found between sedentary parameters and grip strength, the sedentary occupation is reducing the grip strength of all individuals. If grip strength is already relatively lower in this population, it may not be possible to identify associated declines due to spending additional time in SB. The observed reduction in grip strength of 3kg likely represents a meaningful decline, as previous research suggested a 1kg reduction is associated with 3% increased mortality (Cooper et al., 2010). The grip strength of males in this population was between the 25th and 50th percentiles, with females lying around the 25th percentile of norms (Dodds et al., 2014). This suggests the females in this sample were weaker and may have lower fitness compared to the males.

The second aim of this study was to investigate if handgrip strength is associated with time spent in SB. Spending time in overall SB, workplace SB or in prolonged sedentary periods, was not associated with handgrip strength in males or females. This suggests that in these younger adults, spending an increased amount of time sedentary, was not associated with having a negative effect upon their grip strength. Although, as mentioned above, the grip strength of these individuals was already below the norm for the population. The only strong independent predictor of grip strength was mass, with heavier individuals associated with relatively weaker grip strength. These findings support previous research in older community dwelling adults, where television viewing time was not strongly associated with grip strength (Keevil et al., 2015). As previously discussed, SB exposes the musculature of the legs to large periods of inactivity. Reductions in strength due to SB may therefore not be detected in the upper body; research should investigate potential associations between muscular strength and SB in the legs. Desk based work often involves frequent use of the arms and this may attenuate declines in muscular strength in the upper body. Previous research found declines in vascular function in the legs, which were not also observed in the arms (Thosar et al., 2014b). Participants were allowed to use their arms during the seated trial, while the legs were kept immobile, which may explain why declines were not observed in the upper body. A similar affect could be occurring in seated occupations, where grip strength is maintained, due to arm movements conducted during desk based activities.

3.5.4 Walk Speed and Sedentary Behaviour

The third aim of this study was to investigate if time spent sedentary is associated with walk speed. Walk speed was not independently associated with SB or prolonged SB for males, both overall and during workplace hours. Time spent in overall daily SB and prolonged SB explained slightly more of the variance in walk speed, compared to time spent sedentary during workplace hours. As with balance, the weaker associations observed between walk speed and workplace SB, could be related to reducing ST with PA during leisure hours. Spending one additional hour per day sedentary was associated with a reduced usual walk speed of 0.15 $m.s^{-1}$ and fast walked speed of 0.08 $m.s^{-1}$. Spending one additional hour per day in prolonged sedentary periods was associated with slightly smaller reductions, 0.09 $m.s^{-1}$ in usual walk speed and 0.08 $m.s^{-1}$ in fast walk speed. These reductions are greater than significant negative associations observed in older community dwelling adults, where those who viewed the least television walked 0.04 $m.s^{-1}$ quicker at a fast pace, than those who viewed the most television (Keevil et al., 2015). It has been previously suggested in adults over 65 that a 0.1 $m.s^{-1}$ increase in walk speed is associated with an 8% reduction in mortality (Studenski et al., 2011). These observed declines, even though only weakly associated, may suggest SB is having a meaningful impact upon the health of younger adults, through reductions in walk speed. This would support additional research suggesting SB is negatively associated with walk performance, in older adults (Gennuso et al., 2016, Van Der Velde et al., 2017). More research with a larger sample size is required to further investigate associations with walk speed, in younger adult populations, in both males and females.

Compared to published normative values for healthy adults, males walked slightly faster (0.11 $m.s^{-1}$) and females slightly slower (0.04 $m.s^{-1}$), relative to the norm for their age (Bohannon and Williams Andrews, 2011). Both males (0.45 $m.s^{-1}$) and females (0.2 $m.s^{-1}$) walked at a slower fast pace than relative to the norm for their age (Bohannon, 1997). This suggests these individuals were considerably slower than the norm, when walking at a FWS. As with the reduced grip strength observed in these individuals, this may further support how SB may be impairing physical capability. More research is needed to investigate associations between walk speed and sedentary behaviour, in both males and females, across more diverse populations. This would provide a greater understanding into if it too much SB or too little PA, is more strongly associated with walk speed.

3.5.5 Sedentary Occupations and Physical Capability

The negative balance associations observed with SB in males and the relatively lower grip strength and FWS compared to norms in this population, suggest sedentary occupations may be impairing physical capability. This is of vital concern, as this impairment in physical capability in younger adults may be increasing risk for disease and mortality and reducing QoL, as previously discussed (section 2.3) in older populations (Cooper et al., 2010, Cooper et al., 2014). As well as having relatively reduced physical capability, the individuals in this research were extremely sedentary compared to the general population. Together this suggests there is a need to reduce high levels of SB, in order to improve physical capability. Current PA guidelines already exist to offer guidance on the amount of activity individuals should be undertaking (Doh, 2011) Many adults are already failing to meet these requirements, with 33% of men and 45% of women completing insufficient PA to meet guidelines; the proportion of people not meeting guidelines increases with age (Nhs, 2012). There is a need to provide other assistance and opportunities to increase physical activity and reduce sedentariness. Workplace interventions incorporating PA to interrupt prolonged SB, may provide a method by which this can be achieved. This could assist in reducing and breaking up SB more frequently and provide additional PA, which may enhance physical capabilities. Research is therefore required to design and trial exercise interventions within the workplace, which will reduce and break up SB and increase overall engagement in PA, which may result in improved physical capabilities and other associated health benefits.

3.5.6 Limitations

3.5.6.i Accelerometry

There are a number of limitations, which may have affected the ability to detect associations between SB and physical capability in this research. SB was assessed using accelerometers mounted on the hip, which can lead to difficulties in detecting different postures when remaining still. It has been suggested that classifying SB using only the vertical axis, as done in this work, may not be sensitive enough to detect postural change, allowing for the misclassification of ST (Kim et al., 2015a). It is possible that some periods of SB were in fact detecting periods of inactive standing. Inactive standing is not associated with the same detrimental health associations and muscle activity as sitting (see section 2.5) and would not come under the previously described definition of SB (Sedentary Behaviour Research, 2012). Future work should consider potential ways to more accurately monitor SB, this may be possible analysing raw accelerometer signals or with devices which have been shown to better detect posture allocation, such as the thigh mounted ActivePal (Kozey-Keadle et al., 2011, Kim et al., 2015a). Addressing these issues may enable SB to be detected more accurately and provide a greater understanding into potential detrimental associations.

In this study regression was used to adjust for wear time (see section 3.3.4), however this may not still truly represent actual SB. If individuals are removing the device, such as when they are sitting in the evening, important periods of SB are not being detected. If this occurs across a number of individuals, with a smaller sample size such as used in this study, this will likely lead to less accurate adjustment of wear time when using regression predictions. Future work should attempt to conduct constant 24-hour SB monitoring and this would alleviate issues in controlling for wear time. Due to low wear time in the individuals who participated, the decision was taken to analyse accelerometer data from at least three days of valid wear (two weekday & one weekend). Research has suggested to accurately represent SB, 6-8 days of valid wear is required, even after adjusting for wear time (Aadland and Ylvisaker, 2015). Research requiring additional wear time may therefore provide a more accurate representation of normal SB and associations with this.

To investigate associations with workplace SB, accelerometry was analysed during weekdays between 9am-5pm. This was chosen as when analysing diaries this was the most common time worked amongst all individuals. It may be that not all individuals were working during these periods and this may have led to the under or over estimation of workplace SB. Future work should accurately assess when individuals are at work, to more accurately investigate associations with worktime SB.

MPVA was not assessed via accelerometry during this research, due to potential issues in detecting all activities (i.e. resistance exercises) which would come under this PA classification. Previous research (discussed in section 2.5 & 2.6) using accelerometers has controlled for MVPA based on specific cut points, which are associated with sufficient accelerations, for exercise of that intensity (Healy et al., 2008a, Koster et al., 2012, Henson et al., 2013, Davis et al., 2014, Maher et al., 2014, Loprinzi and Davis, 2015, Sardinha et al., 2015, Schmid et al., 2015, Fishman et al., 2016, Bakrania et al., 2016). Using hip mounted accelerometry, it is likely that resistance training exercises may not be detected correctly when using cut points, due to their static nature. This would lead to vital exercise being undetected, which would likely be providing a training stimulus for components of strength and balance. When concerned with cardiometabolic outcomes using cut points to determine MVPA, most cardiorespiratory exercise may be detected. However, it may still be possible that exercises which fall below the cut point threshold are not detected, even if of sufficient intensity to be classified as MVPA. The detection of this activity could be of great importance, especially when considering associated health benefits. Future research should consider this when using accelerometry to detect and control for PA. This may have large implications when trying to determine if associations are related to time spent sedentary or conducting PA. Using raw data signals from accelerometers, it may be possible to detect activities which are currently missed using the cut point classifications. As with SB, if activity levels from accelerometers are adjusted for wear time, this may also lead to inaccuracies and future work should avoid this when possible. Given participation in PA often only comprises a small period of the total day, failing to detect activities during periods of non-wear, could have a large impact on determining associations with PA.

3.5.6.ii Physical Capability

There are no Y-balance test norms available for healthy adults, so it was not possible to compare this population. This may have identified if the individuals involved had relatively reduced balance, as was observed with grip strength and FWS. Due to limited female participants, it was only possible to investigate associations between walk speed and SB in males; future research should investigate associations this in both sexes.

3.5.6.iii Study Population

In this study, all the participants were obtained from similar sedentary work environment, future research should investigate associations between SB and physical capability across a more diverse population. In the work, all individuals were extremely sedentary, much lower than normal for the general population. Investigating associations across a more diverse cross-section, where there is greater variation in SB, may enable associations with physical capability to be detected.

3.5.7 Conclusion

In conclusion, to my knowledge for the first time this study investigated associations between SB and physical capability, in a young healthy adult population, who work in a sedentary occupation. Overall time spent in sedentary and prolonged sedentary periods, were independently associated with balance for males but not for females. This is interesting and if SB is affecting balance differently for males and females, there may be a need for independent sex specific recommendations on how SB should be accumulated. The lack of associations between workplace SB and balance, unlike seen with overall time spent in SB, suggests this may due to PA conducted during leisure hours, which is replacing periods of inactivity and maintaining or improving balance ability. Handgrip strength was not associated with SB overall or at work and there were only weak associations with walk speed. However, all individuals were considerably weaker and walked at a slower fast pace, than compared to UK norms. Therefore, it may be that the sedentary occupation, which was exposing these individuals to high levels of SB, was impairing grip strength and walk speed in all individuals. Future work is required to further investigate associations between SB and physical capability, in more diverse populations, to further investigate. This may provide a better understanding into associations between physical capabilities and time spent in SB. If there is a need to reduce SB and increase PA, to maintain physical capability, workplace exercise interventions may provide individuals with increased opportunities that break up periods of inactivity.

4.0 Chapter 4: Calisthenics Workplace Intervention

4.1 Abstract

Background: More frequently interrupting sedentary behaviour (SB) has been identified as important for cardiometabolic health. In older adults, breaks independent of total sitting are associated with improved physical capability. Interrupting prolonged sitting within the workplace may therefore provide important health benefits. Calisthenics exercises may provide a cost effective and easily implementable intervention, which could be used to interrupt workplace SB. The purpose of this research was to investigate how implementing a calisthenics exercise intervention, within the workplace, improved physical capability.

Methods: Nineteen healthy participants completed a one-week baseline, before being randomly assigned to a control or calisthenics exercise intervention group. The intervention group completed a set of five calisthenics exercises once per hour, when at work, over a two-week period. Post intervention a one-week follow-up was conducted. SB was assessed throughout using accelerometry and measures of physical capability (balance, grip strength, jump power) were taken at baseline, post-intervention and at follow-up.

Results: Completing the intervention increased balance compared to the control group, the greatest change from baseline was in anterior balance ($p<0.05$), observed at follow-up (Control: 1.07% ±1.87; Intervention 3.72% ±0.84). Grip strength and jump power did not improve ($p>0.05$) in the intervention group, compared to the control group, post intervention or a follow-up. Workplace SB was considerably reduced (-35 minutes/day) when completing the exercise intervention.

Findings: A calisthenics exercise intervention used to interrupt workplace SB resulted in improvements in balance, observed following additional recovery one-week post intervention. Completing the intervention did not improve grip strength or jump power, when only conducted over a two-week period. The intervention considerably reduced the time spent sitting during workplace hours; calisthenics exercises appear an effective mode to reduce workplace SB and increase engagement in physical activity.

4.2 Introduction

As discussed in section 2.2 SB has been associated with negative health outcomes and an increased risk for disease and mortality (Ekblom-Bak et al., 2010, Owen et al., 2010b, Wilmot et al., 2012, Levine, 2015). Current UK PA guidelines recommend adults remain active daily, conduct at least 150 minutes of MVPA and include two days with activities to improve muscular strength, per week. The guidelines currently have limited recommendations regarding how much time should be spent sedentary, only stating adults should attempt to minimise the amount of time they spend sitting (Doh, 2011). There is a need for these guidelines to provide more detailed information regarding how adults are accumulating their ST. To assist in informing these guidelines research has investigated breaking up SB and how the mode and frequency of interruption may offer different health benefits.

4.2.1 Breaks in Sedentary Behaviour

As discussed previously (section 2.5) independent of total sitting time, breaks in SB have been beneficially associated with adiposity, lipids, waist circumference, plasma glucose and C-reactive protein (Healy et al., 2008a, Healy et al., 2011); highlighting how more frequent interruption of SB may offer important cardiometabolic health benefits. SB is defined as any waking behaviour which requires an energy expenditure less than 1.5 METs, while in a sitting or reclining posture (Sedentary Behaviour Research, 2012). Sedentary behaviour can be interrupted using posture change such as transitioning from sitting to standing or by breaking up ST using bouts of PA. Better understanding the potential benefits offered by different modes of SB interruption will assist in the design and implementation of more effective interventions.

4.2.2 Sit to Stand

A simple method that has received considerable attention in recent years is breaking up SB by transitioning to periods of standing. Standing instead of sitting at work has been shown to cause a significant increase in the energy expenditure, when trialled with office workers (Buckley et al., 2013). Standing has also been shown to considerably increase muscle activity in the legs (Tikkanen et al., 2013). Replacing periods of sitting with standing may therefore offer important metabolic health benefits and increase muscle activity within the lower extremities.

The potential benefits of replacing sitting with standing have led to interventions trialling the use of STSWs. These workstations provide the ability to transition to periods of standing instead of sitting during desk based activities, achieved using standing desks or adjustable workstations. STSWs have been shown to be effective in reducing the amount of time spent sitting at work (Pronk, 2012, Neuhaus et al., 2014b). Transitioning from workplace sitting to standing was also shown to be effective in reducing back and neck pain, reducing fatigue and maintaining productivity (Pronk, 2012, Thorp et al., 2014). Implementing STSWs however may be difficult on a large scale and come at a cost, requiring the acquisition and implementation of new workstations. There is also a need to better understand the long-term consequences of standing stationary instead of sitting. Transitioning to prolonged periods of standing may cause unwanted detrimental side effects, such as impairing venous return from the legs.

4.2.3 Active Breaks

Another area which has been investigated is the use of active breaks, to interrupt prolonged periods of sitting. Short walking breaks of five minutes or less have been shown to significantly reduce postprandial glucose, insulin levels and increase energy expenditure, compared to remaining sedentary (Dunstan et al., 2012b, Swartz et al., 2011). Short walking breaks were also shown to attenuate declines in vascular function in response to prolonged sitting (Thosar et al., 2014a). Compared to short standing breaks, walking resulted in significant reductions in postprandial glycaemia when used to break up SB (Bailey and Locke, 2015). More frequent activity breaks have been shown to be more effective than a single continuous bout of PA, having a greater effect on postprandial glycaemia and insulinaemia (Peddie et al., 2013). When comparing different modes of exercise, a short bout of calisthenics exercises invoked a greater heart rate and energy expenditure response, when compared to standing or walking for the same duration (Carter et al., 2015). Calisthenics exercises were also found to improve vascular function, when used to repeatedly interrupt prolonged sitting (Carter and Gladwell, 2016).

The potential benefits offered by reducing periods of SB with active breaks has led to interventions investigating the use of active workstations. Active workstations have been shown to provide substantial reductions in SB without impacting upon productivity and were associated with significant improvements in cardiometabolic biomarkers (Neuhaus et al., 2014a, Carr et al., 2016a). As with STSWs, the installation of active work areas requires the implementation of new workspaces at considerable cost. There is a need for cost effective workplace interventions, which provide clinically meaningful health benefits and can be scaled across workplaces. Calisthenics exercise may therefore offer an effective intervention to reduce occupational sitting, requiring little space and no equipment and providing greater cardiometabolic health benefits compared to standing or walking for the same duration.

4.2.4 Physical Capability and Sedentary Behaviour

As discussed in section 2.3, research in older populations has investigated associations between SB and physical capability (Keevil et al., 2015). Components of physical capability are important for conducting tasks of daily living and improving quality of life and have been associated with mortality (Kuh and New Dynamics of Ageing Preparatory, 2007, Cooper et al., 2010, Cooper et al., 2014). Detecting impairments in physical capability at a younger age, may offer a simple and cost-effective method for identifying individuals at risk for future adverse health outcomes. There has been limited research into associations between SB and physical capability. In older adults, increased television viewing time has been associated with reduced walk speed.

In the previous chapter (section 3.0), overall time spent sedentary was found to be independently associated with reduced composite and anterior balance in males. Grip strength and fast walk speed were also shown to be relatively lower, compared to published norms for the UK population. These reductions observed in individuals who work in a sedentary occupation, may be due to time spent inactive outside of work, during leisure hours. Where some individuals are replacing SB by conducting PA, during their leisure time, which improves or maintains their physical capability. Current health guidelines already recommend individuals conduct PA in their leisure time, to maintain their health. As discussed previously (section 3.5.5), a large number of adults are already failing to conduct sufficient activity to meet these guidelines (Nhs, 2012). Therefore, if some individuals are already too inactive in their leisure time, there is a need to provide additional opportunities and motivators to enable them to become more active. This may be achievable using workplace interventions incorporating PA, which may improve components of physical capability, along with providing additional cardiometabolic benefits associated with interrupting sedentary behaviour. If individuals were to engage with these opportunities it may improve confidence and capability, which could lead to more engagement in other activity outside of work hours.

Most research investigating the effect of breaking up SB has focused on cardiometabolic outcomes. In section 2.5, the research into associations between interrupting SB and physical capability, in older populations was discussed, with breaks in ST independent of MVPA and total sitting, associated with improved physical capability (Davis et al., 2014, Sardinha et al., 2015). The University of Essex has conducted pilot work, investigating the effect breaking up SB, using a calisthenics exercise intervention, has upon physical capability. The intervention was conducted with young healthy adults, requiring a two-minute set of calisthenics to be completed once an hour, ten times a day, over a seven-day period. Completing the calisthenics intervention greatly improved composite and anterior balance, with a greater increase observed in the left side. The observed balance improvements were between 5-12%, which as discussed previously (section 3.5.2) likely represents a meaningful increase. The intervention was also shown to provide improvements to flexibility and range of movement. Completing a workplace calisthenics exercise intervention may therefore assist in improving the physical capability of individuals, by offering improvements to balance and flexibility. It would also provide additionally engagement in PA, which may assist in meeting current health guidelines and provide other benefits, associated with interrupting prolonged sedentary behaviour.

4.2.5 Workplace Inactivity

In section 2.7 workplace activity levels were discussed, highlighting how the modern office workplace provides limited opportunities for movement. Office workers spend 70-80% of their time being sedentary, with over half of this in prolonged periods (Thorp et al., 2012, Parry and Straker, 2013, Clemes et al., 2014). This was supported in the previous chapter (section 3.5.1), where individuals with sedentary occupations were observed spending 10 hours a day sedentary, with 60% of this time in prolonged (>15 minute) periods. Workplaces which offer limited abilities for movement, such as call centres, are associated with even greater levels of sedentary behaviour (Thorp et al., 2012). Therefore, interventions aimed at reducing and breaking up SB, may be more effective when targeted at highly sedentary work environments.

Work hours are associated with periods of low activity; it has been suggested individuals who are the most sedentary during work hours, conduct less leisure time LIPA (Clemes et al., 2014). In the previous chapter (section 3.5.1), individuals were shown to spend 75% of their time sedentary at work. However, being sedentary at work was not associated with being more sedentary during leisure time. Work hours in sedentary occupations therefore represent a period where all individuals are being exposed to large periods of inactivity and would be effective areas to target with activity interventions.

In contrast when a very proactive approach to workplace activity is taken, transport employees were shown to conduct more LIPA during work hours, compared to during leisure time (Wong et al., 2014). This suggests interventions to reduce workplace SB and increase PA may be more effective if companies are proactive in their approach. A calisthenics exercise intervention could therefore be effective in reducing prolonged periods of workplace sedentary behaviour, while providing additional opportunities to conduct PA.

4.2.6 Aims of Research

The primary aim of the current study was to investigate the effect completing a calisthenics exercise intervention had on physical capability, when used to reduce, or break up workplace sitting. The secondary aim was to determine if the intervention would affect workplace performance and change workplace SB.

4.2.6.i Research Questions

1. Does completing a workplace calisthenics exercise intervention improve components of physical capability?

    a. Balance

    b. handgrip strength

    c. Leg Power

2. Does completing a workplace calisthenics exercise intervention affect productivity, mood and fatigue?

3. Does completing a workplace calisthenics exercise intervention change workplace SB?

4.3 Methods

4.3.1 Participants

Participants were nineteen (3 male, 16 female) informed and consenting healthy adult volunteers, who worked in an occupation where they spent large periods of time sitting. The participants comprised of nine employees from University staff and ten local council call centre employees. Ethical approval to perform the research was granted by the University of Essex ethics committee and conformed to the declaration of Helsinki. Participant demographic statistics of age, height, mass and BMI are presented in Table 4-1.

Table 4-1. Demographic participant statistics measured at baseline (Mean ±SD)

n	Age (years)	Stature (m)	Mass (kg)	Body Mass Index ($kg.m^2$)
19	44.1 ±12.5	1.65 ±0.89	76.3 ±19.4	28.0 ±5.6

4.3.2 Study Protocol

Participants completed written informed consent and completed a Par-Q General Health Questionnaire prior to participation in the research. Participants were provided with an accelerometer and requested to wear this during all waking hours; they were instructed to remove the device to conduct water based activities (e.g. bathing / swimming). The device was positioned on the right hip and attached by a waist band. A log book (see 7.1) was provided to record the time the device was attached and removed each day, along with any other periods of non-wear. Accelerometer data was collected throughout participation. The protocol comprised of three-time periods over a four-week duration: baseline (week 1), intervention (week 2-3) and a follow-up (week 4). At the end of each of these time periods participants attended a 30-minute testing session to assess outcome measures. During baseline and follow-up, individuals were monitored while requested to continue living normally. Following baseline individuals were randomly assigned to either a control or intervention group.

4.3.3 Intervention Groups

4.3.3.i Control

Participants assigned to the control group were requested to continue living normally, during weeks 2-3 of participation. A diagram of the experimental protocol used for the control group is provided in Figure 4-1.

4.3.3.ii Intervention

Participants assigned to the intervention group were provided with a calisthenics exercise program to complete during weeks 2-3 of participation. They were requested to complete these exercises once per hour while at work, up to a maximum of eight times per day. A logbook was provided to record the number of sets of exercises that were completed (see 7.2). The calisthenics exercises comprised of five different exercise movements: squats, arm circle, calf raises, knees to elbows and lunges. Participants were requested to complete eight repetitions of each exercise, at a rate of one repetition every three seconds, totalling two minutes to complete all exercises. Prior to conducting the intervention, the exercise movements were demonstrated to participants and they were provided with information detailing how to complete the exercises (see 7.3) A diagram of the experimental protocol used for the intervention group is provided in Figure 4-2.

4.3.4 Physical Capability Measures

4.3.4.i Handgrip strength

Handgrip strength was assessed as previously described in section 3.3.3.i.

4.3.4.ii Balance

Composite and anterior balance were assessed as previously described in section 3.3.3.ii.

4.3.4.iii Jump Power

Jump tests were conducted using contact jump mat's (Newtest, Oulu, Finland & SmartJump, Fusion Sport, Queensland, Australia). Peak jump power was assessed using a single maximal jump, repeated three times, with 30s rest between trials. Participants were instructed to stand with their feet shoulder width apart, place hands on their hips and to start from a semi squatted position. Participants were requested to jump vertically with maximal effort, with no countermovement. Flight time was recorded to the nearest 0.01 seconds. Jump height was estimated for each jump using flight time with the following equation:

$$h = \tfrac{1}{2}(t/2)^2\, g$$

Where *h* is the jump height (m), *t* is the flight time (s) and *g* is acceleration due to gravity ($9.81 m.s^{-2}$) (Dias et al., 2011). Using the estimated jump height peak anaerobic power (PAP) was calculated using the following equation (Sayers et al., 1999):

$$PAP\ (W) = 60.7 \times \text{jump height (cm)} + 45.3 \times \text{body mass (kg)} - 2055$$

A mean PAP was calculated from the three maximum jump trials. Average jump power was assessed using a 15 second modified version of the Bosco repeated jumps test (Bosco et al., 1983) (fix reference). Participants were required to keep their hands on their hips throughout the test protocol. Participants were instructed to jump as high and as many times as possible throughout. Average jump power (AvP) was calculated using the following equation:

$$AvP\ (W.kg^{-1}) = (t \times 15 \times g^2) / (4n \times (15 - t))$$

Where n is the number of jumps completed during the test duration.

4.3.5 Mood & Fatigue

Mood state was measured using the Profile of Mood States (POMS) short form questionnaire (Grove and Prapavessis, 1992, Curran et al., 1995). The reliability and validity of the short POMS has been previously established (Grove and Prapavessis, 1992). The six POMS subscales measured were anger, confusion, depression, fatigue, tension and vigour; a total mood disturbance score was calculated from the six subscales. All POMS scores were converted and analysed as T scores.

4.3.6 Workplace Productivity

Workplace productivity was assessed using a 10 point Likert scale (see 7.4) adapted from question A10 of the World Health Organization Health and Performance Questionnaire (HPQ) (Kessler et al., 2003).

4.3.7 Self-reported Sedentary Behaviour and Physical Activity

The International Physical Activity Questionnaire (Short form, IPAQ) was completed to subjectively assess PA and sedentary behaviour. The IPAQ is a reliable measure of adult PA and sedentary behaviour (Booth, 2000, Booth et al., 2003, Rosenberg et al., 2008).

4.3.8 Accelerometer Assessed Sedentary behaviour

Sedentary behaviour assessed using accelerometry was measured and analysed as previously discussed in section 3.3.4.

4.3.9 Accelerometer Assessed Physical Activity

Physical activity assessed using accelerometry was measured and analysed as previously described in section 3.3.5.

4.3.10 Data Analysis

Statistical analysis was conducted using statistical software (SPSS v19, IBM Corporation, Somers, NY, USE), with an accepted significance level of $p<0.05$. Mean ± standard deviation (SD) were calculated for all data and presented in tables and figures. Participants in the intervention group who did not complete at least half the prescribed calisthenics exercises (<37 sets), were analysed as a separate "non-adherer" group (n=4). The non-adherer group were not included in the initial analyses investigating changes in response to the exercise intervention. Change from baseline was calculated for all outcome measures, post intervention and at follow-up, for the control (n=9) and intervention (n=6) groups. A two-way mixed within-between analysis of variance (ANOVA), was conducted to analyse differences between the control and intervention groups, at all time periods. Post hoc analysis was conducted using independent samples t-tests; mean difference (MD) and 95% confidence intervals were reported (95% CI). Effect sizes were calculated and interpreted as has previously been suggested (Cohen, 1988, Pallant, 2007). Descriptive statistics including range for all outcomes, were calculated for all three groups at baseline. The baseline analysis was used to further investigate potential reasons that individuals may not have completed the exercise intervention; there was an inadequate sample size to conduct statistical analysis on these data.

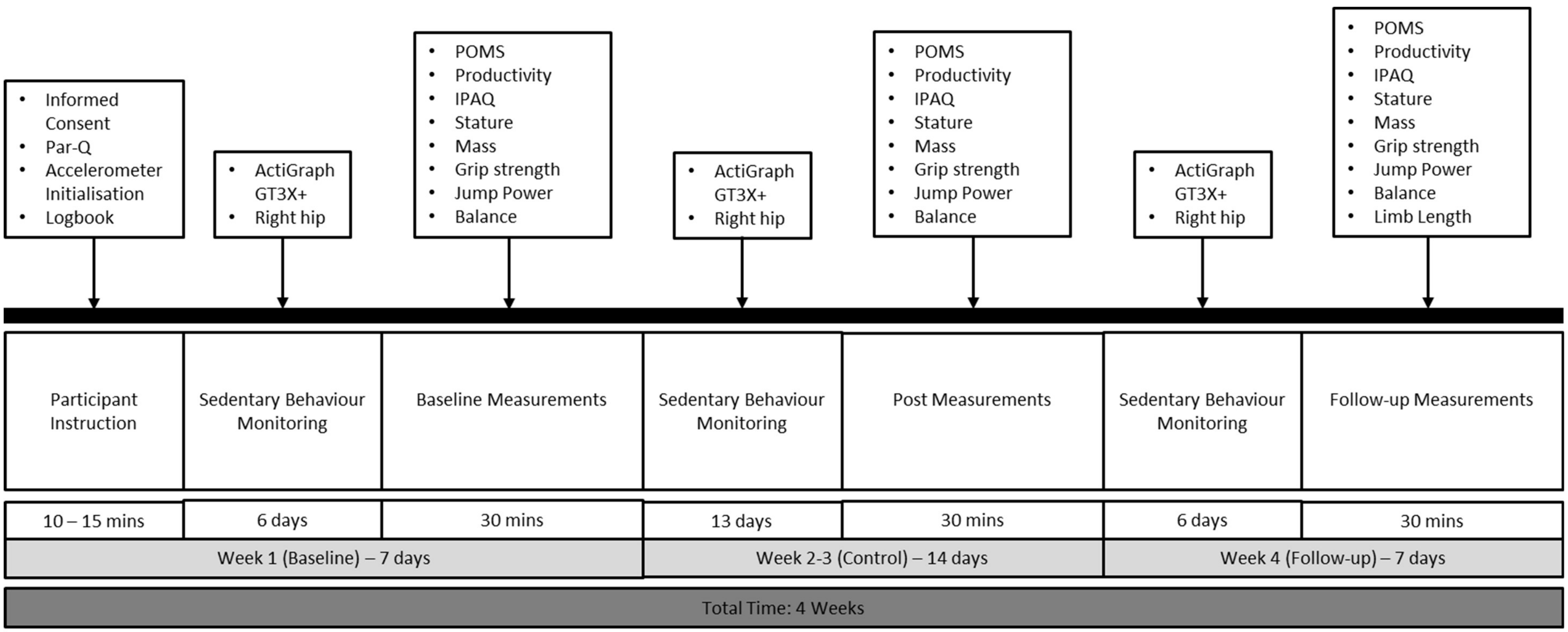


Figure 4-1. Experimental protocol used with the control group

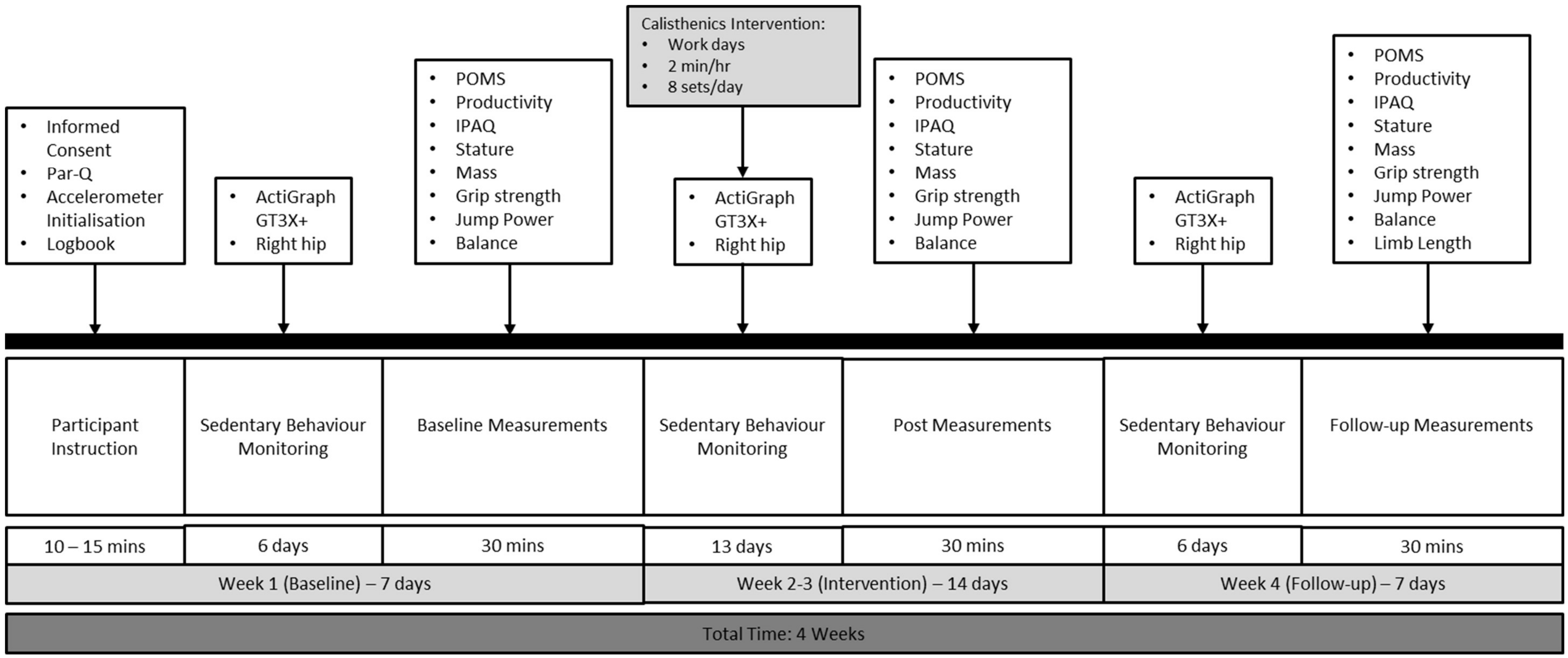


Figure 4-2. Experimental protocol used with the intervention group

4.4 Results

4.4.1 Baseline Comparison

4.4.1.i Baseline demographics statistics

Demographic statistics measured at baseline for the control, intervention and non-adherer groups are presented in Table 4-2.

Table 4-2. Participant demographics measured at baseline for the control, intervention and non-adherer groups (Mean ±SD)

Group	n	Age (years)	Stature (m)	Mass (kg)	Body Mass Index
Control	9	44.1 ±14.1 (42)	1.67 ±0.11 (0.33)	82.3 ±23.3 (68.7)	29.4 ±7.0 (17.7)
Intervention	6	45.0 ±11.6 (28)	1.62 ±0.06 (0.17)	68.8 ±11.1 (28.7)	26.1 ±2.4 (6.1)
Non-adherer	4	42.5 ±13.4 (31)	1.63 ±0.05 (0.12)	74.2 ±19.7 (46.2)	27.7 ±5.7 (13.0)

Note: (Range)

4.4.1.ii Baseline Physical Capability

Components of physical capability measured at baseline for the control, intervention and non-adherer groups are presented in Table 4-5.

Table 4-3. Components of physical capability measured at baseline for the control, intervention and non-adherer groups (Mean ±SD)

Group	Composite Balance (%)	Anterior Balance (%)	Handgrip Strength (kg)	Relative Handgrip Strength	Peak Power ($W.kg^{-1}$)	Average power ($W.kg^{-1}$)
Control	81.1 ±10.3 (31.7)	59.1 ±8.2 (24.8)	28.6 ±5.5 (17.5)	0.36 ±0.09 (0.26)	30.4 ±6.2 (16.8)	9.9 ±3.4 (9.9)
Intervention	82.8 ±9.3 (26.3)	61.6 ±7.5 (20.3)	27.8 ±5.1 (14.8)	0.41 ±0.08 (0.24)	29.1 ±3.7 (9.4)	11.3 ±3.5 (9.2)
Non-adherer	70.7 ±18.5 (36.08)	54.3 ±11.3 (22.6)	25.8 ±6.5 (14.5)	0.37 ±0.13 (0.29)	25.2 ±5.9 (21.9)	9.7 ±2.2 (5.0)

Note: (Range)

4.4.1.iii Baseline productivity, mood and fatigue

Baseline scores for productivity, total mood disturbance and fatigue for the control, intervention and non-adherer groups are presented in Table 4-4.

Table 4-4. Productivity, mood disturbance and fatigue at baseline for the control, intervention and non-adherer groups (Mean ±SD)

Group	Productivity (1-10)	Total Mood Disturbance	Fatigue
Control	6.9 ±1.2 (4)	148.3 ±17.6 (58)	40.4 ±7.5 (22)
Intervention	7.5 ±2.1 (6)	145.8 ±22.5 (59)	40.7 ±7.7 (21)
Non-adherer	7.5 ±1.3 (6)	160.8 ±17.4 (38)	33.0 ±1.4 (3)

Note: (Range), Higher TMD score = more disturbed mood, Higher fatigue score = feeling more fatigued

4.4.1.iv Baseline self-reported physical activity and sitting

Self-reported PA and sitting from the IPAQ recorded at baseline for the control, intervention and non-adherer groups are presented in Table 4-5.

Table 4-5. Self-reported physical activity and sitting from the IPAQ at baseline, for the control, intervention and non-adherer groups (Mean ±SD)

Group	Total Activity (Met-Hours.week^{-1})	Sitting (Hours.day^{-1})
Control	48.2 ±26.5 (75.7)	9.0 ±2.0 (5)
Intervention	30.4 ±25.9 (63.6)	10.2 ±3.1 (9)
Non-adherer	50.9 ±26.8 (53.2)	8.5 ±2.4 (5)

4.4.1.v Baseline Accelerometer Assessed Sedentary Behaviour

Sedentary behaviour assessed using accelerometry at baseline for the control, intervention and non-adherer groups are presented in Table 4-6.

Table 4-6. Accelerometer assessed sedentary behaviour at baseline, for the control, intervention and non-adherer groups (Mean ±SD)

Group	SB (Hours.day^{-1})	PSB (Hours.day^{-1})	Workplace SB (Hours.day^{-1})	Workplace PSB (Hours.day^{-1})
Control	9.9 ±0.8 (2.4)	5.7 ±0.6 (1.9)	5.9 ±0.8 (2.3)	3.8 ±1.4 (3.6)
Intervention	10.1 ±0.8 (2.0)	5.8 ±0.6 (1.6)	6.3 ±0.5 (1.5)	4.3 ±1.5 (3.7)
Non-adherer	9.4 ±0.4 (0.8)	5.4 ±0.3 (0.4)	6.1 ±0.4 (0.8)	3.4 ±0.7 (1.3)

Note: Sedentary behaviour (SB), Prolonged sedentary behaviour (PSB)

4.4.1.vi Baseline Accelerometer Assessed Physical Activity

Physical activity assessed using accelerometry at baseline for the control, intervention and non-adherer groups are presented in Table 4-7.

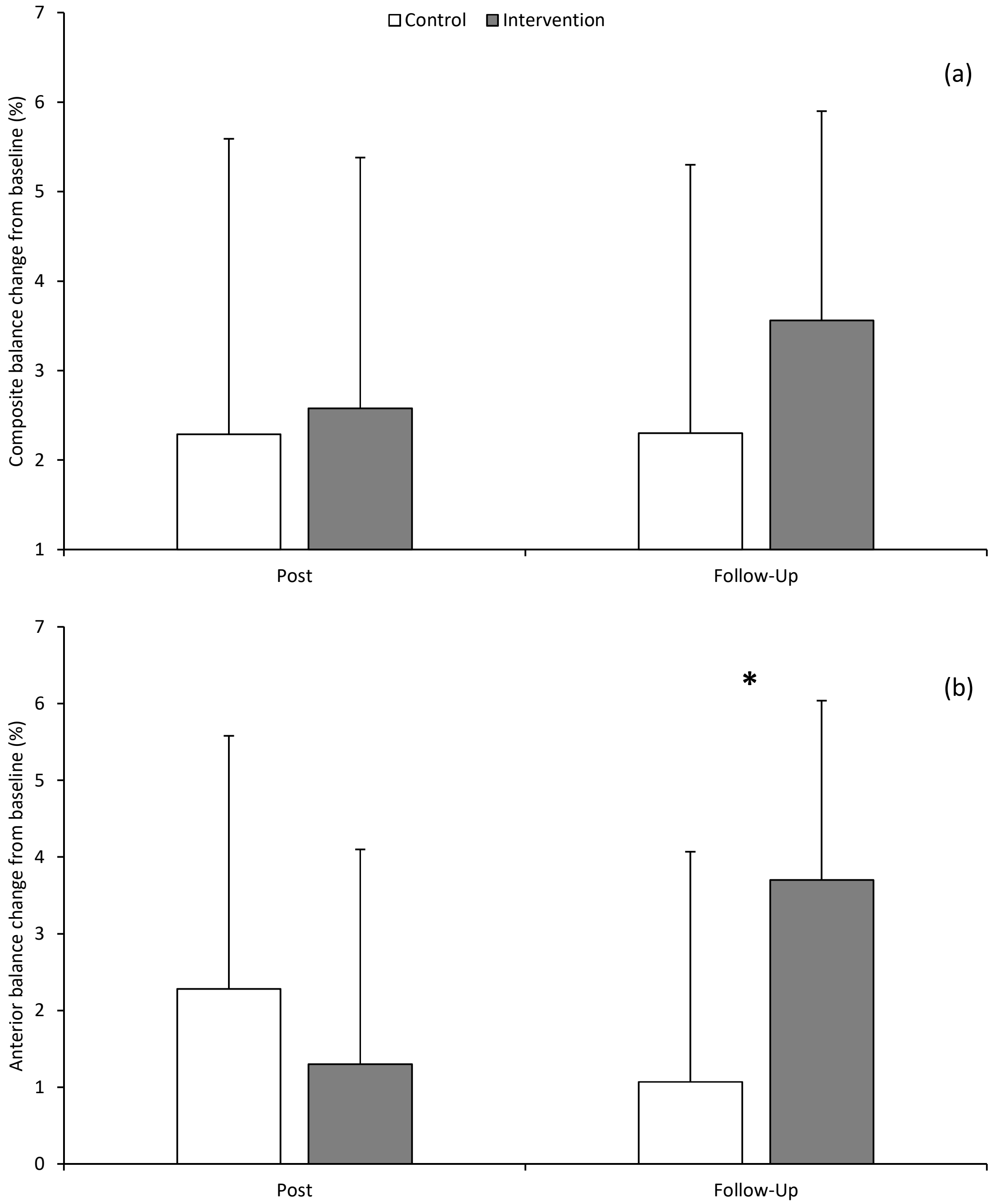
Table 4-7. Accelerometer assessed moderate-to-vigorous physical activity (MVPA) at baseline, for the control, intervention and non-adherer groups (Mean ±SD)

Group	SB ($Mins.day^{-1}$)	Workplace SB ($Mins.day^{-1}$)
Control	49.4 ±33.1 (87.7)	21.4 ±22.3 (73.5)
Intervention	29.9 ±17.4 (44.1)	19.8 ±9.9 (21.0)
Non-adherer	16.2 ±7.6 (13.7)	12.2 ±4.4 (8.5)

4.4.2 Composite & Anterior Balance

There was no statistically significant interaction effect between time and group on composite balance change from baseline, $F(1,12) = 1.31$, $p>0.05$, $\eta^2 = 0.1$ (Figure 4-3). There was no statistically significant effect for time $F(1,12) = 1.32$, $p>0.05$, $\eta^2 = 0.1$ or group $F(1,12) = 0.23$, $p>0.05$, $\eta^2 = 0.19$ on composite balance change from baseline. The difference between the control (2.29 ±3.30) and intervention (2.58 ±2.80) groups composite balance change from baseline post intervention (MD = -0.29, 95% CI: -4.1 to 3.53), was very small ($\eta^2 = 0.002$). The difference between the control (2.30 ±3.00) and intervention (3.56 ±2.34) groups composite balance change from baseline at follow-up (MD = -1.26, 95% CI: -4.67 to 2.14), was moderate ($\eta^2 = 0.05$).

There was a statistically significant interaction effect between time and intervention group on anterior balance change from baseline, $F(1,11) = 7.78$, $p<0.05$, $\eta^2 = 0.41$ (Figure 4-3). There was no main effect for time, $F(1,11) = 0.87$, $p>0.05$, $\eta^2 = 0.07$ or group $F(1,11) = 0.78$, $p>0.05$, $\eta^2 = 0.07$ on anterior balance change from baseline. There was no statistically significant difference between the control (2.28 ±1.69) and intervention (1.30 ±3.04) groups anterior balance change from baseline post intervention; $t(11) = 0.763$, $p>0.05$ The magnitude of difference (MD = 0.98, 95% CI: -1.85 to 3.81) was moderate ($\eta^2 = 0.05$). There was a statistically significant difference between the control (1.07 ±1.87) and intervention (3.72 ±0.84) groups anterior balance change from baseline at follow-up; $t(11) = -2.67$, $p<0.05$. The magnitude of difference (MD = -2.65, 95% CI: -4.83 to -0.47) was very large ($\eta^2 = 0.39$).



Note: * = p<0.05 between control and intervention group, n=4 for intervention group anterior balance

Figure 4-3. Composite (a) and anterior (b) balance change from baseline measured post intervention and at follow-up, for the control (n=9) and intervention groups (n=5) (Mean ±SD)

4.4.3 Handgrip Strength

There was no statistically significant interaction effect between measurement time and intervention group on handgrip strength change from baseline, $F(1,13) = 0.28$, $p>0.05$, $\eta^2 = 0.02$ (Figure 4-4). There was no main effect for time $F(1,13) = 1.47$, $p>0.05$, $\eta^2 = 1.01$ or group $F(1,13) = 3.99$, $p>0.05$, $\eta^2 = 0.03$ on handgrip strength change from baseline. The difference between the control (0.25 ±2.72) and intervention (-0.13 ±1.97) groups handgrip strength change from baseline post intervention (MD = 0.38, 95% CI: -3.20 to 3.95), was very small ($\eta^2 = 0.004$). The difference between the control (-0.22 ±1.83) and intervention (-1.33 ±1.96) groups handgrip strength change from baseline at follow-up (MD = 1.11, 95% CI: -1.04 to 3.26), was moderate ($\eta^2 = 0.09$).

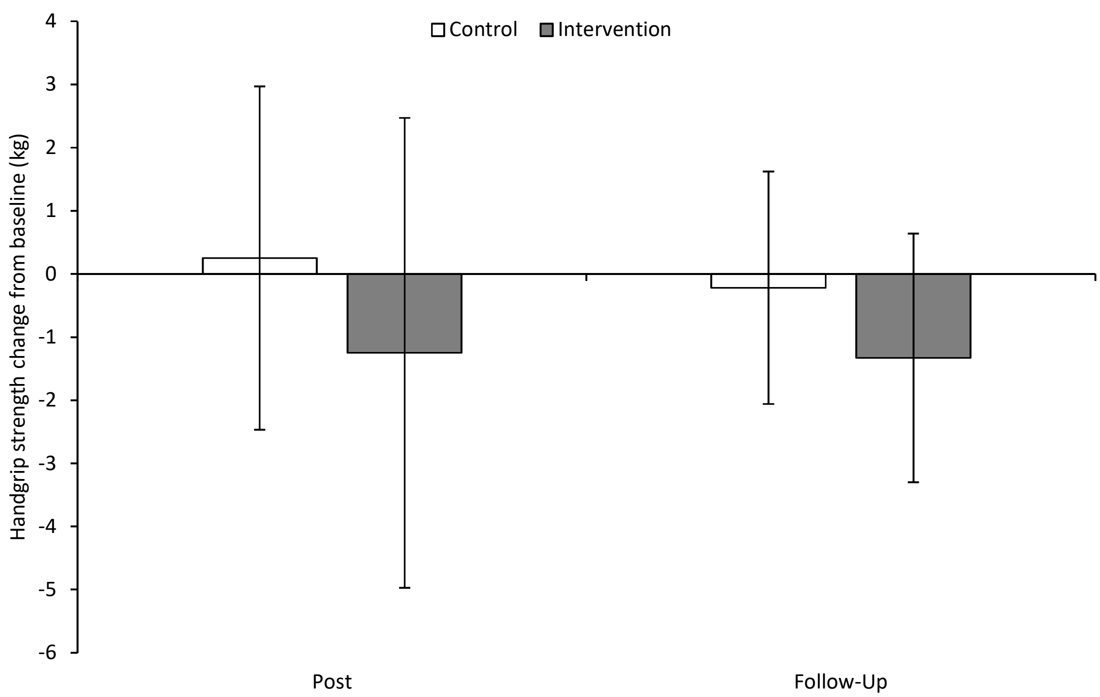
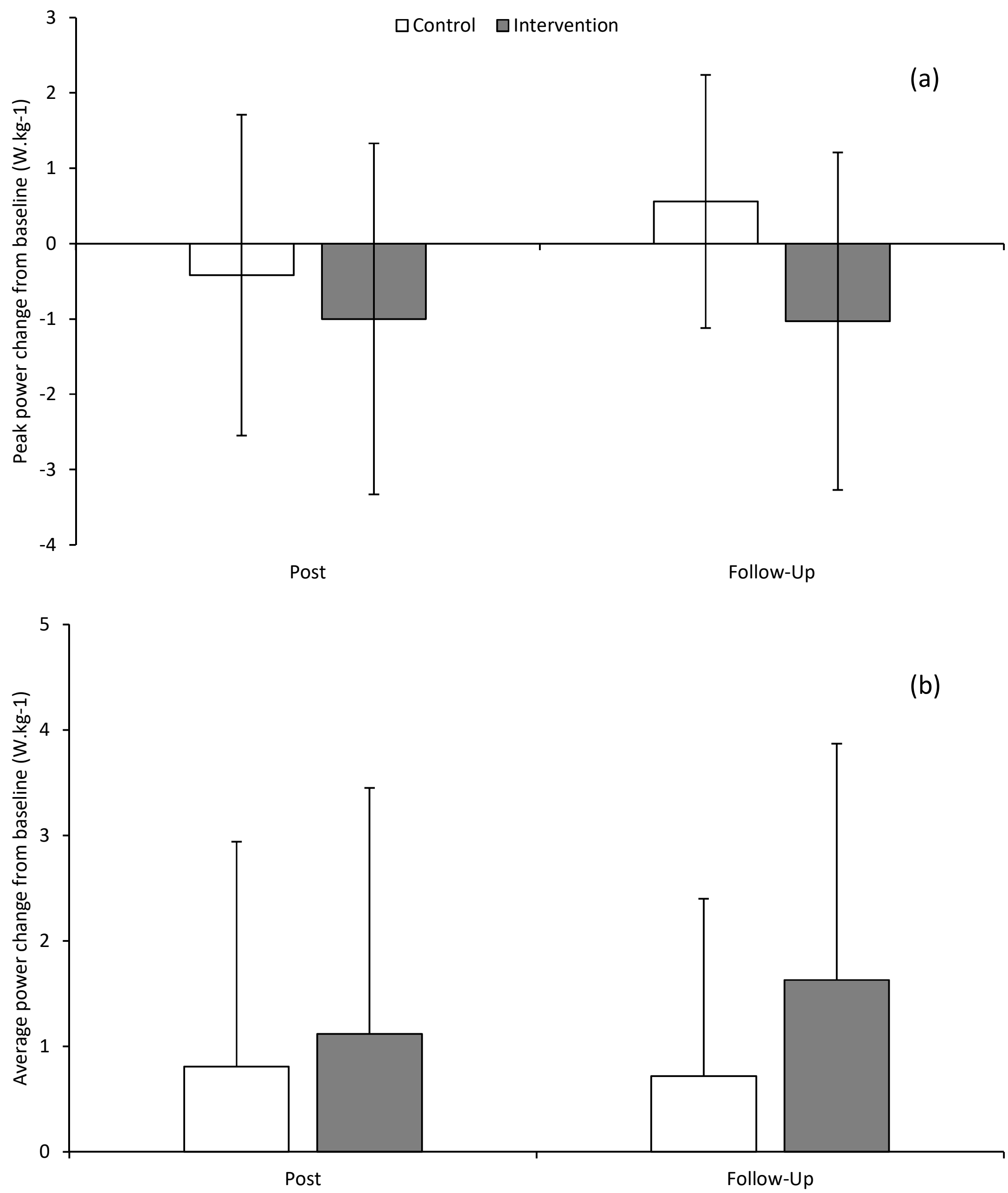


Figure 4-4. Handgrip strength change from baseline measured post intervention and at follow-up, for the control (n=9) and intervention (n=6) groups (Mean ±SD)

4.4.4 Jump Power

There was no statistically significant interaction effect between time and intervention group on peak jump power change from baseline, $F(1,11) = 4.24$, $p>0.05$, $\eta^2 = 0.28$ (Figure 4-5). There was no main effect for time $F(1,11) = 3.83$, $p>0.05$, $\eta^2 = 0.26$ or group $F(1,11) = 0.82$, $p>0.05$, $\eta^2 = 0.07$ on peak jump power change from baseline. The difference between the control (-0.42 ±2.13) and intervention (-1.00 ±2.32) groups peak power change from baseline post intervention (MD = 0.58, 95% CI: -2.32 to 3.47), was small ($\eta^2 = 0.02$). The difference between the control (0.56 ±1.67) and intervention (-1.03 ±2.24) groups peak power change from baseline at follow-up (MD = 1.58, 95% CI: -0.58 to 4.02), was large ($\eta^2 = 0.16$).

There was no statistically significant interaction effect between time and group on average jump power change from baseline, $F(1,9) = 0.25$, $p>0.05$, $\eta^2 = 0.03$ (Figure 4-5). There was no statistically significant effect for time $F(1,9) = 0.12$, $p>0.05$, $\eta^2 = 0.01$ or intervention group $F(1,9) = 0.19$, $p>0.05$, $\eta^2 = 0.02$ on average jump power change from baseline. The difference between the control (0.80 ±1.06) and intervention (1.12 ±2.70) groups average power change from baseline post intervention (MD = -0.31, 95% CI: -3.00 to 2.38), was very small ($\eta^2 = 0.006$). The difference between the control (0.72 ±0.45) and intervention (1.63 ±4.36) groups average power change from baseline at follow-up (MD = -0.92, 95% CI: -4.92 to 3.09), was small ($\eta^2 = 0.02$).



Note: n=4 for intervention group peak power, n=6 for control group average power

Figure 4-5. Peak (a) and average (b) jump power change from baseline measured post intervention and at follow-up, for the control (n=9) and intervention groups (n=5) (Mean ±SD)

4.4.5 Productivity, mood and fatigue

There was no statistically significant interaction effect between time and group on productivity change from baseline, F (1,13) = 2.18, p>0.05, η^2 = 0.14 (Table 4-8). There was no statistically significant main effect for time F (1,13) = 0.20, p>0.05, η^2 = 0.02 or group F (1,13) = 0.10, p>0.05, η^2 = 0.01 on productivity change from baseline. The difference between the control (-0.11 ±1.54) and intervention (0.33 ±1.21) groups productivity change from baseline post intervention (MD = -0.44, 95% CI: -2.03 to 1.17), was small (η^2 = 0.03). The difference between the control (0.33 ±1.00) and intervention (-0.50 ±1.97) groups productivity change from baseline at follow-up (MD = 0.83, 95% CI: -1.25 to 2.91), was moderate (η^2 = 0.07).

There was no statistically significant interaction effect between time and group on TMD change from baseline, F (1,13) = 0.00, p>0.05, η^2 = 0.00 (Table 4-8). There was no statistically significant main effect for time F (1,13) = 0.13 or group F (1,13) = 0.71, p>0.05, η^2 = 0.05 on TMD change from baseline. The difference between the control (9.33 ±25.11) and intervention (3.00 ±18.29) groups TMD change from baseline post intervention (MD = 6.33, 95% CI: -19.55 to 32.2), was small (η^2 = 0.02). The difference between the control (6.56 ±17.13) and intervention (0.50 ±14.35) groups TMD change from baseline at follow-up (MD = 6.06, 95% CI: -12.30 to 24.41), was small (η^2 = 0.02).

There was no statistically significant interaction between time and group on fatigue change from baseline, F (1,13) = 0.22, p>0.05, η^2 = 0.02 (Table 4-8). There was no statistically significant main effect for time F (1,13) = 0.00, p>0.05, η^2 = 0.00 or intervention F (1,13) = 0.85, p>0.05, η^2 = 0.06 on fatigue change from baseline. The difference between the control (-3.78 ±10.77) and intervention (0.67 ±3.72) groups fatigue change from baseline post intervention (MD = -4.44, 95% CI: -14.42 to 5.53), was moderate (η^2 = 0.027). The difference between the control (-2.56 ±8.71) and intervention (-0.50 ±5.57) groups fatigue change from baseline at follow-up (MD = -2.06, 95% CI: -10.77 to 6.66), was small (η^2 = 0.02).

Table 4-8. Productivity, mood disturbance and fatigue change from baseline, measured post intervention and at follow-up for the control (n=9) and intervention (n=6) groups (Mean ±SD)

Group	Productivity (1-10)		Total Mood Disturbance		Fatigue	
	Post	**Follow-Up**	**Post**	**Follow-Up**	**Post**	**Follow-Up**
Control	-0.1 ±1.5	0.3 ±1.0	9.3 ±25.1	6.6 ±17.1	-3.8 ±10.8	-2.6 ±8.7
Intervention	0.3 ±1.0	-0.5 ±2.0	3.0 ±18.3	0.5 ±14.3	0.7 ±3.7	-1.7 ±7.4

4.4.6 Self-Reported Physical Activity and Sitting from the IPAQ

The was no statistically significant interaction effect between time and group on self-reported PA change from baseline, F (1,10) = 0.05, p>0.05, η^2 = 0.01 (Table 4-9). The was no statistically significant main effect for time F (1,10) = 0.31, p>0.05, η^2 = 0.03 or group F (1,10) = 0.07, p>0.05, η^2 = 0.01 on self-reported PA change from baseline. The difference between the control (-10.08 ±14.07) and intervention (10.30 ±23.37) groups self-reported PA change from baseline post intervention (MD = 0.023, 95% CI: -23.73 to 24.19), was extremely small (η^2 = 0.00). The difference between the control (-3.99 ±22.27) and intervention (-7.81 ±14.69) groups self-reported PA change from baseline at follow-up (MD = 3.82, 95% CI: -21.74 to 29.38), was small (η^2 = 0.01).

There was no statistically significant interaction effect between time and group on self-reported sitting time change from baseline, F (1,11) = 1.37, p>0.05, η^2 = 0.11 (Table 4-9). The was no significant main effect for time F (1,11) = 0.55, p>0.05, η^2 = 0.05 or group F (1,11) = 1.77, p>0.05, η^2 = 0.14 on self-reported sitting time change from baseline. The difference between the control (0.53 ±1.03) and intervention (-0.75 ±1.5) groups self-reported sitting change from baseline post intervention (MD = 1.28, 95% CI: -0.28 to 2.84), was very large (η^2 = 0.23). The difference between the control (0.36 ±1.46) and intervention (0.00 ±0.00) groups self-reported sitting change from baseline at follow-up (MD = 0.36, 95% CI: -1.29 to 2.01), was moderate (η^2 = 0.05).

Table 4-9. Change in self-reported physical activity and sitting from baseline, measured post intervention and at follow-up, for the control (n=9) and intervention (n=5) groups (Mean ±SD)

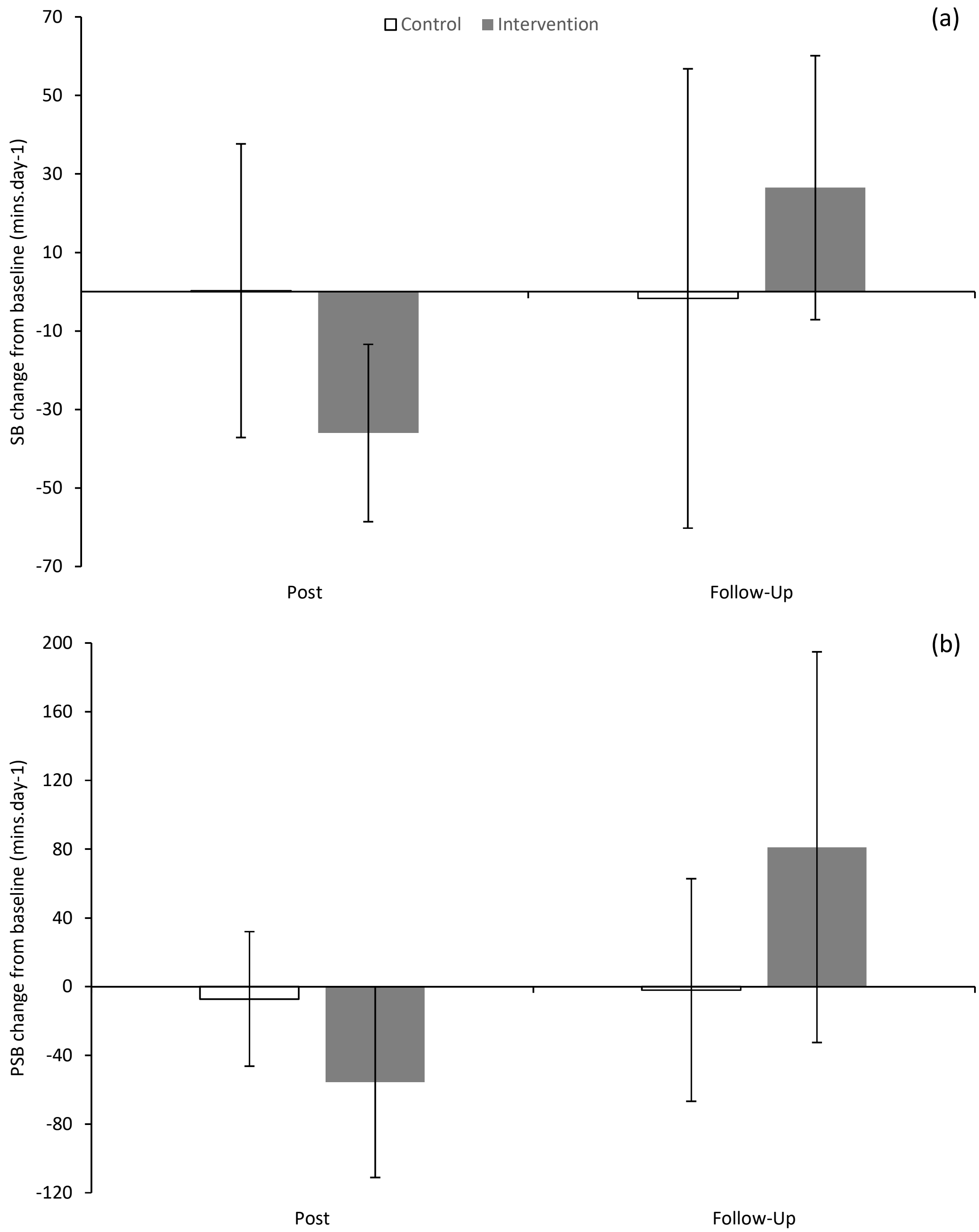
Group	Physical Activity (Hours.week^{-1})		Sitting (Hours.day^{-1})	
	Post	Follow-Up	Post	Follow-Up
Control	-10.1 ±14.1	-4.0 ±22.3	0.5 ±1.0	0.4 ±1.5
Intervention	-10.3 ±23.4	-7.8 ±14.7	-0.8 ±1.5	0.0 ±0.0

Note: n=7 for control group physical activity, n=4 for intervention group sitting

4.4.7 Accelerometer Assessed Sedentary behaviour

There was a statistically significant interaction effect between time and group on workplace SB change from baseline, F (1,8) = 5.97, $p<0.05$, $\eta^2 = 0.43$ (Figure 4-6). There was a statistically significant main effect for time F (1,8) = 5.42, $p<0.05$, $\eta^2 = 0.43$ but not for group F (1,8) = 0.02, $p>0.05$, $\eta^2 = 0.003$ on workplace SB change from baseline. There was no statistically significant difference between the control (0.33 ±40.03) and intervention (-35.00 ±28.93) groups workplace SB change from baseline post intervention; t (8) = 1.51, $p>0.05$. The magnitude of difference (MD = 35.33, 95% CI: -18.65 to 89.31) was very large ($\eta^2 = 0.19$). There was no statistically significant difference between the control (-1.17 ±58.52) and intervention (26.50 ±33.57) groups workplace SB change from baseline at follow-up; t (8) = -0.85, $p>0.05$. The magnitude of difference (MD = -27.67, 95% CI: -103.02 to 47.69) was large ($\eta^2 = 0.11$).

There was a statistically significant interaction effect between time and group on workplace prolonged SB change from baseline, F (1,8) = 13.413, $p<0.05$, $\eta^2 = 0.63$ (Figure 4-6). The was a statistically significant main effect for measurement time F (1,8) = 12.285, $p<0.05$, $\eta^2 = 0.61$ but not for intervention group F (1,8) = 1.555, $p>0.05$, $\eta^2 = 0.02$ on workplace prolonged SB change from baseline. There was no statistically significant difference between the control (0.83 ±28.67) and intervention (-47.75 ±69.84) groups workplace prolonged SB change from baseline post intervention; t (8) = 1.51, $p>0.05$. The magnitude of difference (MD = 48.58, 95% CI: -23.47 to 120.64) was very large ($\eta^2 = 0.20$). There was no statistically significant difference between the control (-2.00 ±64.86) and intervention (81.25 ±113.69) groups workplace prolonged SB change from baseline at follow-up; t (8) = -1.492, $p>0.05$. The magnitude of difference (MD = -83.25, 95% CI: -211.95 to 45.45) was very large ($\eta^2 = 0.27$).



Note: Sedentary behaviour (SB), prolonged sedentary behaviour (PSB)

Figure 4-6. Change in workplace sedentary behaviour (a) and workplace prolonged sedentary behaviour (b) from baseline, measured post intervention and at follow-up, for the control (n=6) and intervention (n=4) group (Mean ±SD)

4.4.8 Exercise Intervention Completion

The number of prescribed exercise sets completed and percentage of participants who achieved this, are presented in Table 4-10.

Table 4-10. The percentage of participants and number of exercise sets completed, for the prescribed workplace intervention.

Exercise Sets Completed	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80
Participants (%)	20	-	10	10	-	20	20	20

4.5 Discussion

The major findings of this study were that implementing a calisthenics workplace intervention, resulted in considerable reductions in both overall and prolonged periods of sitting, while at work. This was associated with improving balance ability, observed after additional recovery and adaptation post intervention. Completing the intervention did not impair work performance and provides support for implementing PA interventions within the workplace.

4.5.1 Calisthenics Exercise Intervention

4.5.1.i Balance

The primary purpose of this study, was to investigate if completing a calisthenics exercise intervention within the workplace, was able to improve components of physical capability, measured using balance, grip strength and leg power. Following the two-week intervention there was little change in composite or anterior balance, for both the control and intervention groups. The slight improvement observed for both groups was likely due to learning effects of the balance test. When measured one week later at follow-up, the intervention groups composite and anterior balance had increased by a greater amount from baseline, compared to the control group. The greater increases were associated with moderate and very large effect sizes. This change in balance between groups, from post intervention, to one week later, when measured at follow-up, may indicate that the intervention group continued to recover and adapt. Therefore, improvements in balance were not being observed until when measured a week following the intervention.

The increases seen in both composite and anterior balance in intervention group, were 1-3% greater compared to the control group; anterior balance increases were greater than composite balance improvements. The squat and lunges completed during the intervention may explain why greater increases were observed in anterior balance, due to the anterior component of the balance test, requiring a similar movement to a single leg squat. The calisthenics exercises would provide good upper leg strength training, which would facilitate performance on the anterior portion of the test. Sitting exposes the legs to large periods of inactivity, which has been shown to be associated with very low leg muscle activation (Tikkanen et al., 2013). Therefore, in these sedentary individuals, the increases in leg muscle activation, required to complete the calisthenics exercises, provide greater training to anterior balance. Stronger associations were found between SB and anterior balance compared to composite balance, in the previous chapter (section 3.5.2). This would support why breaking up and reducing SB using the exercise intervention, would provide greater increases in anterior balance.

As discussed previously (section 4.2.4), when a similar calisthenics intervention was conducted with younger university students in pilot research, a greater increase was also observed in anterior balance compared to composite. The intervention resulted in greater balance improvements compared to those observed in this study, even though only conducted over a shorter one-week period. This may be due to younger participants being more able to conduct the required calisthenics exercise movements, resulting in greater training benefits. The improvements observed in the current study, still likely represent a meaningful increase in balance, with the intervention only being completed over a two-week period. More research is required to determine if greater balance improvements would continue to occur, with an intervention of longer duration.

4.5.1.ii Handgrip Strength

A second component of physical capability which was assessed to determine if the exercise intervention was improving physical capability, was handgrip strength. When measured post intervention there was little change in grip strength in both groups, with the control slightly increased and the intervention slightly reduced from baseline. At follow-up, the control group had a slightly reduced grip strength compared to baseline, the intervention group remained similar to when measured post intervention. The small changes observed in grip strength were only associated with small to moderate effect sizes. It appears that completing the calisthenics exercises in this study did not provide improvements in grip strength, as may have been expected. Only one of the five calisthenics exercises completed during the intervention required use of the arms (arm circles). Therefore, it may be that the calisthenics exercises used in this intervention, do not offer a great enough training stimulus, to increase the grip strength in the arms. If as discussed in the previous chapter (section 3.5.3), individuals who work in sedentary occupations have reduced grip strength, there is a need for interventions to further address this. An exercise intervention incorporating more upper body exercises, may be more effective in providing improvements in grip strength; research is required to investigate this.

4.5.1.iii Jump Power

The final component, assessed to determine if the exercise intervention was improving physical capability, was jump power. There was little change from baseline in the PAP of both groups, when measured post intervention. When measured a week later at follow-up, the change remained minimal from baseline for both groups, with the intervention group remaining slightly reduced. The differences in peak power were associated with small effect sizes and overlapping confidence intervals. This suggests the calisthenics exercise intervention was not providing improvements in peak leg power, as may have been expected. The exercises were completed at a steady tempo, which may not provide an adequate training stimulus for an explosive movement, as required during a single maximal jump.

Average leg power increased from baseline for both groups, both post intervention and at follow-up. The increase observed across both groups is likely due to becoming more accustomed to the repeated jump test protocol. The increase observed from baseline was slightly greater in the intervention group compared to the control group, with the greatest difference between groups observed at follow-up. However, the difference between groups was small, with small effect sizes and overlapping confidence intervals. Calisthenics exercises may be more likely to improve AvP compared to PAP, due to providing a more muscular endurance training stimulus. As with balance, the greater increase observed between groups at follow-up, may indicate a recovery element, and explain the continued improvement in performance. If the increases observed in anterior balance were due to improvements in leg muscle function, it is unexpected that increases in leg power would not also be observed. More work is needed to determine if the small increases observed in AvP were due to the exercise intervention. If conducted over a longer duration with improved compliance, the intervention may result in greater changes in leg power and support how interrupting SB using calisthenics, improves leg muscle function.

In contrast, previous research in older adults, associated breaks in ST and increased time in MVPA, with improved lower extremity function (Davis et al., 2014). Therefore, if the intervention was increasing the frequency of SB interruption and providing additional engagement in PA, it would be expected improvements in leg power would be observed.

4.5.2 Productivity, mood and fatigue

A secondary research question of this study was to determine if completing the calisthenics exercise intervention would affect productivity, mood and fatigue. The intervention did not appear to have much effect on the productivity of the intervention group. There was little difference between the change from baseline, when comparing both groups post intervention and at follow up. Completing the exercise intervention did not therefore appear to reduce the productivity of the intervention group. Previous work using a workplace intervention to reduce SB, was also said not to impair the productivity of workers (Thorp et al., 2014). This provides support for how employers can implement interventions to assist their employees in becoming more active, without having a detrimental effect on work performance.

The intervention group appeared to have less mood disturbance than the control group, both when measured post intervention and at follow-up. However, the confidence intervals and small effect sizes suggest there was quite a lot of variance in the difference between groups. It is therefore not possible to determine if the exercise intervention was having a beneficial effect upon mood and more research is required to further investigate this.

Completing the exercise intervention did not appear to change the fatigue of the intervention group. There was no interaction, with a small effect size between time and group on fatigue scores. This suggests that completing the exercise intervention was not increasing levels of fatigue. Completing the exercise intervention did not provide reductions in fatigue as shown when breaking up workplace sitting using adjustable workstations, to transition from periods of sitting to standing (Thorp et al., 2014). The trial was conducted in a simulated work environment, with obese/overweight individuals and may explain why we did not see improvements in fatigue, when interrupting sitting in this study. Fatigue was also assessed using a more detailed multi-component questionnaire, which may be more appropriate for assessing fatigue in a working population.

This suggests that completing a workplace exercise intervention did not impair productivity or have a detrimental effect on mood and fatigue of workers. Highlighting how it is possible to allow individuals to take time to interrupt their occupational sitting, with small amounts of PA without having a detrimental effect on work performance.

4.5.3 Sedentary Behaviour & Physical Activity

The final question in this research was to investigate if completing a calisthenics exercise intervention, changes workplace SB. The intervention group did not perceive they were completing more PA during the intervention period. Perceived PA was reduced from baseline; however, this was also observed in the control group and likely represents different working conditions between the two-time periods. A week later, at follow-up, perceived PA was increased in both groups but was still below the level reported at baseline. This likely suggests changes in self-reported PA were not occurring in response to completing the exercise intervention.

Self-reported sitting was perceived to be reduced by those completing the intervention compared to the control group. One-week post intervention, the perception of sitting was similar across both groups and had returned to levels similar to baseline. This appears to suggest that while completing the exercise intervention, individuals were perceiving they sat less but not that they were conducting additional PA. Due to the small amount of time required to conduct a set of the exercises, it may be that individuals do not perceive they are having to conduct additional PA. This could be important for engaging with individuals who do not like participating in exercise, when incorporating small bouts of activity in workplace interventions.

Accelerometry was used to objectively investigate how completing calisthenics exercise intervention, altered workplace SB. In the control group, SB remained similar both during the intervention period and at follow-up. This is as expected and likely represents how the requirements to sit were similar between work weeks. In the intervention group, when completing the exercises, workplace sitting was reduced. This was shown for both overall sedentary and prolonged sedentary periods. This suggests the intervention was effective at reducing prolonged periods of inactivity at work, which is important for previously discussed (section 2.5) health benefits, associated with reducing periods of prolonged sitting. This further highlights how it is unexpected that improvements in jump power were not observed, as the intervention was increasing SB interruption, which has been previously associated with increased lower extremity function in older adults (Davis et al., 2014).

The reduction observed in workplace sitting while conducting the exercise intervention, was 35 minutes per day. The prescribed sets of exercise only required 16 minutes a day to complete, so interestingly, implementing the intervention resulted in additional SB reduction, outside of the time required to complete the exercises. The reductions in SB were similar to those observed during an intervention trialling STSWs, which requires the costly implementation of new workstations (Neuhaus et al., 2014b). Using calisthenics exercises resulted in comparable reductions in sitting, while also providing additional engagement in PA, while occurring no additional costs. These reductions in SB might have been even greater, if all participants had conducted the full prescription of exercises. Calisthenics exercises therefore appear a more cost effective and practical intervention, which could be implemented in the workplace to reduce sitting, while also providing increases in PA levels.

Interestingly, at follow-up, the intervention group were even more sedentary than at baseline. There was an even greater increase in the amount of time being spent in prolonged sedentary periods, so SB was being interrupted less frequently. It may be that in response to having completed exercises in the previous weeks, individuals were less aware with how sedentary they were. It is unlikely they sat more due to being fatigued, as they reported being slightly less fatigued than when measured the previous week, following the intervention. More research is required to determine how behaviour changes in response to workplace interventions which reduce SB. Interventions of a greater durations may be more effective in causing permanent behaviour change. It has been suggested previously that a behaviour needs to be repeated for 66 days, for it to become habit (Lally et al., 2010). Workplace interventions should be trialled over longer periods, to determine if greater durations (2-3 months) are able to permanently change SB.

4.5.4 Baseline Comparison

Due to the explanatory nature of this pilot intervention research and small sample size, an intention to treat analysis was not conducted. The purpose of this research was to determine if individuals who completed the intervention had improved physical capability; including individuals who did not complete the intervention in the primary analysis, would have masked this effect. It is however interesting to consider possible motives for failing to complete the exercise intervention, to assist in designing and implementing future work place interventions. During this intervention, 40% of individuals in intervention group did not complete sufficient exercises and were considered to have dropped out. For an intervention to provide its associated benefits it is very important that individuals adhere to it. Comparing measures at baseline it is possible to investigate potential causes that led to some individuals dropping out of the intervention. Body composition was similar among all groups, so it does not appear being more overweight was related to dropping out of the intervention.

Those who dropped out of the intervention appear to have both worse composite and anterior balance, than the individuals in both the control and intervention groups. Due to the nature of the calisthenics exercises, having impaired balance would make them more difficult to complete. Therefore, individuals with worse balance may have not been as comfortable or found the exercises too difficult, limiting the amount they could complete or leading them to drop out completely. This is interesting, as individuals with low balance are more likely to gain training benefits from completing the exercises, so the individuals who may potentially benefit the most could be missing out. Relative to the other groups, individuals in the non-adherer group had similar handgrip strength and average leg power. However, they did have reduced peak leg power in comparison, which may indicate reduced muscular fitness in the legs compared to the other groups. As with reduced balance, a reduction in muscle capability in the legs may impair the ability to complete the required calisthenics exercises. More research is needed to investigate non-adherer in workplace exercise interventions and how physical capabilities may affect the ability to complete exercise interventions.

When considering work performance, the non-adherer group were similar to the other groups. Therefore, it was unlikely that their productivity and motivation had an impact on the completing of the intervention. Individuals in the non-adherer group reported more disturbed mood and less fatigue compared to the other groups. It is possible the mood disturbance affected their desire to complete the exercises.

When monitored objectively the non-adherer group reported sitting comparable to the other groups; subjectively they perceived they sat slightly less. If individuals believe they sit less, then they may be less motivated to engage with interventions aimed at interrupting workplace sitting, than those who think they sit more. Perception of PA levels was similar among all groups, so it is unlikely this was affecting intervention adherence.

4.5.5 Limitations

There are some limitations which may have reduced the effectiveness of this calisthenics workplace intervention and should be considered in future work. To remain in the intervention group, it was required that individuals complete at least half of the prescribed sets of exercise. This still left many of the intervention group who did not complete the full eight sets of exercises a day, over the two-week period. Failure to complete the intervention fully may have limited training benefits and therefore potential associated improvements in physical capability. The intervention was conducted on work days over two weeks, this may not be sufficient time for adequate adaptation to occur, to improve the measured components of physical capability. Future research should trial workplace exercise interventions over a greater duration, to investigate if this results in greater improvements in physical capability. The calisthenics exercises used were mainly comprised of lower body movements. Future research should trial exercises requiring more upper body involvement, to determine if this can provide improvements to upper body physical capability, such as grip strength. The measures used to assess physical capability were quick and simple to conduct in the field. Future work in younger adult populations may be more effective if using more sensitive laboratory tests, which may be better at detecting small change.

The monitoring of the intervention completion was self-reported by individuals. It is not possible therefore to be certain the reported completed exercises were accurate; future work should attempt to objectively track intervention compliance. In this intervention, there were no additional behaviour change techniques included, which may assist in adhering to the exercise. As discussed previously (section 2.8) interventions to reduce SB have been shown to be more effective when containing multiple components. When multiple components were included in a sit to stand intervention, it resulted in three times the reduction in sitting, compared to providing the work station alone (Neuhaus et al., 2014b). Future work should investigate the prescription of a calisthenics workplace intervention along with additional behaviour change techniques, such as management consolation, staff education and reminder procedures. These additional components may increase adherence, which could facilitate greater improvements in physical capability and other associated health benefits, in response to reducing SB and increasing PA.

Using accelerometry may have led to inaccurate monitoring of workplace SB and the limitations and possible solutions to resolve this, were previously discussed in more detail in section 3.5.6.i.

4.5.6 Conclusion

In conclusion, for the first time this study implemented a calisthenics workplace exercise intervention, aimed at breaking up periods of prolonged SB. Balance improved in response to the intervention but this was not observed until follow-up, likely due to recovery occurring once the intervention had been completed. Handgrip strength and leg power did not appear to improve in response to the intervention; the exercises used and the duration of the intervention may not have been sufficient for this to occur. Conducting the workplace exercises did not appear to impair, productivity, mood and fatigue, suggesting completing workplace exercise interventions, does not detrimentally affect work performance. The intervention was effective in reducing the overall time spent sedentary at work, including reducing time spent in prolonged sedentary periods. One-week post intervention, at follow-up, individuals were even more sedentary during work hours than at baseline. This suggests interventions are required over greater periods to induce permanent changes in behaviour. Future work should investigate motives and beliefs which affect engagement in interventions, as this is vital for their successful implementation. There is a need to trial future workplace exercises interventions over longer durations, which incorporate multiple components, assisting in behaviour change. This may result in more effective reductions in workplace SB, while enhancing PA levels and provide benefits to health.

5.0 Chapter 5: Conclusions and Implications of Research

5.1 Main Findings of Research

5.1.1 Sedentary Behaviour & Physical Capability

The first study in this thesis (section 3.0) investigated associations between SB and components of physical capability, in adults below retirement age, who worked in a sedentary occupation. These individuals were extremely sedentary compared to the general population, spending almost three quarters of their work time inactive. Balance was independently associated with time spent in both overall and prolonged SB for males, but not females. These associations were not observed with worktime SB, which may suggest activities occurring during leisure hours, are associated the maintenance or improvement of balance. Conversely, associations were not observed between time spent in SB and grip strength in this population. There were weak associations between SB and walk speed in males, which may further support associations between increased SB and reduced physical capability. The grip strength and FWS of both males and females, was relatively reduced, compared to UK population norms. This suggests physical capability is already reduced in all these individuals, which may affect the ability to detect associations with SB.

5.1.2 Calisthenics Workplace Intervention

The second study in this thesis (section 4.0) implemented a two-week workplace intervention, using calisthenics exercises, to break up sitting. Completing the intervention resulted in an improvement in balance, a component of physical capability but this was not observed until measured one-week post intervention. The delay before the improvement in balance was observed, is likely due to additional recovery and adaptation occurring, once the requirement to conduct the exercises was completed. Completing the exercise intervention, over a two-week period, did not appear to increase grip strength or jump ability. A two-week intervention period may not provide sufficient training for increases to be observed, in these measures of physical capability. Completing the intervention did not increase fatigue, reduce productivity or increase mood disturbance. This suggests it was possible to implement small periods of PA during workplace hours, without impairing work performance. The intervention was effective in reducing overall time spent sedentary and increasing the frequency SB interruption, during work hours.

5.2 Practical Implications

5.2.1 Physical Capability & Health

The extremely high levels of sitting and relatively lower grip strength and fast walk speed, observed in the individuals in study one, may represent how a highly sedentary lifestyle is already impairing physical capability, in adults below retirement age. If physical capability is already being impaired at a younger age, this may lead to less healthy ageing and increase the risk for future adverse health outcomes. There are already many adults in the UK failing to achieve government recommended guidelines on PA and sitting (Nhs, 2012). There is therefore an urgent need to provide more opportunities, to assist individuals in reducing sitting and increase participation in physical activity. Implementing interventions during workplace hours, would target high periods of inactivity and provide additional opportunities to engage in PA. This may improve the fitness and capability of individuals, which could improve confidence and motivation and lead to additional engagement in PA outside of work hours. Together this may improve the physical capability and well-being of individuals, facilitating more healthy ageing and improve QoL.

The observed associations between balance and SB, for males but not females, may indicate time spent in SB may affect men and women differently. If this is the case, there may be a need for guidelines to provide sex specific recommendations, on how sitting is accumulated.

5.2.2 Workplace Interventions

The reductions observed in workplace SB, when implementing the calisthenics exercise intervention, support its effectiveness in reducing and breaking up workplace sitting. The exercise intervention resulted in similar reductions in sitting compared to trials using adjustable workstations (Neuhaus et al., 2014b), which are costly to implement. A calisthenics exercise intervention is low cost and may therefore be more easily implemented across highly sedentary work environments, to reduce and break up prolonged sitting. This may provide improvements to balance, as observed during the current intervention, along with providing cardiometabolic benefits, associated with interrupting SB using calisthenics exercises (Carter et al., 2015, Carter and Gladwell, 2016).

A large barrier to implementing exercise interventions within the workplace, is the effect this may have upon productivity. The results of this intervention suggest completing the exercises did not impair workplace productivity or increase fatigue. This supports how employers can provide the opportunity to conduct a small amount of PA during work hours, which is beneficial for health, without detrimentally affecting work performance.

5.3 Future Research & Challenges

5.3.1 Physical Capability

Research should build on and further investigate work conducted in this thesis, to provide more understanding into associations between physical capability and SB, in adults below retirement age. Investigating associations between SB and physical capability across a more diverse population, encompassing different work environments, may provide individuals with more varied SB. This would assist in determining if the relatively weaker grip strength and walk speed observed in this research, is due to being exposed to high levels of inactivity. If relative reductions are observed across a more diverse population and not associated with SB, it may indicate that reductions in physical capability are due to insufficient engagement in PA.

Associations between SB and balance were only observed for males in the current work, future research should expand on this to provide more insight into possible sex specific associations, between SB and physical capability. Reductions in balance were associated with time spent in both overall and prolonged SB, in males. Future work should investigate further, to determine if the overall time spent sedentary or the frequency of SB interruption, is more strongly associated with balance.

5.3.2 Workplace Interventions

The intervention implemented in this research was of a short two-week duration, future work should investigate the effect of implementing a workplace exercise intervention over a more prolonged period. This may provide an increased training stimulus and provide greater improvements to physical capability, not observed during this research. Interventions of greater duration (>3 months), may also provide further understanding into their effect to provide permanent behaviour change.

The exercises used in the current research mainly required the use of the lower limbs and may explain why there were no improvements observed in grip strength. Future work should investigate the effect of incorporating more upper body movements in workplace exercise interventions, to determine if this can provide increases in upper body components of physical capability. The measures used to assess components of physical capability in this research, were chosen due to the speed and ability to be conducted in the field. Future work may be more able to detect physical capability changes in response to an exercise intervention, if conducted using more sensitive tests.

Future research faces the challenge of increasing intervention compliance, as not all individuals conducted the intervention sufficiently, as prescribed, in the current trial. Interventions including additional components, such as staff education, reminder prompts and coaching, may increase the intervention effectiveness, as has been observed in previous work (Neuhaus et al., 2014a).

5.3.3 Monitoring Sedentary Behaviour & Physical Activity

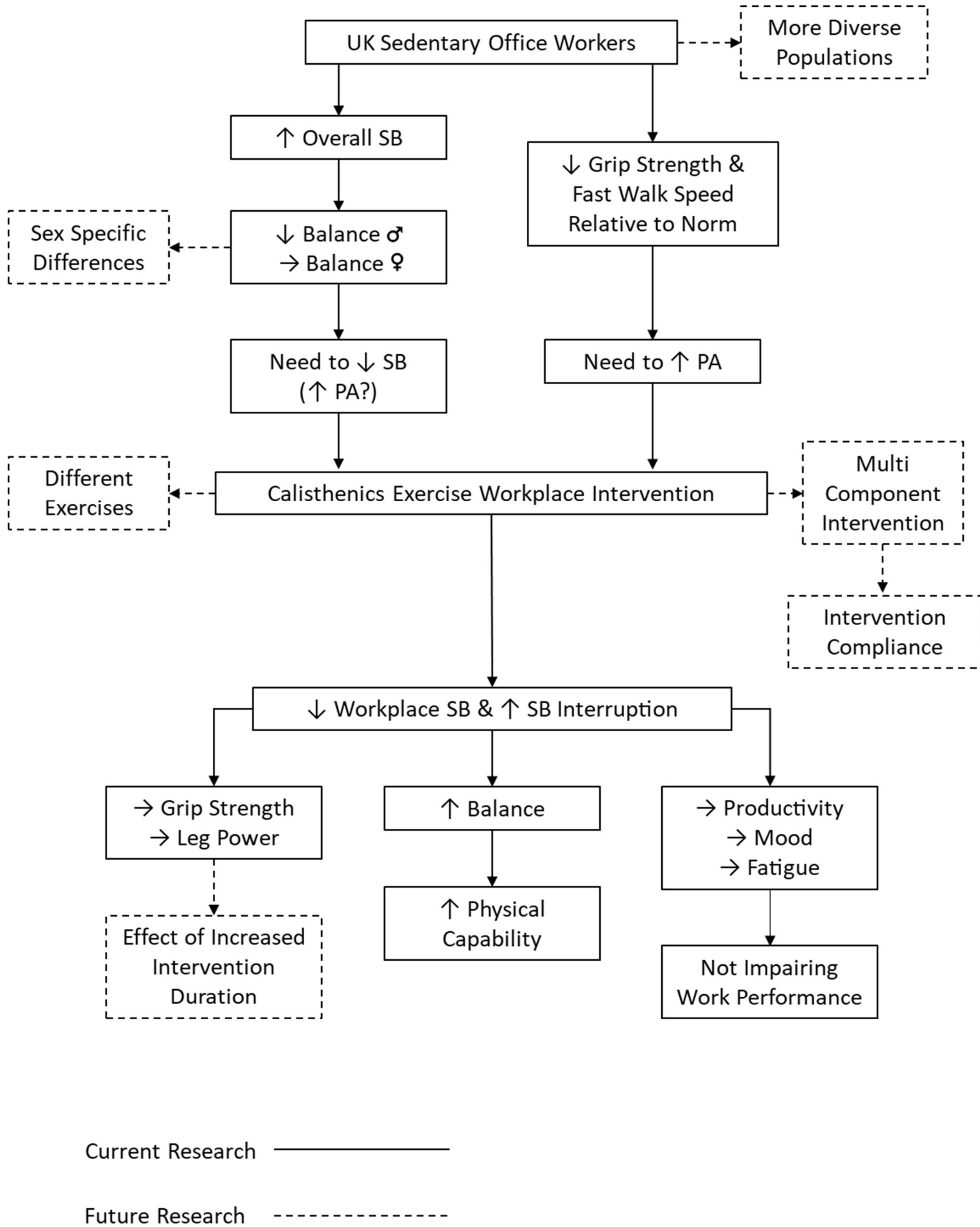
As highlighted by the current research, to investigate associations with SB or monitor changes in SB due to an intervention, there is a need to objectively measure free living behaviour. There are challenges which future research needs to address, to ensure the assessment of SB is more accurate. As previously discussed (section 3.5.6.i), using accelerometry cut points to determine SB may lead to misclassification of activities, such as inactive standing being considered sitting. Future research should attempt to use devices which better detect posture allocation, which has been suggested to provide more accurate SB measurement (Kozey-Keadle et al., 2011, Kim et al., 2015a). The analysis of raw accelerometer signals may provide another method by which SB can be more accurately detected (Lyden et al., 2014).

When monitoring overall daily SB, there were differences between individuals in reported wear time, which requires adjustment. As discussed previously in more detail (section 3.5.6.i), this adjustment using regression may result in a less accurate representation of true SB. Future research assessing SB should attempt to monitor over 24-hour periods, removing the need to conduct wear time adjustment. Future research should collect accelerometer data for greater durations than conducted in this research, as it has been suggested 6-8 days of valid wear is required, to accurately represent normal SB (Aadland and Ylvisaker, 2015). Workplace SB was considered from periods between 9am-5pm on weekdays, during the current research. Future research should provide individuals with work diaries and cross reference with accelerometer data, to more accurately analyse periods of workplace SB.

In the current research accelerometry was only used to assess SB and PA was not considered. As previously discussed in more detail (section 3.5.6.i), measuring PA using accelerometry cut points, could lead to misclassifying or not detecting important activity, such as resistance training. This activity could be of vital concern when considering associations with health; a challenge for future research is to detect or monitor all PA. This is of vital importance when determining if too much SB or too little PA, is responsible for detrimental associations with health and fitness.

5.3.4 Conclusion

The primary aim of this thesis was to expand on work in older adults and investigate physical capability and SB, in adults below retirement age (Figure 5-1). The findings suggest in these extremely sedentary office workers, physical capability was impaired, compared to the general population, which may be due to high levels of inactivity. Further research with more diverse populations, will provide more understanding into what may be causing these reductions in physical capability. A calisthenics exercise intervention, represents an effective mode by which workplace inactivity can be reduced and may offer improvements to physical capability. Future work should expand on this and determine if multi-component interventions, conducted over a greater duration, may be more effective.



Note: Physical activity (PA)

Figure 5-1. Summary of research investigating sedentary behaviour (SB) and physical capability in UK office workers

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7.0 Appendices

7.1 Wear Time Diary

Day 1 - Thursday	
Accelerometer Wear Time	
Time first equipped:	
Time removed at end of day:	
Other periods of non-wear: (Please provide times & reason for removal)	
Work Hours	
Did you work today?	Yes / No (If yes please provide information below)
Mode of commute:	
Time arrived at work:	
Time finished at work:	

Day 2 - Friday	
Accelerometer Wear Time	
Time first equipped:	
Time removed at end of day:	
Other periods of non-wear: (Please provide times & reason for removal)	
Work Hours	
Did you work today?	Yes / No (If yes please provide information below)
Mode of commute:	
Time arrived at work:	
Time finished at work:	

Day 3 - Saturday	
Accelerometer Wear Time	
Time first equipped:	
Time removed at end of day:	
Other periods of non-wear: (Please provide times & reason for removal)	
Work Hours	
Did you work today?	Yes / No (If yes please provide information below)
Mode of commute:	
Time arrived at work:	
Time finished at work:	

Day 4 - Sunday	
Accelerometer Wear Time	
Time first equipped:	
Time removed at end of day:	
Other periods of non-wear: (Please provide times & reason for removal)	
Work Hours	
Did you work today?	Yes / No (If yes please provide information below)
Mode of commute:	
Time arrived at work:	
Time finished at work:	

Day 5 - Monday
Accelerometer Wear Time
Time first equipped: Time removed at end of day: Other periods of non-wear: (Please provide times & reason for removal)
Work Hours
Did you work today? Yes / No (If yes please provide information below) Mode of commute: Time arrived at work: Time finished at work:

Day 6 - Tuesday
Accelerometer Wear Time
Time first equipped: Time removed at end of day: Other periods of non-wear: (Please provide times & reason for removal)
Work Hours
Did you work today? Yes / No (If yes please provide information below) Mode of commute: Time arrived at work: Time finished at work:

7.2 Exercise Log Book

Participant ID: Date:

Calisthenics Exercise Logbook

You have been assigned to the calisthenics exercise group and I therefore require you to complete the bodyweight exercises once per hour, for eight hours of your working days.

Please only complete and record exercises on days you work.

Day	Date	Number of exercises sets completed? (Once per hour)
1		out of 8
2		out of 8
3		out of 8
4		out of 8
5		out of 8
6		out of 8
7		out of 8
8		out of 8
9		out of 8
10		out of 8
11		out of 8
12		out of 8
13		out of 8

7.3 Calisthenics Exercises Information Sheet

PARTICIPANT INFORMATION SHEET- BODY WEIGHT EXERCISES

If assigned to the calisthenics group you will be required to complete the following bodyweight exercises during weeks two and three of the study. These will be completed once every hour while at work, for eight hours of the working day.

Each time you will perform five different exercises in the following order:

1. Squats
2. Arm Circles
3. Calf Raises
4. Knees to Elbows
5. Lunges

Please read the following information regarding how the exercises should be performed:

- You will complete the exercises for a total of 2 minutes.
- You will perform 8 repetitions of each individual exercise.
- It should take you 3 seconds to complete 1 repetition of each individual exercise.
    - Therefore, you will perform each different exercise for a total 24 seconds.
- Once one exercise is complete you should move straight into the next exercise e.g. squats into arm circles.

Please look at the pictures below and read the information so you are aware how each exercise should be performed during testing.

1. **Squats**

How to Perform

1. Stand with feet shoulder-width apart, arms out in front of you
2. Bend your knees and lower body downwards as though you are going to sit in a chair. Your knees should stay behind the toes
3. Squat as low as you can or until the thighs are parallel to the floor
4. Push back up to standing position
5. Repeat

Tempo of Exercise

1. 1 second to bend your knees and lower your body to the floor
2. 1 second to extend your knees and return to the starting position
3. 1 second to recover

2. Arm Circles

How to Perform

1. Stand with feet hip width apart
2. Lift your arms out to the side with a slight bend in your elbows
3. Rotate arms at the shoulder in a clockwise direction so they extend fully above your head and down to your hips
4. Repeat

Tempo of Exercise

1. Complete one complete circle within the 3 seconds
2.

3. Calf Raises

How to Perform

1. Stand with feet shoulder width apart
2. Raise your heels off the floor
3. Return to the starting position by slowly lowering your heels
4. Repeat

Tempo of Exercise

1. 1 second to raise off your heels
2. 1 second to lower back to starting position
3. 1 second to recover

4. Elbow to Knees

How to Perform

1. Stand with your feet hip-width apart and hands behind your head with your elbows bent and out to the sides
2. Bring the right knee up and across the body and bring your left shoulder towards the right hip.
3. Return to start
4. Repeat on opposite side

Tempo of Exercise

1. 1 second to bring your knee towards your elbow
2. 1 second to return to the starting position
3. 1 second to recover

5. Lunges

How to Perform

1. Place hands by your sides and step forwards with your right leg
2. Bend your knee and lower your body towards the ground
3. Stand up, bringing your right leg back in-line with your left leg
4. Repeat movement, stepping forwards with your left leg

Tempo of Exercise

1. 1 second to bend your knees and lower your body to the floor
2. 1 second to extend your knees and return to the starting position
3. 1 second to recover

7.4 Workplace Productivity Questionnaire

Participant ID: Date:

On a scale from 0 to 10 where 0 is the worst job performance anyone could have at your job and 10 is the performance of a top worker, how would you rate your overall performance on the days you worked during the last 7 days?

Worst Performance										Top Performance
0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**