PHYSICAL ACTIVITY VS SEDENTARY BEHAVIOUR AT WORK: INDEPENDENT ASSOCIATIONS WITH WORK- AND HEALTH-RELATED OUTCOMES IN ADULTS

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A thesis submitted in partial fulfilment of the requirements of Liverpool John Moores University for the degree of Master of Philosophy

October 2017

Abstract

Background: Physical activity (PA) and sedentary behaviour (SB) have been shown to be independent risk factors for adverse health outcomes in adults such as diabetes, obesity and chronic heart disease. Little is known however about the independent associations between worktime PA, worktime SB and absenteeism, presenteeism, body composition and musculoskeletal troubles. The aim of this study was to examine independent associations between worktime PA, worktime SB, and absenteeism, presenteeism, body composition and musculoskeletal problems in a representative population of adult workers in the North West of England. **Methods:** 134 sedentary workers (64.2% female, mean age 44.6 ± 9.3 years) received an ActiGraph tri-axial accelerometer to measure PA and SB. The Work Limitations Questionnaire assessed absenteeism and presenteeism, the 27-item Nordic Musculoskeletal Questionnaire assessed musculoskeletal trouble, and body mass index was the body composition marker. **Results:** There was a significant and positive association between worktime SB and reduced Output (OR = 1.01; 95% CI: 1.00 to 1.02, P = 0.047). Increasing worktime LPA by 10 minutes/day was significantly associated with a decrease in expected number of days off in the previous 12 months by a factor of exp(-0.1243)=0.883 or 11.7% (*P* = 0.044). Increasing MVPA by 10 minutes/day was significantly associated with an increase of 12-month absenteeism by a factor of exp(0.1239)=1.132 or 13.2% (*P* = 0.044). No significant associations were found between worktime PA, worktime SB, and BMI or musculoskeletal troubles. **Conclusions:** Worktime LPA decreases the expected days absent in the last 12 months; while MVPA increases expected days absent in the last 12 months. No other significant associations were found between worktime LPA, MVPA, total PA and musculoskeletal trouble, 2-week absence, BMI or presenteeism. No significant

relationships were found between worktime SB and presenteeism, absenteeism, BMI or musculoskeletal troubles. Therefore, this would suggest worktime PA rather worktime SB should be targeted in future workplace health interventions.

Acknowledgements

Firstly, I would like to thank my supervisory team Dr Lee Graves, Dr Rebecca Murphy and Dr Sam Shepherd. A special thank you goes to my director of studies, Dr Lee Graves who guided me constantly throughout the year and was never far away when I needed him. I can confidently say without his help I would not have been able to complete this MPhil, both to the standard it is and literally – he informed me about the post. Another thank you goes to Dr Andrew Thompson who agreed to help late on with running the statistical tests and ensuring all was correct.

A big thank you to the undergraduate students who helped with my data collection (David, Luke, Richie, Matty and Tom), without them, I would have not been able to achieve the numbers I did. Additionally, a thank you to all the PAEx team, both students and staff, for making it an enjoyable environment to work in and provide a helping hand whenever needed. It has been a good year, with good people and a lot of good times – so thanks!

Finally, I would like to thank my family, for without them it is unlikely I would have gone to university, never mind continue to postgraduate level. They have provided continual support, whether it be 'a touch' financially or just a calming influence.

Declaration

I declare that the work within this thesis is entirely my own.

Poster communications

Rourke, S., Murphy, R., Shepherd, S.O., Graves, L.E.F. Associations between sedentary behaviour, physical activity and absenteeism, presenteeism, job satisfaction and musculoskeletal symptoms in UK workers *Graduate School Research Conference, 2017.*

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List of Abbreviations

BMI	Body mass index
CVD	Cardiovascular disease
IPAQ	International physical activity questionnaire
LPA	Light physical activity
METs	Metabolic equivalents
MPA	Moderate physical activity
MVPA	Moderate-vigorous physical activity
PA	Physical activity
SB	Sedentary Behaviour
VPA	Vigorous physical activity
WLQ	Work limitations questionnaire

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CHAPTER 1

LITERATURE REVIEW

1.1 Physical Activity and Sedentary Behaviour

Caspersen, Powell and Christenson, (1985) defined physical activity (PA) as “any bodily movement produced by skeletal muscles that results in energy expenditure” (p.126). Expressed as metabolic equivalents of task (METs), PA intensity in adults is categorised into light (1.5-2.99 METs), moderate (3-5.99 METs) and vigorous (>6 METs) intensities. Sedentary behaviour (SB) conversely is defined as “any waking behaviour characterised by an energy expenditure ≤1.5 METs, while in a sitting, reclining or lying posture” (Tremblay et al., 2017, p. 9). Both behaviours can occur in various environments (e.g. the workplace, home, community) and for different purposes (e.g. occupation, leisure, transport).

SB should not be used interchangeably with physical inactivity, as both have different determinants (Pearson *et al.*, 2014). Physical inactivity is recognised as the failure to meet current national guidelines of 150 mins/week moderate PA (MPA) or 75 mins/week vigorous PA (VPA; Department of Health, 2011). Similarly, PA should not be confused with exercise, as while they share common elements, exercise is a subcategory of PA defined as “planned, structured, repetitive and purposive in the sense that improvement or maintenance of one or more components of physical fitness is an objective’ (Caspersen, Powell and Christenson, 1985, p.128).

1.2 Relationship between Physical Activity, Sedentary Behaviour and Physical Health

1.2.1 Non-communicable Disease and All-cause Mortality

PA has a curvilinear dose-response relationship with risk of diseases such as type 2 diabetes and coronary heart disease, with the greatest risk reduction occurring when shifting from inactive to low activity (Department of Health, 2011). Further, regular participation in PA can attenuate the risk of chronic heart disease, diabetes, obesity, premature mortality and some cancers (Healy et al., 2008a; Neuhaus et al., 2014). Given PA is essential for our body to develop and function in an optimal way (Booth *et al.*, 2008), it is unsurprising that physical inactivity is the fourth leading cause of death worldwide (Kohl *et al.*, 2012) and linked to one in six deaths in the UK (Varney, Brannan and Aaltonen, 2014). Lee et al. (2012) reported that in the UK, physical inactivity causes 10.5% of the burden of disease from coronary heart disease, 13% from type 2 diabetes, 19.9% from breast cancer, 18.7% from colon cancer and 16.9% of all-cause mortality. These are worrying statistics compared to the median respective figures for Europe of 5.5%, 6.8%, 9.3%, 9.8% and 8.8%. Lee et al. (2012) further estimated that a realistic goal of decreasing prevalence of physical inactivity by 10% could decrease deaths by 533,000 worldwide, highlighting the huge potential benefit of reducing physical inactivity in adults.

Due to SB being a relatively new public health issue, less literature is available compared to PA, however robust studies are emerging. Two systematic reviews and meta-analysis found higher levels of SB increased the incidence of cardiovascular disease (CVD), cancer and diabetes (Biswas et al., 2015; Wilmot et al., 2012). Further, it was concluded that sedentary time is associated with increased levels all-cause mortality, cardiovascular mortality and cancer mortality (Biswas et al., 2015; Wilmot et al., 2012). Katzmarzyk et al. (2009) found a dose-response relationship between sitting time and all-cause mortality and CVD. Seguin *et al.* (2014) similarly found a linear dose-response relationship between SB and all-cause mortality, plus increased sitting time was associated with increased CVD risk. Interestingly, no associations between sitting time and cancer were found (Seguin et al., 2014), contrasting previous findings (Biswas et al., 2015; Wilmot et al., 2012). These findings suggest reducing SB levels is important for future disease and mortality risk in adults.

Ekelund et al., (2016) conducted a meta-analysis, including over 1 million adults, and found that those who accumulated over 8 hours/day sitting time and showed low levels of PA had similar increased mortality risk (58%) to that of smoking and obesity. Inconsistent literature regarding the relationship between disease and mortality risk, and moderate-to-vigorous PA (MVPA) and SB is evident. Thorp et al. (2011) suggests that after accounting for MVPA the risks associated with sitting time are still apparent. Those with high levels of sitting time per day (>10 hours) had a significantly higher hazard ratio for CVD compared to those with <10 hours/day, independent of PA (Chomistek *et al.*, 2013). Additionally, Wilmot et al. (2012), in a sample of 794,577, reported an increased CVD risk of 147% in those with the highest sedentary time in comparison to those with the lowest. Independent associations have been found (Chomistek et al., 2013), and those accumulating high levels of SB and low levels of PA show the highest CVD risk (Maddison *et al.*, 2016). However, Ekelund et al. (2016) also found that meeting current guidelines can attenuate the risk of premature mortality from high SB. Critically, it was shown that 60-75 min/day of MPA in individuals who sat for more than 8 hours daily significantly lowered the risk of dying than those who sat for less than 4 hours but only accumulated low levels of MPA (5 min/day). Further research is required however to confirm these findings and fully understand the relationship between total PA, SB and health disease and mortality risk.

Limited evidence exists on the independent associations between domain specific SB and PA, and disease risk and incidence, for example in occupational and leisure time (Hu *et al.*, 2001). Morris et al. (1953) investigated the relationship between PA and CVD risk, reporting that London bus conductors experienced half the CVD incidence than their counterparts, sedentary bus drivers. It was speculated that worktime PA played a role in this relationship, and this study was key in the development of PA epidemiology (I.-M. Lee *et al.*, 2009). Since this initial observation, numerous studies have produced similar results. A meta-analysis of prospective cohort studies, Li and Siegrist, (2012) indicated that leisure time PA yielded greatest reductions in CVD risk (20-30%), while occupational PA reduced risk by 10-20%. Therefore, it is suggested that different domains (e.g. occupation, leisure, transport) and environments (e.g. workplace, home, community) influence an individual's PA and SB, and subsequent disease risk and incidence, with the literature suggesting that for greatest health benefits, both PA and SB should be targeted simultaneously.

1.2.2 Cardiometabolic Risk

The metabolic syndrome consists of five cardiometabolic risk factors, including visceral obesity, insulin resistance, hypertension, high triglycerides and low high-density lipoprotein (HDL) cholesterol. Metzger et al. (2010) found higher levels of objectively measured PA were associated with reduced risk factors of each individual component of metabolic syndrome. Meeting current PA guidelines(Tucker *et al.*, 2016) and increasing steps per day (Sisson *et al.*, 2010) have also been shown to lower the risk of metabolic syndrome and each of its components. Regardless of PA, SB has been shown to be an independent risk factor for blood pressure, blood glucose, body mass index (BMI) and waist circumference in men and woman, and blood cholesterol and triglycerides in women (Healy et al., 2008b). Bakrania et al. (2016) reported similar findings, with lower SB associated with higher HDL cholesterol, independent of PA. Moreover, in workers, a higher frequency of breaks in prolonged sitting periods is associated with improved cardiometabolic risk profiles including lower BMI, waist circumference, blood glucose and insulin (Buckley et al., 2013; Dempsey et al., 2014;

Healy et al., 2008a). Accordingly, both PA and SB appear important to target to improve an adults cardiometabolic risk profile.

The role of PA and SB in obesity has been well documented. Bradbury et al. (2016) analysed nearly 260,000 (140,578 female) middle aged (40-69 years) UK citizens using the validated International Physical Activity Questionnaire (Craig *et al.*, 2003; IPAQ) to measure PA, and its association with BMI and body fat percentage. The results found an inverse association between both BMI and body fat percentage, and PA. Similarly, Heinonen et al. (2013) studied the associations between SB, BMI and waist circumference in 1993 Finish males and females. SB was categorised into TV viewing, computer use, reading, and listening to music, and of these, TV viewing time had the strongest positive relationship with BMI and waist circumference in both genders. Increasing TV time by 1 hour/day was associated with waist circumference by 1.8cm and 2.0cm in males and females, respectively. Despite TV time being associated with poor dietary choices (e.g. beer and fatty meats) and limited 'good choices' such as fish, oats and fruit, significant relationships were still observed between TV time, BMI and waist circumference after controlling for diet, though the associations were diluted somewhat. Pulsford et al. (2013) supports these findings by concluding that BMI determined obesity (≥30 kg/m^2) was only associated with TV viewing and no other type of sitting. Ryde et al. (2013) examined occupational sitting time and body composition found that those with the highest desk-based sitting time were 2.7 times more likely to have increased waist circumference (≥94cm male, ≥80cm female) and 9 times more likely to have a BMI of ≥30 kg/m^2. Eriksen et al. (2015) examined five-year changes between worktime sitting and BMI and found that in women, increased occupational sitting time was associated with an increased BMI, while no associations were found in men. These collective findings suggest therefore that PA, and SB for work and TV viewing, are strongly associated with body size and obesity in adults.

Due to cross-sectional design of the majority of studies, causality is difficult to establish. Future research should look to rectify this gap in the literature. Overall, total PA and SB are strongly linked with obesity, with independent associations between both BMI and waist circumference evident (Healy et al., 2008b). In practical terms, being physically active and reducing SB, specifically prolonged bouts, appear key for a healthier cardiometabolic risk profile, particularly body composition. However, little is known about the specific contribution of occupational PA and SB to cardiometabolic risk, independent of total PA and SB, with more research needed to identify whether workplace PA and/or SB, or neither behaviour, should be targeted in future interventions.

1.2.3 Musculoskeletal Troubles

Musculoskeletal troubles are one of the major health concerns for the working population. In the UK, 30.8 of the 137.3 million sick days in 2016 were due to musculoskeletal problems, which was the second highest contributor to sick days after minor illnesses such as coughs and colds (UK National Statistics, 2017). The preventative role of PA for musculoskeletal troubles has also been demonstrated. Morken, Magerøy and Moen, (2007) found that PA was inversely associated with musculoskeletal trouble in all sites except elbows, knees and feet. Additionally, Holth et al. (2008) found that in those who accrued higher amounts of PA, the risk of chronic musculoskeletal troubles decreased by 28% when compared to those classed as inactive. More recently, the role of tailored workplace PA has been shown to prevent musculoskeletal disorders in office workers who are at high risk of upper limb problems

(Rasotto et al., 2014). Collins and O'Sullivan, (2015) examined sport, work and leisure PA and found only leisure time PA and musculoskeletal problems were negatively, and significantly associated - specifically lower back. Conversely, Sitthipornvorakul et al. (2011) conducted a systematic review on PA and the two most common sites for musculoskeletal problems, the neck and lower back, and high levels of worktime PA and low levels of leisure time PA were associated with higher prevalence of lower back pain. However, results were inconsistent and should be viewed tentatively due to a lack of objective measurement tools for PA in the majority of the studies reviewed.

Computer use, a surrogate of SB, has been shown to be positively and significantly associated with neck problems (Collins and O'Sullivan, 2015), whilst wrist/hand symptoms have also been shown (Lee *et al.*, 2009). These results are supported by a systematic review conducted by IJmker et al. (2007) who found a dose-response relationship between mouse use and hand/arm symptoms for pain, and weaker associations between computer use and neck/shoulder problems. This is supported by intervention research that showed a reduction in occupational sitting time by 66 mins/day (224%) due to provision of a sit-stand workstation to complete computer based tasks, was reported alongside a 54% reduction in upper back and neck pain in workers (Pronk *et al.*, 2012). Conversely however, a systematic review of 22 studies examining upper extremity disorders and computer work, stated there is limited epidemiological evidence that can be considered moderate or strong(Waersted, Hanvold and Veiersted, 2010). Additionally, Chen et al. (2009) reviewed literature on SB and risk of lower back pain, and only one of 15 studies included reported a positive association between lower back pain and sitting time at work, with all other studies finding no significant relationships. In conclusion, interventions targeting both worktime SB and computer use appear warranted to improve musculoskeletal troubles. However, the relationship between PA and musculoskeletal troubles is less clear, as while greater total PA has been shown to lower prevalence/reduce risk of musculoskeletal troubles, contradictive results on the effects of worktime and leisure time PA on such troubles suggest a need for further research.

1.3 Physical Activity and Sedentary Behaviour Guidelines

1.3.1 Government Physical Activity and Sedentary Behaviour Guidelines

The physical health benefits of increasing PA and reducing SB are well documented. Accordingly, UK guidelines suggest adults aged 19-64 years should engage in at least 150 minutes of MPA, or 75 minutes of VPA, across the week (Department of Health, 2011). Further, adults are recommended to minimise the amount of time spent being sedentary (sitting) for extended periods (Department of Health, 2011). These guidelines are stated as a minimum requirement to maintain health, which implies more PA and less time sedentary is better. Additionally, while the guidelines recommend a specific dose and intensity for PA, more robust longitudinal studies are needed for SB to determine cause and effect/dose.

More recently, Canada published a 24-hour movement guideline for children aged 5-17 years (Tremblay *et al.*, 2016). A focus of MVPA is still evident, however the guidelines stresses the importance of light PA, and specifically how it is an effective substitute for SB. Moreover, SB has been given a specific guideline of <2 hours of recreational screen time a day, and desired hours of sleep is suggested. The paradigm of a 24-hour guideline, is one which puts emphasis on creating a healthy movement profile, rather than improving an individual behaviour (i.e. >150 mins/week MPA). It is yet to be established as to whether a shift in focus to 24-hour guidelines is effective. However, the health benefits of a focus on 'the whole day matters' and the added guidance on all movement behaviours, is one which outweighs any potential risks (Tremblay et al., 2016). Further research is needed to understand whether a 24-hour guideline, focused on three key behaviours (sleep, SB and PA) is warranted for the adult population. Additionally, a gap within the literature yet to be addressed is the lack of occupational specific guidelines in national recommendations.

1.3.2 Workplace Recommendations

Recently, a group of experts were gathered to provide guidance, based on current research, for highly sedentary workplaces on how to improve both health and productivity of its workers. The recommendations suggest mainly desk-based workers should accumulate 2 hours of standing and light walking during working hours each day, with the target of eventually accruing 4 hours a day (Buckley *et al.*, 2015). The expert statement also states mainly desk-based workers should regularly break up prolonged seated work with standing work and vice versa to promote health. The recommendation stresses that prolonged time in a static standing position has similar detrimental health concerns as prolonged sitting (Messing *et al.*, 2014). There was also a main objective within the expert statement of how a less sedentary office may affect productivity, both intrinsically for the individual and extrinsically for the company (i.e. economic savings and reduced sickness). The recommendations provide an in depth analysis of the limited research that is currently available, however, more evidence is needed to validate/inform the recommendations particularly with regard to the feasibility of achieving them.

1.4 Prevalence Statistics

1.4.1 National Physical Activity Guidelines

In the UK, 39% (11.8 million females, 8.3 million males) of the adult population (≥16 years old) are inactive with women 36% more likely to be inactive (British Heart Foundation, 2017). Surprisingly, only 40% of the adult population were aware of the current PA guidelines (British Heart Foundation, 2017). Northern Ireland was the most inactive country within the UK with nearly half of the population classified as inactive (46%), while Scotland had the lowest levels of inactivity at 37% (British Heart Foundation, 2017). The North West of England (47%), Northern Ireland (46%) and Wales (42%) were the three regions with the highest levels of inactivity, however, London had the highest number inactive adults at 2,670,000 (British Heart Foundation, 2017). These current behaviour statistics come at a time when 58% of women and 68% of men, in England, are overweight or obese (UK National Statistics, 2017b). Furthermore, global prevalence of diabetes is at an all-time high of 422 million (World Health Organization, 2016) and physical inactivity represents a huge financial burden, with an estimated cost of £1.2 billion annually on UK healthcare (British Heart Foundation, 2017). The statistics provide a compelling insight to the pandemic that is physical inactivity (Kohl et al., 2012), and the need for scientifically robust interventions to promote PA, specifically in the North West of England.

1.4.2 Sedentary Time

The average adult in the UK spends nearly 30 hours a week watching TV, which equates to 64 days a year (Ofcom, 2016). Men have been reported to have longer total sitting times compared to women, 78 and 74 days a year, respectively (British Heart Foundation, 2017). Using accelerometry, Colley et al. (2011) found that 69% of a day was spent sedentary by adults. A systematic review, involving studies from seven different countries, including both self-report and objective measures of SB, reported that the 60% of older adults sat for over 4 hours/day (Matthews *et al.*, 2008). The one objectively measured study found that 67% of the older adults were sedentary for over 8.5 hours/day (Harvey, Chastin and Skelton, 2013). Overall, these statistics show how SB is pervasive in the lives of adults, and as previously discussed is a serious health threat.

1.4.3 Work-based Physical Activity and Sedentary Behaviour

It is evident that total daily PA levels are low and SB time is high for a large proportion of the UK adult population. To inform future interventions targeting PA and SB however, it is important to understand when and under what circumstances (e.g. domain and environment) PA and SB time are accumulated. Given that an average adult will spend over a third of their life at work (World Health Organization, 2013), workplace PA and SB has logically become a topic of investigation for researchers. Parry and Straker, (2013) examined the role that office work has on PA and SB levels. Fifty office workers from Australia wore an accelerometer for 7 days to examine differences between activity patterns during work and non-work hours. Working hours had a negative effect on both PA and SB, as 78% of participants were more sedentary and 84% were less active on working days compared to non-work days. SB showed the most significant changes, with 81.8% of a work day spent sedentary compared to 68.9% on a non-workday. It was also reported that long periods of prolonged SB and few breaks in SB were evident within the sample. Clemes et al. (2014), who reported higher SB levels on a workday (68%) when compared to a non-workday (60%), support these findings.

In a similar study, Smith et al. (2015) used five day inclinometer data in English office workers (n=164) to measure sitting, standing and stepping, and reported similar findings to Parry and Stalker, as SB was the most common behaviour at 10.6 hours/day compared to 4.1 hours/day standing. In contrast, Smith et al. (2015) found similar levels of SB on both workdays and non-workdays, both at 10.6 hours/day. Furthermore, minimal differences were found between standing time, step counts and postural changes when comparing workday and non-workday. Despite some conflicting findings, the literature generally suggests that office workers are exposed to higher levels of SB on a workday than a non-workday.

1.5 Why target the workplace

Due to the exponential increase of sedentary occupations in recent decades, the removal of statutory retirement, and job type being an important determinant of PA and SB (Brownson, Boehmer and Luke, 2005), highly sedentary workplaces represent an urgent public health and economic threat, and have become a key setting for health promotion strategies (WHO, 2010). Office-based workplaces are currently one of the largest occupational groups globally (Alkhajah *et al.*, 2012). Desk-based office workers are subjected to numerous environmental cues that encourage prolonged periods in a seated static posture, which is an ergonomic hazard in the work environment (WHO, 2010). Research has shown that those in a sedentary occupation can accumulate highs of 11 hours/day of sitting time on a working day (Graves et al., 2015; Smith et al., 2015). Those accumulating the upper limit of 11 hours of sitting per day could therefore be at risk of a 20% increased chance of premature mortality (Chau *et al.*, 2012). Accordingly, such behaviour statistics and associated increases in health risks provide a compelling rationale for research focused on increasing PA and decreasing SB during worktime.

1.6 Relationship between Physical Activity, Sedentary Behaviour and Work Outcomes

1.6.1 Absenteeism

Literature researching absenteeism has suggested that PA is inversely associated with sickness absences (Kuoppala et al., 2008). A recent systematic review of 37 studies, examining the impact PA has on sickness absence, stated that the majority of studies concluded that increased levels of PA reduced absenteeism (Amlani and Munir, 2014). The review included 17 interventions (9 randomised control trial, 4 non-RCTs and 4 pre-post trials), 11 prospective cohort studies and 9 cross-sectional studies. Evidence from RCTs suggest that MVPA does not reduce absenteeism. However, in non-RCTs and comparison studies, increased levels of MVPA have been shown to reduce absenteeism (Baun et al., 1986; Lechner et al., 1997). Eleven prospective cohort studies looked at the effect PA has on absence, with one study showing that workplace PA increased the risk of absence, although leisure time PA reduced the risk (Holtermann *et al.*, 2012), and two studies found no significant associations (Bergström et al., 2008; Christensen et al., 2007) . Evidence from cross-sectional studies were generally weak with the higher quality studies focused on physical fitness rather than PA. However, two key methodological flaws were consistent throughout the majority of studies. Firstly, it was stated that a number of studies lack clarification of which PA intensity has an impact on absenteeism, therefore, we cannot determine which PA intensity has the most positive/negative effect, which reduces the ability to compare and assess effectiveness of studies. Secondly, the majority of studies used a self-report tool to measure PA, therefore introducing the chance of bias from recall errors and social desirability biases (Sallis and Saelens, 2000; Adams *et al.*, 2005). More recently, Losina et al., (2017) conducted a goal-based 24-week intervention to encourage PA in sedentary workers. Those with low levels of PA (0-74 min/week) and those who were categorised as medium level (75-149 min/week) had 3.5 and 2.4 times higher rate of absence, when compared to those who met current PA guidelines. However, despite some literature suggesting that increasing PA will reduce absenteeism, there is a paucity of high quality studies investigating the relationship between objectively measured PA and absenteeism, particularly the association between workplace PA and absenteeism, which can inform future workplace interventions.

Limited studies have also examined the associations between SB and absenteeism. Neuhaus et al. (2014b) conducted a systematic review and meta-analysis on the effect of activity permissive workstations on sedentary time, and health- and work-related outcomes. Five of the included studies measured absenteeism, with four classed as a long study duration (≥12 weeks). Four studies have shown reductions in sedentary time, two of RCTs and two control trials, though no associations were found between reducing SB and absenteeism. However, Neuahaus et al. (2014a) found potentially meaningful intervention effects (≥20%; Batterham and Hopkins, 2006) in increased absenteeism in the comparison group. As previously stated sitting time is high within the workplace and associated with musculoskeletal troubles, which is the second highest contributor of absence in the UK (UK National Statistics, 2017a). Therefore, further research is warranted to understand these relationships. In conclusion, total PA and leisure time PA has shown limited negative relationships with absenteeism, while worktime PA suggested an increase in absenteeism. To date, SB has shown no associations with absenteeism.

1.6.2 Presenteeism

More recently, presenteeism has emerged as an area of interest. Chapman, (2005) described presenteeism as the measurable extent to which physical or psychosocial symptoms, conditions and diseases adversely affect the work productivity of individuals who chose to remain at work. Presenteeism has been shown to incur 5.1 times more costs than absenteeism (Goetzel *et al.*, 2004), which is a substantial financial burden on the economy. Common psychosocial conditions associated with increased presenteeism are depression and anxiety (Wang, Simon and Kessler, 2003). PA has been shown to improve and protect an individual from both depression and anxiety (Ströhle, 2009), however, whilst the associations between PA and health (mental and physical), and, health and productivity (Schultz and Edington, 2007) are well established, the relationship between PA and presenteeism is not.

Limited research has been conducted between presenteeism and PA, with evidence showing some positive results (Nurminen *et al.*, 2002). Brown et al. (2013) objectively measured 7-day SB and PA and subjectively assessed presenteeism using the validated Work Limitations Questionnaire (WLQ; Lerner et al., 2001). Due to limited variation in presenteeism scores, participants were categorised as impaired (>5% WLQ index score) or not impaired (<5% WLQ index score). The majority of participants (58%) were classified as not impaired and only 6% reported moderate impairment or above (≥11% WLQ index score). Significant positive relationships were observed between presenteeism and sedentary time before and after work, overall light PA, and light PA during workday lunch hours. Workers who had higher levels of sedentary time (before and after work) were more than twice as likely to report impairment. Interestingly, MVPA had no association with presenteeism. More recently, Burton et al. (2014) used self-report data and found lower levels of absenteeism and presenteeism in workers who achieved the recommended guidelines in comparison to inactive workers. Brown et al. (2011) suggested the reason behind the scarcity of research in this area is because presenteeism has not yet been widely considered, agreed upon or evaluated. Therefore, further research using objectively measured PA and SB is needed to better understand these relationships, as the majority of previous literature has focused on investigating the measurement of presenteeism.

CHAPTER 2

PHYSICAL ACTIVITY VS SEDENTARY BEHAVIOUR AT WORK: INDEPENDENT ASSOCIATIONS WITH WORK- AND HEALTH-REALTED OUTCOMES IN ADULTS

2.1 Introduction

In the UK, physical inactivity causes 10.5% of the burden of disease from coronary heart disease, 13% from type 2 diabetes, 19.9% from breast cancer, 18.7% from colon cancer and 16.9% of all-cause mortality (Lee *et al.*, 2012). Similarly, increased SB is linked with higher risk of chronic heart disease, obesity, premature mortality and some cancers (Dunstan *et al.*, 2010; Evans *et al.*, 2012; Wilmot *et al.*, 2012). While regular PA has an inverse association with disease and mortality risk (Bauman, 2004; Lee *et al.*, 2012), high levels of both PA and SB can coexist (Dempsey et al., 2014; Healy et al., 2008b). Given that PA and SB are independent risk factors of poor health (Thorp *et al.*, 2011), unless high levels of MPA (60-75 min/day) are accrued (Ekelund *et al.*, 2016), the role of PA as a precautionary behaviour may be limited in highly sedentary people. A target of 60-75 minutes of MPA may represent an unrealistic target for many adults, as this is 2.8-3.5 times greater than current national guidelines, of which 33% of males and 45% of females do not currently achieve (British Heart Foundation, 2015).

SB has been shown to occupy 69% of a person's waking hours (Colley *et al.*, 2011), and more so in men (British Heart Foundation, 2017) and on work rather than non-work days. Using accelerometry, Parry and Stalker (2013) found a 12.9% increase in sedentary time on a workday (81.8%) compared to a non-workday (68.9%), as supported by Clemes et al. (2014) who reported an 8% increase in sedentary time on work days compared to non-workdays. Sedentary workplaces therefore, through the promotion of prolonged and total sitting time, expose a majority of the adult working population to major health risks (Biswas et al., 2015; Dunstan et al., 2010; Hamilton, Hamilton and Zderic, 2007; Healy et al., 2008a; Neuhaus et al., 2014b), with prolonged static sitting representing an ergonomic hazard in the workplace (WHO, 2010). Such evidence supports the workplace as a key setting to reduce sitting time and promote PA (The National Institute for Health and Care Excellence, 2008).

Absenteeism from work costs the economy upwards of £13 billion annually (Improving health and work: changing lives, 2008), and presenteeism costs up to 5.1 times more than absenteeism (The sainsbury Centre for Mental Health, 2007). Reducing absenteeism and presenteeism is therefore important for businesses and the economy. Absenteeism is positively associated with obesity (Lehnert et al., 2014) and musculoskeletal problems, with the latter being the second highest contributor to workplace absence after minor illnesses such as coughs and colds (UK National Statistics, 2016). Further, presenteeism is linked with a number of cardiometabolic disorders (Chapman, 2005; Schultz & Edington, 2007) and musculoskeletal trouble, specifically back pain (Ricci et al., 2006). Therefore, understanding factors associated with such outcomes can inform workplace interventions to help improve employee health and, in turn, decrease employer costs.

Evidence suggests that higher levels of PA and lower levels of SB can positively affect musculoskeletal troubles (Collins et al., 2015; Lee et al., 2008; Morken et al., 2007; Rasotto et al., 2014), body composition (Bradbury et al., 2016; Fletcher et al., 2017; Heinonen et al., 2013), absenteeism (Amlani and Munir, 2014; Kuoppala et al., 2008; Losina et al., 2012) and presenteeism (Brown et al., 2013; Burton et al., 2014). This implies that PA and SB could play a vital role in creating a healthier and more productive workforce, and reduce costs to the economy. Less is known however about the independent associations between worktime PA, worktime SB, and, musculoskeletal troubles, body composition, absenteeism and presenteeism. Such research can inform interventions, national guidelines, and expert statements (e.g.

Buckley et al. (2015)) that target workplace PA and SB, and specifically what behaviour to target, i.e. worktime PA, SB or both.

The aim of the present study therefore was to examine independent associations between worktime PA, worktime SB, and absenteeism, presenteeism, body composition and musculoskeletal problems in a population of adult workers in the North West of England. Potential confounders of these relationships were assessed to determine for whom and under which sociodemographic circumstances relationships may exist.

2.2 Methods

2.2.1 Study design

A cross-sectional design was used to investigate the studies aims. Trained researchers collected data across four organisations in the North West of England between December 2014–March 2017. Each participant attended one data collection session at their workplace or in a Liverpool John Moores University (LJMU) laboratory, followed by accelerometry wear for 7 days to assess habitual PA and SB, and finally completion of an online survey. This study was ethically approved by LJMU.

2.2.2 Recruitment

Convenience sampling, through contacts of the research team, was used to recruit the four public sector organisations (University, City Council, Clinical Commissioning Group, NHS Foundation Trust). After face-to-face or email discussions with organisational gatekeepers, gatekeeper consent was obtained to approach their employees and where appropriate, to conduct data collection at their workplace or for their employees to visit LJMU. Employees were approached through email and researcher-led information sessions. Emails contained a study overview, participant information sheet, and web link (created using www.doodle.com) whereby participants could sign up to a data collection slot. The study was advertised as an educational health check through which participants could receive feedback on their lifestyle behaviours and health. As such, any employee at the four organisations was able to sign up to a health check, however, only full time employees (≥0.8 full time or part time equivalent worker) and those whose jobs were predominantly sedentary (identified by survey used in the health check) were considered for inclusion in data analyses for this study. Individual assessments were confirmed by email by the research team. At the start of each assessment, the study purpose and protocol were explained verbally to the participant with the participant information sheet as a visual aid. After participant queries were answered, written consent was obtained before data collection began.

2.2.3 Study Procedure

The data collection sessions were conducted in comfortable, well-ventilated, quiet rooms with only the participant and trained researcher present. Measurements in the data collection session were taken between 08:00 and 11:45, and included surveys, cardiometabolic health markers (resting blood pressure, resting heart rate, blood glucose, blood cholesterol) and anthropometrics. Accordingly, participants were asked to fast for a minimum 8 hours, and avoid consumption of alcohol and strenuous exercise for a minimum of 12 hours prior to the session. Following the data collection session, participants wore an accelerometer for 7 days. Once the 7-day period was over, participants received an email containing a web link to a survey (created using www.surveymonkey.com). The survey included questionnaires to assess absenteeism, presenteeism, musculoskeletal troubles, job satisfaction and habitual sitting. The research team encouraged completion of the survey as soon as possible to ensure the recall period was consistent with the accelerometer-monitoring period. Electronic survey data was excluded from analyses if the survey completion date was +7 days to that of their last day of wearing the accelerometer.

2.2.4 Assessments

The following sections only describe the measurements relevant to data reported in this thesis.

2.2.4.1 Sociodemographic, Work-related and Office Environment Characteristics

Participants self-reported sociodemographic characteristics (age, gender, ethnicity, marital status, education attainment, medical history, smoking history, alcohol consumption, diet), work history (employment history, employment status, job category, hours worked per week, main work tasks) and work environment (number of people in their office) using a non-validated survey used in a previous study by the authors (Graves et al., 2015).

2.2.4.2 Anthropometry

Using standard anthropometric techniques (Lohman *et al.,* 1991), stature was measured to the nearest 0.1 cm using a portable stadiometer and body mass to the nearest 0.1 kg using a calibrated mechanical flat scale (both Seca Ltd, Birmingham, UK). Participants removed shoes and wore light clothing. BMI was calculated as mass divided by stature squared (kg/m^2). All measurements were taken twice. Third measurements were taken if results differed by ±1%. The means were calculated for both stature and body mass, where three measurements were taken, the median was calculated.

2.2.4.3 Objectively Measured PA and SB

Participants received either an ActiGraph GT3X+, wGT3X+ or wGT3X-BT tri-axial accelerometer (ActiGraph, Pensacola, FL, USA) initialised to a sample rate of 30 Hz. Reliability and validity of these devices, in adults, has been demonstrated (Aadland & Ylvisåker, 2015). Participants were asked to wear the monitor on their right hip, during waking hours, for seven consecutive days. Participants were familiarised with the accelerometer through a demonstration of monitor placement and elastic belt adjustment, and an information sheet they kept. Participants were instructed to remove the monitor during any water activities or contact sports. To promote compliance and minimise data loss, participants were asked to complete a wear time diary each day using a paper-based template. The diary collected information on the day type (work or non-workday), the time the monitor was put on, the time participants started and stopped work, and the time the monitor was taken off. To further promote compliance, each morning during the 7-day period, participants received an email to remind them to wear the accelerometer and complete the wear diary.

Upon monitor return, data were downloaded at 60-second epoch length by the ActiGraph propriety software (ActiLife various versions, Pensacola, FL, USA). Data were processed in May 2017 using ActiLife software v.6.13.3. Non-wear was determined using vector magnitude data, as 90-consecutive minutes of 0 counts per minute (CPM), with a 2-minute spike tolerance if accompanied by a 30-consecutive minute small window length of 0 CPM (Choi *et al.*, 2011; Winkler *et al*., 2012). A time filter was applied in ActiLife to include only data between 0500 and 2359, representing typical waking hours. Identical thresholds to those used in Brown et al. (2013) were replicated to determine SB and LPA, while Sasaki et al. (2011) cut points, commonly referred to as Freedson Adult VM3 (2011), were used to determine MPA and VPA intensity: sedentary (<150 counts.min^{-1}), light (151-2689 counts.min^{-1}), moderate (2690-6166 counts.min^{-1}), and vigorous (≥6167 counts.min^{-1}). Participants were included in analyses if they provided ≥10 hours of wear on ≥3 workdays and ≥1 non-workday (Trost *et al.,* 2005). For inclusion of valid workday, participants needed 75%+ wear time of working hours (Graves *et al*., 2015). This was achieved by loading log diaries into ActiLife and calculating the percentage of wear time within the participants given work hours. All participants received individual feedback on their PA and SB levels post analysis.

2.2.4.4 Absenteeism

Questions for absenteeism were taken from the Work Limitations Questionnaire 4-question time loss module (WLQ; Lerner et al., 2001). Three questions were included on the electronic survey. The first two questions were taken from the WLQ and asked how many full workdays and part of a workday were missed, in the last two weeks, due to health or medical care. A third question was added, asking how many full workdays were missed in the last 12 months due to health or medical care. For analysis, full workday and part of workday missed over the past two weeks were combined to create a composite score.

2.2.4.5 Presenteeism

The 25-item WLQ was used to assess presenteeism. The WLQ uses a five-point Likert scale to rate the level of difficulty a person has when performing 25 common job tasks. Responses to the WLQ are split into four subscales: time management (five items), physical scale (six items), mental-interpersonal scale (nine items) and the output scale (five items). Using WLQ scoring documentation (Lerner *et al.,* 2003), a final score can be obtained, reflecting the percentage of productivity lost at work due to health. Participants are then categorised as no impairment (<5%), mild impairment (5-10.9%), moderate impairment (11-16.9%) and severe impairment (>17%). Similar to a previous study (Brown *et al*., 2013), participants were coded as “not impaired” (WLQ index score <5%) and “impaired” (≥5%) for analyses.

2.2.4.5 Musculoskeletal Troubles

Musculoskeletal troubles in the last 7 days and 12 months, at nine symptom sites was assessed via The 27-item Nordic Musculoskeletal Questionnaire (Dickinson *et al.*, 1992). Symptom sites were the neck, shoulders, elbows, wrist/hands, upper back, lower back, hips/thighs/buttocks, knees and ankles/feet. Responses were given in simple yes/no form, unless further clarification was needed (e.g. left hand, right hand, both hands). For analyses, musculoskeletal troubles were coded into: i) neck, ii) upper extremity, iii) lower back and iv) lower extremity and v) trouble in any site.

2.2.5 Statistical Analysis

Data was analysed using SPSS version 24 (IBM, New York, USA) and R (https://www.r-project.org/). Descriptive statistics were presented as means ± standard deviations (SD) for continuous data and as percentages for categorical data. Linear regression was conducted to examine associations between worktime PA (total: i.e. LPA + MPA + VPA), worktime LPA, worktime MVPA and worktime SB and BMI. Binary logistic regression was conducted to examine associations between worktime PA (total), worktime LPA, worktime MVPA and worktime SB, and presenteeism (WLQ index score, time management, physical, mental-interpersonal and output), absenteeism over the last two weeks and musculoskeletal troubles. Zero-inflated Poisson regression was used for worktime PA (total), worktime LPA, worktime MVPA and worktime SB, and absenteeism over the last 12 months. All models were adjusted for age, sex, marital status, job category and accelerometer wear time. For analyses of worktime PA, total SB, leisure time PA on workdays and total PA on non-workdays was also adjusted for. For worktime SB, total PA, leisure time SB on workdays and total non-workday SB was adjusted for. The comparison group for marital status was ‘married’, and for job category, ‘clerical’ was the comparison group. Odds ratios and 95% confidence intervals were reported. All data was checked for distribution and sex differences were tested using independent t-tests, Mann-whitney U test or Chi-square test where appropriate. Differences in key characteristics were examined between those who were included in final accelerometer analysis and those who were not. Statistical significance was set at $P \leq 0.05$.

2.3 Results

Of the 326 people who took part, only 134 participants were included for data analysis. Seventy participants did not complete the post-accelerometery survey and 35 did not return or sufficiently complete the accelerometer wear diary. Twenty-five had no non-workday, 22 were lost due to an accelerometer software malfunction and 16 were not full-time employees. Additionally, 8 had less than 3 valid workdays, 7 participants did not represent our target population (sedentary workers), 5 did not fully complete the WLQ and 4 did not complete the online survey within the specified time. Sociodemographic characteristics of participants are presented in Table 1. Participants (mean age 44.6 ± 9.3 years) were predominantly female (64.2%), White British (97.1%) and educated at a tertiary level (94.8%).

There was no significant difference between participants included in analysis (n = 134) and participants who were not (n = 192), for key characteristics: age, sex and education level ($p > 0.05$; independent t-test or Mann-Whitney test based on data normality by group; data not shown). Similarly, there were no significant differences between included participants (n = 134) and those not included, but did complete the post-accelerometery survey (n = 122), for the main outcome variables: absenteeism, presenteeism, body composition and musculoskeletal troubles ($p > 0.05$; data not shown).

Table 1: Sample sociodemographic and health characteristics reported as mean ± standard deviation or median (interquartile range).

	Total (n = 134)	Male (n = 48)	Female (n = 86)
Age (y)	44.6 ± 9.3	44.6 ± 9.0	44.7 ± 9.6
Ethnicity, White British, n (%)	132 (97.1)	48 (100.0)	84 (97.7)
Education level, tertiary, n (%)	127 (94.8)	46 (95.8)	81 (94.2)
Sedentary time (minutes/day)			
Total	484.1 ± 72.4	501.3 ± 75.7	473.4 ± 69.2 *
Percentage of wear time (%)	56.7	57.5	56.2
During work	324.0 ± 56.3	321.2 ± 62.0	324.7 ± 53.3
Percentage of wear time (%)	65.4	64.3	66.1
Non-workday	394.2 ± 114.1	425.0 ± 125.5	377.0 ± 103.3 *
Percentage of wear time (%)	49.5	52.4	47.8
Light physical activity (minutes/day)			
Total	311.0 ± 61.3	306.2 ± 63.2	313.7 ± 60.0
Percentage of wear time (%)	36.5	35.1	37.2
During work	137.5 (53.2)	138.5 (52.2)	137.2 (53.9)
Percentage of wear time (%)	28.5	28.1	28.5
Non-workday	345.8 ± 97.4	327.7 ± 89.4	356.0 ± 100.6
Percentage of wear time (%)	43.4	40.4	45.1
Moderate-to-vigorous physical activity (minutes/day)			
Total	56.6 (37.9)	57.7 (37.5)	56.1 (40.5)
Percentage of wear time (%)	6.6	6.6	6.5
During work	22.7 (18.7)	26.1 (18.4)	20.3 (16.1) *
Percentage of wear time (%)	4.7	5.3	4.2
Non-workday	45.5 (54.0)	42.0 (57.9)	48.5 (50.3)
Percentage of wear time (%)	5.8	5.2	6.2
Total physical activity (minutes/day)			
Total	369.0 ± 67.8	370.3 ± 77.0	369.4 ± 62.9
Percentage of wear time (%)	43.3	42.5	43.8
During work	162.5 (53.9)	171.7 (72.7)	159.5 (54.8)
Percentage of wear time (%)	33.9	34.8	33.1

Non-workday	392.0 (162.8)	362.5 (189.4)	401.5 (151.5)	
Percentage of wear time (%)	49.6	44.9	51.2	
Presenteeism				
Impaired, Yes n (%)	21 (15.7)	9 (18.8)	12 (14.0)	
WLQ Index Score	1.2 (3.6)	0.8 (3.4)	1.3 (3.5)	
Absenteeism				
Absent in past 2 weeks, Yes n (%)	16 (11.9)	2 (4.2)	14 (16.3)	*
Absent in past 12 months	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	
BMI (kg/m^2)	25.2 (5.9)	26.4 (5.4)	25.5 (4.9)	*
Musculoskeletal trouble in past 12-months, Yes n (%)				
Neck	12 (9.0)	2 (4.2)	10 (11.6)	
Lower back	29 (21.6)	9 (18.8)	20 (23.3)	
Upper extremity	22 (16.4)	4 (8.3)	18 (20.9)	
Lower extremity	31 (23.1)	14 (29.2)	17 (19.8)	
Any	58 (43.3)	20 (41.7)	38 (44.2)	

*Indicates a significant difference between males and females ($P < 0.05$)

2.3.1 Objectively measured PA and SB

Time spent in PA and SB are presented in Table 1. Mean accelerometer wear time was 853.1 ± 66.5 minutes/day (range: 660.6 to 1114.4 minutes/day). Of total wear time, 56.7% was spent sedentary, 36.5% in LPA, 6.6 in MVPA and 43.3% in PA. Sedentary time was the predominant behaviour during worktime (65.4%), with worktime showing highest percentages of SB. However, total PA was the predominant behaviour on non-workdays (49.6%), although only minimally. Males had significantly higher levels of total SB ($P = 0.033$), SB on a non-workday ($P = 0.019$) and MVPA during work ($P = 0.001$).

2.3.1.2 Presenteeism

The number of impaired participants and index score from the WLQ are presented in Table 1. Based on the WLQ index score, the majority of participants reported no impairment (84.3%; n = 113), with 13.4% (n = 18) classified as having mild impairment, 0.7% (n = 1) moderate impairment and 1.5% (n = 2) severe impairment. WLQ index scores ranged from 0.0% to 18.0%. No sex differences were found for WLQ index score or number of participants impaired.

2.3.1.3 Absenteeism

Absenteeism results are presented in Table 1. Sixteen (12%) participants reported absence within the last 2 weeks, for either a part or full day due to their health. There was a significant sex difference in 2-week absence ($P = 0.038$), with females more likely to report absence. Median (interquartile range) for absence over the last 12 months was 0.0 (0.0), and no significant sex differences were found.

2.3.1.4 BMI

BMI data is presented in Table 1. Median (interquartile range) for BMI was 25.2 kg/m^2 (5.9). Males had significantly higher BMI than females ($P = 0.004$). The majority of participants were categorised as ideal weight (47.0%; n = 63), with 34.0% (n = 45) overweight, 18.7% (n = 25) obese and 0.7% (n = 1) underweight.

2.3.1.5 Musculoskeletal Trouble

Musculoskeletal trouble data is presented in Table 1. Lower extremity was the most common reported problem (23.1%; n = 22), followed by lower back (21.65; n = 29), upper extremity (16.4%; n = 22) and neck trouble (9.0%; n = 12). Overall, 58 participants (43.3%) reported a minimum of one problem at any site. No significant sex differences were found.

Table 2: Odds Ratios and 95% Confidence Intervals for presenteeism, absenteeism and musculoskeletal trouble at different worktime behaviours

	Odds Ratio	95% Confidence Interval
Presenteeism – Index Score		
SB	1.00	0.99 – 1.01
LPA	1.03	0.98 – 1.07
MVPA	0.98	0.93 – 1.02
Total PA	0.06	0.00 – 72.75
Presenteeism – Time Management		
SB	1.00	0.99 – 1.01
LPA	0.97	0.93 – 1.00
MVPA	1.04	1.00 – 1.08
Total PA	0.70	0.00 – 133.04
Presenteeism – Physical		
SB	0.99	0.99 – 1.01
LPA	0.99	0.96 – 1.03
MVPA	1.00	0.97 – 1.04
Total PA	4.53	0.02 – 946.91
Presenteeism – Mental-Interpersonal		
SB	1.00	0.99 – 1.01
LPA	0.98	0.96 – 1.03
MVPA	1.02	0.99 – 1.06
Total PA	1.02	0.01 – 166.35
Presenteeism – Output		
SB	1.01	1.00 – 1.02*
LPA	0.98	0.94 – 1.01
MVPA	1.02	0.99 – 1.06
Total PA	5.92	0.03 – 1014.84
Absenteeism		
SB	1.01	1.00 – 1.03
LPA	0.98	0.92 – 1.01
MVPA	1.02	0.95 – 1.01
Total PA	1.00	0.99 – 1.02
Any MSK		
SB	0.99	0.99 – 1.00
LPA	1.00	0.97 – 1.04
MVPA	1.00	0.97 – 1.03
Total PA	1.01	1.00 – 1.02
Neck		
SB	0.99	0.98 – 1.01
LPA	0.97	0.91 – 1.03
MVPA	1.03	0.97 – 1.10
Total PA	1.01	1.00 – 1.03
Lower Back		
SB	1.00	0.99 – 1.01
LPA	1.01	0.97 – 1.05
MVPA	1.00	0.96 – 1.04
Total PA	1.00	0.99 – 1.01
Upper Extremity		
SB	0.99	0.98 – 1.00
LPA	0.99	0.94 – 1.04
MVPA	1.01	0.97 – 1.06
Total PA	1.01	0.99 – 1.02
Lower Extremity		

SB	0.99	0.98 – 1.00
LPA	0.99	0.98 – 1.03
MVPA	1.01	0.97 – 1.05
Total PA	1.01	1.00 – 1.02

*Indicates *P* < 0.05

2.3.2 Associations between PA, SB and Presenteeism

No significant associations were found between WLQ index score and worktime SB and, worktime LPA, worktime MVPA and total PA (Table 2). There was a significant and positive association between worktime SB and reduced Output (OR = 1.01; 95% CI: 1.00 to 1.02, P = 0.047). Time spent in worktime LPA was inversely associated with poor time management and approached significance (OR = 0.97; 95% CI: 0.93 to 1.00, P = 0.051). Time spent in worktime MVPA was positively associated with poor time management and approached significance (OR = 1.04; 95% CI: 1.00 to 1.08, P = 0.051). The 95% CIs for the total PA and presenteeism analyses were large compared to those for the other variables (See Table 1).

2.3.2.2 Associations between PA, SB and Absenteeism

Associations between worktime SB and any days missed in the last 2 weeks approached significance, with increased sedentary time suggesting increased likelihood of absence (Table 2). Age significantly added to this model, with a lower risk of absence as age increased (OR = 0.90; 95% CI: 0.84 to 0.98, P = 0.01).

No significant associations were found between 2-week absenteeism and worktime LPA, worktime MVPA or total worktime PA, see Table 2. Age significantly added to all models: LPA (OR = 0.91; 95% CI 0.84 to 0.99, P = 0.023), MVPA (OR = 0.91; 95% CI: 0.84 to 0.99, P = 0.023) and total PA (OR = 0.92; 95% CI: 0-.85 to 0.99, P = 0.02). Females were significantly associated with an increased risk of 2-week absenteeism compared to males in the total PA model (OR = 5.75, 95% CI: 1.00 to 33.09, P = 0.05).

No significant associations were found between worktime SB at work and 12-month absenteeism. However, increasing total weekly PA by 10 minutes/day increased the expected number of days off by a factor of exp(0.0700)=1.037 or 3.7% and was statistically significant ($P < 0.0001$) . Age significantly added to the model, as increase in age was associated with an increase of 12-month absenteeism by a factor of exp(0.0166)=1.017 or 1.7% ($P = 0.033$).

Increasing worktime LPA by 10 minutes/day was significantly associated with a decrease in expected number of days off in the previous 12 months by a factor of exp(-0.1243)=0.883 or 11.7% ($P = 0.044$). Weekly SB was associated with a decrease in 12-month absenteeism by a factor of exp(-0.1794)=0.836 or 16.4%, and was statistically significant ($P = 0.012$). Increase in age was significantly associated with increase in absenteeism by a factor of exp(0.0209)=1.021 or 2.1% ($P = 0.008$).

Increasing MVPA by 10 minutes/day was significantly associated with an increase of 12-month absenteeism by a factor of exp(0.1239)=1.132 or 13.2% ($P = 0.044$). Increasing leisure time PA by 10 minutes/day on a workday (exp(0.0523=1.054 or 5.4%; $P = 0.043$) and increase in age (exp(0.0209=1.021 or 2.1%; $P = 0.007$) were both significantly associated with increase in expected absence in the previous 12 months.

Total worktime PA was not significantly associated with previous 12-month absenteeism. However, increasing total weekly SB by 10 minutes/day was significantly associated with a decrease in absence by a factor of exp(-0.0669)=0.935 or 6.5% ($P < 0.0001$). Increase in age was associated with an increase in expected 12-month absenteeism by a factor of exp(0.0177)=1.018 or 1.8% ($P = 0.022$)

2.3.2.3 Associations between PA, SB and BMI

The worktime SB model significantly predicted BMI (R^2 = 0.16; P = 0.009). However, only total PA per week added significantly to the model (P = 0.001) with a decrease of 0.027 kg/m^2 for every minute increase of daily PA. No significant associations were found between worktime SB and BMI.

The worktime LPA or worktime MVPA model did not contain any significant predictors. The total worktime PA model was significant (R^2 = 0.16; P = 0.018). No significant associations were found between total worktime PA. However, non-workday PA was associated with a decrease of 0.010 kg/m^2 for every minute increase of non-workday PA (P = 0.023). The relationship between those who were single and those who were married approached significance, with those who were single associated with a lower BMI of 1.80 kg/m^2 (P = 0.059).

2.3.2.4 Associations between PA, SB and Musculoskeletal Troubles

There were no significant associations between worktime SB and neck trouble, lower back trouble, upper extremity trouble, lower extremity trouble or any musculoskeletal trouble (Table 2).

There were no significant associations between worktime LPA and neck trouble, lower back trouble, upper extremity trouble, lower extremity trouble or any musculoskeletal trouble (Table 2).

There was no significant associations between worktime MVPA and neck trouble, lower back trouble, upper extremity trouble, lower extremity or any musculoskeletal trouble (Table 2).

There were no significant associations between total worktime PA and neck trouble, lower back trouble, upper extremity, lower extremity trouble or any musculoskeletal trouble (Table 2).

2.4. Discussion

The aim of this current study was to examine independent associations between worktime PA, worktime SB, and absenteeism, presenteeism, body composition and musculoskeletal problems in a representative population of adult workers in the North West of England. The main findings show that worktime LPA had a significant inverse association with levels of 12-month absenteeism; however, worktime MVPA was significantly, positively associated with 12-month absence. Increased worktime SB was associated with an increased likelihood of 2-week absenteeism and approached significance.

2.4.1 PA, SB and Presenteeism

Findings from the present study suggest those who spend more time sedentary were more likely to report higher scores on the output scale, while those who spent less time in LPA were more likely to report poor time management. These findings are partially supported by a similar cross-sectional study, Brown et al. (2013), who used objective measures of PA and SB and reported no associations between worktime PA or worktime SB and WLQ index score, indicating PA and SB during working hours has no significant associations with WLQ index score. However, this present study found associations with worktime SB and LPA, and WLQ subscales, whereas Brown et al. (2013) found no associations with overall worktime SB or PA and WLQ subscales. Instead, Brown et al. (2013) showed LPA to be inversely associated with presenteeism and SB to be positively associated with presenteeism (Brown *et al.,* 2013). More specifically, Brown et al. (2013) reported a significant inverse association between LPA during non-workdays and poor time management, and total SB and reduced output. These findings are partially consistent with that of the current study; however, while each association is linked with the same behaviour, the behaviour occurs at different time points. Regarding the associations between total PA and presenteeism, the analyses revealed large 95% CIs, and warrant further investigation to fully understand the values.

Total PA or total SB did not significantly add to any model in the analysis. In contrast, Burton et al. (2014) found significant associations between subjective measures of PA and presenteeism. Specifically, Burton et al. (2014) reported that those meeting current national guidelines had significantly lower presenteeism than physically inactive adults. The majority of participants within the present study (95%) however met current guidelines of 150 minutes of MPA across the monitored week, which may explain why no significant relationship was observed between total PA and presenteeism. Walker et al. (2017) examined the longitudinal relationship between PA and presenteeism and concluded that increasing PA, in turn, significantly decreased presenteeism. Critically however, there were no significant associations between PA and presenteeism at baseline (Walker et al., 2017), which also supports the present study's findings. Further longitudinal research is required to confirm or refute the relationship Walker et al. (2017) observed between PA and presenteeism, plus, investigate the relationship between total and workplace SB and presenteeism.

Lack of significant findings in the present study may be due to the sample having limited presenteeism (15.7% impaired). This has been previously cited as a limitation, specifically the lack of variation among participants reporting moderate impairment and higher (Brown et al., 2013). Only 2.2% of participants in this study reported moderate impairment and higher, compared with Brown et al. (2013) reporting <6%, indicating this is a common problem. Therefore, further research is needed with higher variation across all categories of impairment, to better understand the relationships between worktime PA and SB, and presenteeism.

2.4.2 PA, SB and Absenteeism

No significant associations were found between worktime LPA, MVPA, total PA and SB, and absence over the last two weeks. Increased levels of worktime LPA was associated with a decrease in expected number of days absent over the past 12-months. Interestingly, increasing worktime MVPA was shown to significantly increase the expected number of days absent over the last 12-months. This relationship has been previously shown in Holtermann et al. (2012), whereby it was reported that occupational PA increased the risk for long term absence. High levels of occupational PA have shown significant associations with increased musculoskeletal troubles (Sitthipornvorakul *et al.*, 2011), which in turn, is the second highest contributor for sick days (UK National Statistics, 2016). This could offer a possible understanding as to why worktime PA increases absenteeism, thus warranting further research.

In the present study, worktime LPA decreased absenteeism for every 10-minute increase in worktime LPA (11.7%); however, increasing worktime MVPA by 10-minute was associated with an increase in absenteeism (13.2%), suggesting that targeting the correct PA intensity is vital to help reduce absenteeism. Limited studies have examined the associations between worktime PA and SB, so further research is warranted to fully understand these relationships. Additionally, the present study reported no associations between total PA and absenteeism, which is inconsistent with previous literature from Losina et al. (2017) who suggested that those with higher levels of PA were 2.4 to 3.5 times less likely to report absence. This suggests further research is also required to better understand the relationship between total PA, SB and absenteeism.

2.4.3 PA, SB and BMI

No significant associations were found for worktime SB and BMI. Relationships between worktime SB and BMI in previous research is unclear. A systematic review found evidence of a positive association between worktime SB and BMI in only five out ten studies (Van Uffelen et al., 2010). More recently, Chau et al. (2013) found that adults with a predominantly sitting job had a higher risk of obesity when compared to adults with mostly standing jobs, independent of PA. Critically however, no significant associations were found for higher risk of obesity across occupational groups, and instead it was suggested that leisure time SB is associated with body composition and not worktime SB. In contrast, Ryde et al. (2013) examined occupational sitting time and body composition and found that those with the highest desk-based sitting time were nine times more likely to have a BMI ≥ 30 kg/m^2. Limited studies have examined worktime SB and instead placed focus on total SB.

No significant associations were found between worktime LPA, MVPA, total PA and BMI. Similarly to SB, there is a paucity of literature studying worktime PA and markers of body composition. An inverse association between total PA and BMI has previously been reported however, using both objective (Hemmingsson & Ekelund, 2006) and subjective (Bradbury et al., 2016) measures of PA. The present study somewhat supports these findings, by showing a decrease in BMI of 0.027 kg/m^2 for every increase of 1 min/day PA, while adjusting for worktime SB, age, sex, job category and marital status, and was statistically significant.

In conclusion, the role of worktime PA and worktime SB in relation to BMI is less clear than that of total PA and total SB. Therefore, further research is warranted to better understand the relationships, if any, between body composition and worktime PA and worktime SB. While the relationship between total PA, SB and BMI is clearer, more research is needed to confirm or refute the relationship between worktime LPA, MVPA, total PA and SB, and BMI. This is important given worktime can occupy approximately half of an adults waking hours (Tudor-Locke *et al.*, 2013), and has been shown to increase sitting time (Parry & Straker, 2013), decrease PA (Parry & Straker, 2013) and was cited as a key setting to reduce SB (The National Institute for Health and Care Excellence, 2008).

2.4.4. PA, SB and Musculoskeletal Troubles

Worktime SB was not significantly associated with musculoskeletal troubles. These findings are supported in a systematic review, whereby it was stated that there was limited strong epidemiological evidence suggesting a relationship between SB and musculoskeletal troubles, with only weakly designed studies reporting any relationships (Waersted et al., 2010). Additionally, Chen et al. (2009) found only one of 15 studies to show any significant relationship between SB and lower back pain, with the one significant relationship showing a positive association. However, there have been previous literature stating that computer use, a surrogate of SB, is positively and significantly associated with neck problems (Collins et al., 2015) and wrist/hand symptoms (Lee *et al.*, 2012). Moreover, Ijmker et al. (2007) found a dose-response relationship between mouse use and hand/arm and neck/shoulder troubles. Therefore, targeting computer use appears warranted in future interventions, while further research is needed to understand the relationship between worktime SB and musculoskeletal troubles.

The relationship between PA and musculoskeletal troubles is less clear, as the current study did not find any associations between worktime LPA, MVPA and total PA, and musculoskeletal troubles. This is supported by Collins et al. (2015) reported that there were no significant associations between worktime PA and risk of musculoskeletal trouble, instead only leisure time PA had a significant negative association with musculoskeletal troubles, specifically lower back. Conversely, Rasotto et al. (2014) found that worktime PA can reduce the risk of upper extremity musculoskeletal troubles in the upper extremity, whereas the present study found increasing worktime PA increases risk of upper extremity troubles. Critically, increasing work time LPA, MVPA or total PA has not been shown to have a negative effect on any musculoskeletal symptom. Therefore, from a musculoskeletal standpoint, it is suggested that it is safe to increase PA, at any intensity, at the workplace.

2.4.5. Strengths and Limitations

A strength of this study was the use of zero-inflated Poisson regression, which few studies have used before to investigate associations between PA, SB and absenteeism. The study used zero-inflated Poisson to prevent underestimation of standard errors and p-values, and therefore reducing the chance of an inflated Type I error. Furthermore, the data contained a large number of zeros for absenteeism, which standard Poisson struggles to cope with and hence the reason for using a zero-inflation method. Accordingly, it is recommended that future studies with similar high values of zeros incorporate such methodologies. Another key strength was the use of objective measurements of PA and SB. Accelerometers have been shown to be a reliable and valid way to measure PA and SB (Sasaki, John and Freedson, 2011), which can help to overcome recall inaccuracy from the use of self-report measures. Additionally, the use of validated WLQ and the Nordic Musculoskeletal Questionnaire allowed rigorous assessments of absenteeism, presenteeism and musculoskeletal troubles. Another strength of this study was the focus on the independent associations between the work- and health-related outcomes and worktime PA and worktime SB, as limited research has previously investigated this.

One limitation of the study was the cross-sectional design, which prevents the authors suggesting causality. Therefore, longitudinal data is need to greater understand the observed relationships. Additionally, the lack of variation in presenteeism (84.3% not impaired) and a highly active sample (95% met guidelines) could reduce generalisability to the public. As 47% of the North-West were classified as inactive (British Heart Foundation, 2017), this would suggest the current sample failed to represent the general population of this geographical area. More targeted sampling is perhaps needed to recruit those with higher levels of presenteeism and varying levels of PA. Another limitation was the subjective measure of absenteeism, with previous studies (Bergstrom *et al.,* 2008; Christensen *et* al., 2007; Holtermnann *et al.,* 2011) using objective measure of absenteeism from national registers and company pay rolls. Another limitation of this study was low compliance; however, this is a common issue in research studies where accelerometers are used. This limitation is prominent within this current study as it has been shown that using hip-worn accelerometers instead of wrist-worn monitors, yields a lower compliance rate (Scott *et al.*, 2017). Furthermore, accelerometers define behaviours using acceleration, as a result, they often misclassify standing as SB, as both behaviours require no/minimal acceleration (Winkler, 2014). Inclinometers such as the activPAL are becoming more commonly used to measure SB as they have been shown to have higher accuracy and sensitivity when compared to ActiGraph GT3X+ accelerometers (Kozey-Keadle *et al*., 2011; Ryde *et al*.., 2012). The use of convenience sampling was a further limitation as it is a non-random selection of participants; therefore, this increases the chance of bias and ultimately hinders the researcher's ability to draw interpretations about a population (Etikan *et* al., 2016). Finally, the present study did not control for seasons/weather within the analyses, which has been shown to affect behaviour and therefore may not represent behaviour accurately. For example, it has been shown that poor weather (cold and wet) can significantly decrease participation in PA (Tucker and Gilliland, 2007). Therefore, any differences between participants PA/SB levels could be a direct result of when the participants were tested, rather than an association with one of the key variables.

2.4.6 Implications and Future Directions

The main implications of this current study are that worktime LPA was associated decrease in 12-month absenteeism, independent of weekly SB, age, sex, job category and marital status. However, worktime MVPA and 12-month absenteeism were significantly and positively associated, whilst keeping all variable constant. Future research is needed to confirm or refute these relationships. For the majority of tests, no significant associations were found. Possible reasons for this have been stated earlier. As a result, future research should look to seek greater variation in presenteeism and PA, with a focus on worktime movement patterns, in a large sample size. Finally, studies should look to use objective measurement tools, and where possible a mixture of devices that complement each other, such as an accelerometer and inclinometer (Pfister *et al.*, 2017), and where possible use prospective or longitudinal designs to increase rigour and allow conclusions on causality. This research is important for confirming or refuting the current findings, and subsequently informing future interventions and recommendations for workplace PA and SB.

2.4.7 Conclusion

To conclude, worktime SB was significantly associated with reduced output, worktime LPA decreases the expected days absent in the last 12 months; while MVPA increases expected days absent in the last 12 months. No other significant associations were found between worktime LPA, MVPA, total PA and musculoskeletal trouble, 2-week absence, BMI or presenteeism. No significant relationships were found between worktime SB and absenteeism, BMI or musculoskeletal troubles. Therefore, this would suggest worktime PA rather worktime SB should be targeted in future workplace health interventions.

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