School of Physiotherapy and Exercise Science

Sedentary time and physical activity exposure patterns and musculoskeletal symptoms of Australian office workers

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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Results of this thesis have been presented in part, in the following publications and at the following scientific meetings:

Parry, S and Straker, L (2011). “Occupational physical activity of contemporary office workers – comparison between sitting and standing workstations using accelerometry”. *Proceedings International Behavioural Nutrition and Physical Activity Conference,* Melbourne, July 2011.

Parry, S and Straker, L (2012). “Does work contribute to the sedentary risk of office workers?” *Proceedings of 4th International Congress on Physical Activity and Public Health*, Sydney, October 2012

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SIGNATURE:____

DATE:____

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Abstract

Background

Public health messages over the last decades have emphasised the importance of participation in moderate and vigorous physical activity (MVPA) to maintain good health and to prevent many chronic diseases. However, until recently there has been less attention to reducing and modifying daily sedentary exposure. Results from recent large population studies indicate that sustained and uninterrupted sedentary time is associated with poor health and mortality, potentially independent of participation in MVPA. Further, participation in light intensity activity has been found to positively impact health risk factors such as glucose metabolism. With an increasing proportion of the workforce now employed in low activity or sedentary occupations such as office work, there is a growing concern that occupational sedentary time may contribute a high proportion of overall daily sedentary exposure. However there is very limited evidence on the contribution of occupational sedentary time and thus the associated health risks for office workers. This thesis aimed to describe the amount and pattern of sedentary, light intensity activity and MVPA exposure of office workers at work and during non-work periods (Study 1).

If occupational sedentary time contributes significantly to overall sedentary exposure for office workers, they may be at a greater risk of poor health and mortality compared to other workers with similar skill sets. There is a paucity of literature that examines the physical activity and sedentary time of different occupational groups and very limited research that has used objective measures to compare sedentary time and physical activity levels and patterns between workers in different professions during work hours and during non-work periods. Therefore this thesis aimed to compare the overall amount and pattern of exposure of physical activity and sedentary time of office workers and school teachers (Study 2).

The growing recognition of the importance of occupational sedentary exposure as a potential risk to poor health has highlighted the need to develop targeted workplace interventions that address a reduction in occupational sedentary time and the promotion of participation in light intensity activity into the working day. Sit-stand workstations and break-prompting software have been promoted as strategies to reduce sitting time of office workers. This thesis aimed to compare the overall amount and pattern of exposure of sedentary time, light activity, MVPA in a small group of office workers that were using a sit-stand workstation with office workers using a traditional desk and chair arrangement (Study 3).

There is limited research that has compared a number of different workplace intervention approaches to reducing occupational sedentary time. Further, workplace physical activity interventions have examined the impact of improving occupational physical activity on musculoskeletal pain of office workers but there are only a few studies that explored the effects of reducing sedentary time or sitting on musculoskeletal pain. Therefore, this thesis aimed to determine if a variety of workplace interventions could modify the overall amount and pattern of exposure of sedentary time, light intensity activity and MVPA of office workers at work and during non-work periods and whether changes in sedentary time and physical activity would relate to changes in musculoskeletal symptoms, job satisfaction and work productivity (Study 4).

Methods

Three observational studies involving 50 office workers at traditional desk/chair workstations (Study 1), 34 teachers (Study 2) and 8 office workers at sit-stand workstations (Study 3) were conducted. Participants wore an Actical accelerometer for 7 days and completed physical activity, work productivity, job satisfaction and musculoskeletal questionnaires. Participants recorded wear time, work hours and daily activities in an activity diary. Accelerometer determined sedentary time, sustained sedentary time, breaks in sedentary time, light activity and MVPA at work and during non-work periods was analyzed using one-way analysis of variance (ANOVA), chi squared tests, t-tests and Pearson's correlations.

In addition, a randomised controlled trial (ANZCTR number: ACTN12612000743864) was conducted using 62 office workers (clerical, call centre and data processing) from 3 large government organisations (Study 4). Three groups developed interventions using a 'participatory approach': 'Active office' (n = 19) aimed to reduce occupational sedentary time by promotion of increasing office incidental activity with participants having access to an 'Active Workstation'; 'Traditional physical activity' (n = 14) aimed to increase activity between productive work time with participants taking part in a pedometer challenge; and 'Office ergonomics' (n= 29) aimed to reduce sustained occupational sitting by encouraging 'active sitting'. Participants wore an ActiGraph GT3X accelerometer for 7 days before the intervention period and again following the 12 week intervention. Participants also completed physical activity, work productivity, job satisfaction, musculoskeletal and readiness for physical activity questionnaires. Accelerometer determined sedentary time, sustained sedentary time, breaks in sedentary time, light activity and MVPA at work and during non-work periods was analysed using repeated measures t-tests to evaluate the overall effect of any intervention across all participants. Linear regression models (ANCOVA) were used to test effects between the organisations and between intervention groups. McNemar's test was used to assess changes in musculoskeletal pain, job satisfaction, work productivity and readiness for physical activity following the intervention period.

Results

In Study 1, office workers were sedentary for 82% of working hours (light activity 15% and MVPA 3%), which was significantly greater than the sedentary time during total non-work hours (69% of total non-work time, $p < 0.001$). Office workers participated in significantly more sustained sedentary bouts (>30 minutes) and significantly less brief bouts of light intensity activity (0-10 minutes) during work hours compared to total non-work time ($p < 0.001$). In addition, office workers had fewer breaks in sedentary time during work hours compared to total non-work time ($p < 0.001$).

In Study 2 office workers were significantly more sedentary during work hours (work hours: office workers 82%; teachers 62%, $p < 0.001$) and participated in significantly less light intensity activity (work hours: office workers 15%; teachers 34%, $p < 0.001$) compared to teachers. In addition, office workers spent a significantly greater proportion of work hours in sustained sedentary bouts (> 30 minutes) compared to teachers (work hours: office workers 41%; teachers 8%, $p < 0.001$). There was no difference in sedentary time, light activity, MVPA, sustained sedentary time and break rate between teachers and offices workers on non-work days and for total non-work time.

In Study 3 the small group (n = 8) of office workers that were using a sit-stand workstation, was not significantly different to the seated office workers in overall sedentary time, light activity, MVPA, sustained sedentary time and break rate during work hours, however the sit-stand office workers participated in significantly more short bouts (0-5 and 5-10 minutes) of light intensity activity compared to seated office workers (sit-stand office workers light activity (0-<5 minutes) 13% wear time; seated office workers light activity (0-<5 minutes) 7% wear time, $p < 0.001$; sit-stand office workers light activity (5-<10 minutes) 3% wear time; seated office workers light activity (5-<10 minutes) 2% wear time, $p < 0.001$).

Following the 12 week participatory workplace intervention of Study 4, when examining intervention effects for all participants, there was a significant reduction in sedentary time during work hours (2% wear time or 8 less sedentary minutes; $p = 0.006$) and a significant increase in light activity during work hours (2% wear time or 7 more light minutes; $p = 0.036$). In addition, there was a significant increase in the number of breaks/ sedentary hour during work hours (0.64 breaks/sedentary hour, $p = 0.005$) and a significant reduction in waist girth across all participants (1.8 cm, $p = 0.005$). When considering the intervention effects between the organisations, sedentary time and MVPA during work hours differed significantly with participants from Organisation 1 responding most to the interventions ($p = 0.043$). None of the three interventions ('active office', 'traditional physical activity' and 'office ergonomics') were clearly more effective at improving occupational sedentary behaviour. Further, following the intervention period, there was no significant difference in the proportion of participants reporting musculoskeletal pain in the different body regions nor was there a significant difference in the reported number of body regions experiencing musculoskeletal pain. Similarly, there was no difference in self-reported job satisfaction or work productivity following the intervention period

Conclusions

Office work is characterised by sustained sedentary time and is likely to contribute significantly to the overall sedentary exposure of office workers. When compared to teachers, office workers were more sedentary during work hours and a greater proportion of working hours consisted of sustained sedentary periods suggesting that office workers may be at greater risk of poor health, compared to teachers, as a consequence of excessive sedentary exposure. The use of a sit-stand workstation has the potential to change the pattern of activity of office workers that may positively impact health. Participatory workplace interventions that modify work practice to reduce occupational sedentary behaviour can reduce sedentary time, increase the frequency of breaks in sedentary time and improve light intensity activity and MVPA of office workers. There is inconclusive evidence of a relationship between sedentary time, physical activity and musculoskeletal pain of office workers. It is anticipated that the findings from this thesis will contribute positively to the growing body of literature regarding occupational sedentary behaviour.

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MET	metabolic equivalent
MVPA	moderate/vigorous physical activity
IPAQ	International Physical Activity Questionnaire
NHANES	National Health and Nutritional Examination Survey
WA	Western Australia
CHMS	The Canadian Health Measures Survey
AusDiab	Australian Diabetes, Obesity and Lifestyle Study
ABS	Australian Bureau of Statistics
BMI	Body Mass Index
HPQ	Health and Work Performance Questionnaire
EVA	Exposure Variance Analysis
ANOVA	One-way analysis of variance
ABW	Activity based work

1.0 Thesis: Sedentary time and physical activity exposure patterns and musculoskeletal symptoms of Australian office workers

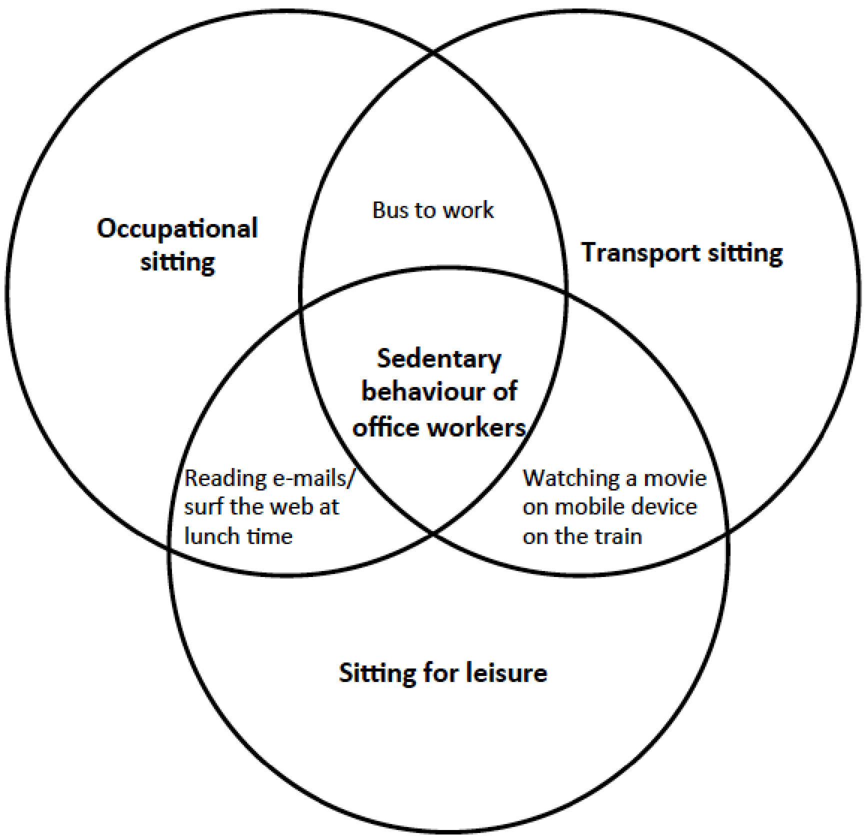
1.1 Thesis introduction

"Stand up while you read this" (New York Times, February 23, 2010), *"Beware of the chair"* (Sydney Morning Herald, March 4, 2010), *"Sitting is the new smoking"* (Sydney Morning Herald, May 30, 2013), *"The perils of sitting down – standing orders"* (The Economist, August 10, 2013) and *"The health hazards of sitting"* (The Washington Post, January 20, 2014). These popular press articles are just a sample of the hundreds of recent mainstream media releases describing the risks associated with prolonged sitting. Sitting is a form of sedentary behaviour, which is defined as any waking behaviour characterised by an energy expenditure ≤ 1.5 resting metabolic equivalents (METs) while sitting or reclining (Owen et al., 2011; Proper, Singh, van Mechelen, & Chinapaw, 2011; Sedentary Behaviour Research Network, 2012).

There is now a substantial body of literature that suggests that excessive sedentary time is associated with an increased risk of cardiometabolic disorders and many chronic diseases (Bauman et al., 2011; George, Rosenkranz, & Kolt, 2013; van Uffelen et al., 2010) as well as increased mortality risk (Healy, Dunstan, Salmon, Shaw, et al., 2008; Katzmarzyk, Church, Craig, & Bouchard, 2009; van der Ploeg, Chey, Korda, Banks, & Bauman, 2012). There is also evidence to suggest that this increased risk may be at least partly independent of participation in moderate/vigorous physical activity (MVPA - activities requiring energy expenditures of 3 or more METs (Sedentary Behaviour Research Network, 2012) such as brisk walking or running) (Healy, Dunstan, Salmon, Shaw, et al., 2008; Healy, Mathews, Dunstan, Winkler, & Owen, 2011; Healy, Wijndaele, et al., 2008; van der Ploeg et al., 2012). However, there are inconsistencies in the evidence with respect to the relationship between sedentary time and cardiometabolic risk factors (Lynch et al., 2014; Maher, Olds, Mire, & Katzmarzyk, 2014). Further, prolonged or uninterrupted sedentary time has been found to be a risk factor to poor cardiometabolic health, potentially independent of total sedentary time and MVPA (Carlson et al., In Press; Healy, Dunstan, Salmon, Cerin, et al., 2008; Healy, Mathews, et al., 2011). In addition, light intensity activity (leisure, domestic or occupational activities requiring an energy expenditure of 1.6-3.0 METs (Sedentary Behaviour Research Network, 2012) such as gentle walking) has been found to be associated with improved plasma glucose levels, again potentially independent of MVPA (Healy et al., 2007).

Sedentary behaviour typically occurs in three main domains: occupation, transport and leisure (Owen, Bauman, & Brown, 2009) and includes popular activities such as sitting at a desk, driving, TV viewing, using a computer and reading from paper. The contribution of each of these domains is likely to vary between individuals. However, individuals with occupations which require sitting to complete work tasks, such as office workers (clerical, call centre workers, data entry workers), may be particularly vulnerable to the cardiometabolic risks associated with sitting due to the necessity to sit while completing work tasks. It is therefore arguable that office workers may be exposed to an unreasonable level of risk of poor health due to the requirement to sit while working (Straker, Healy, Dunstan, & Atherton, In Press). The interaction between the domains of sedentary behaviour for office workers is illustrated in Figure 1.1. For office workers, occupational sitting may contribute a greater proportion to overall sedentary behaviour than for other more active occupational groups. Even if office workers have greater leisure and transport related physical activity, this may not overcome the detrimental effects of prolonged sedentary exposure as evidence suggests sedentary risks may be at least partly independent of participation in physical activity. While a limited number of recent studies have examined the sedentary exposure of office workers (Clemes, O'Connell, & Edwardson, 2014; Clemes, Patel, Mahon, & Griffiths, 2014; Thorp et al., 2012; Tigbe, Lean, & Granat, 2011), to date there are no reports of research that has specifically examined the exposure pattern of sedentary behaviour, light activity and MVPA of office workers at work and outside of work hours and compared the pattern of sedentary behaviour of office workers with other occupational groups.

Figure 1.1: Sedentary exposure of office workers



A number of workplace-based interventions to reduce sedentary behaviour and sitting for office workers have been trialled such as break-prompting software (Evans et al., 2012) and the use of a standing 'hot' desk (Gilson, Suppini, Ryde, Brown, & Brown, 2012) with variable success (Chau et al., 2010). Most recently, the introduction of sit-stand workstations has demonstrated favourable results (Alkhajah et al., 2012; Healy et al., 2013). However, there is limited research that compares a number of different work-based intervention approaches that aim to reduce occupational sedentary behaviour and improve occupational light intensity activity of office workers (Healy et al., 2013; Neuhaus, Healy, Dunstan, Owen, & Eakin, 2014).

Workplace health may also be influenced by a variety of work factors. Job satisfaction has been found to impact mental health, stress and cardiovascular symptoms (Bogg & Cooper, 1995; Heslop, Davey Smith, Metcalfe, Macleod, & Hart, 2002) but there does not appear to be any research that has examined the relationship between job satisfaction and occupational sedentary behaviour and physical activity. Further, to date there is very limited evidence available regarding the relationship between sedentary behaviour/physical activity and self-reported work productivity (Bernaards, Proper, & Hildebrandt, 2007; H. Brown, Ryde, Gilson, Burton, & Brown, 2012; Grunseit, Chau, Van Der Ploeg, & Bauman, 2013).

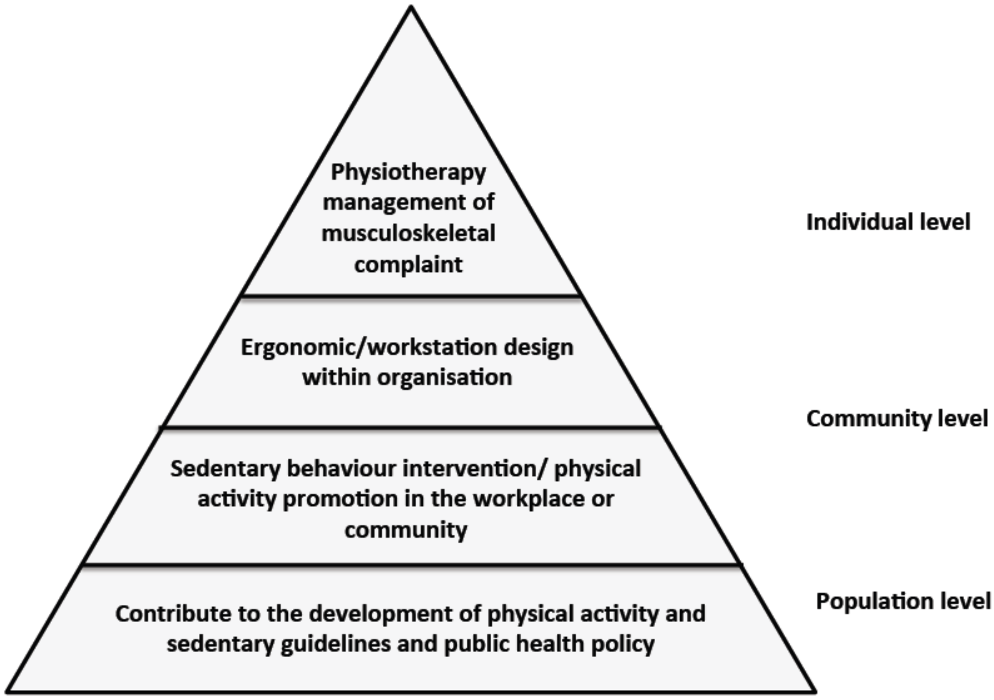
This thesis aims to bring together the fields of physiotherapy, ergonomics, occupational health, epidemiology and health promotion to develop and examine interventions aimed at improving occupational sedentary behaviour. During the 1980's, with the introduction of desktop computers, office workers were exposed to risks associated with prolonged and uninterrupted typing or data entry. Musculoskeletal complaints in the upper quadrant were commonly associated with computer-based tasks (Cho, Hwang, & Cherng, 2012; Widanarko et al., 2011). At that time, recommendations for work practices were developed with the aim of reducing the musculoskeletal risks associated with repetitive computer use (1986). In recent times, the evidence of an association between prolonged sitting and musculoskeletal pain is less clear (Roffey, Wai, Bishop, Kwon, & Dagenais, 2010). To date there does not appear to be any high quality studies that examine the relationship between objectively determined sedentary time and musculoskeletal pain. Further, while a number of workplace-based interventions have examined the impact of physical activity on musculoskeletal complaints (L. L. Andersen et al., 2010; L. L. Andersen et al., 2011; Blagsted, Søgaard, Hansen, Hannerz, & Sjøgaard, 2008), there is limited research that has explored the effect of reducing sedentary exposure and introducing light intensity activity on musculoskeletal pain (Davis, Kotowski, Sharma, Herrmann, & Krishnan, 2009; Hedge & Ray, 2004; Husemann, Von Mach, Borsotto, Zepf, & Scharnbacher, 2009).

Physiotherapy in Australia encompasses an evidence-based practice approach in combination with the clinical reasoning process. Physiotherapy:

> "involves a holistic approach to the prevention, diagnosis, and therapeutic management of pain, disorders of movement or optimisation of function to enhance the health and welfare of the community from an individual or population perspective" (Australian Physiotherapy Council, 2006, p. 6, p6).

Figure 1.2 was developed by the author to illustrate the interactions of physiotherapy with office workers from an individual to population approach. When working with office workers, physiotherapy practice often involves interaction at the individual level, for example by providing management of musculoskeletal complaints or ergonomics advice and interventions to prevent musculoskeletal symptoms. Physiotherapists may also consult with management within an organisation to assist in workstation and office design to optimise the musculoskeletal health of office workers. The emphasis of physiotherapy involving office workers has been on management and prevention of musculoskeletal disorders at an individual and community level, however, there is also the opportunity for the physiotherapy profession to participate in preventative initiatives at the population level. Physiotherapists may be involved in population research, incorporating the evidence from sedentary behaviour population research into clinical practice and by contributing to the public health guidelines and policy (Straker, 2012).

Figure 1.2: Physiotherapy in relation to office workers



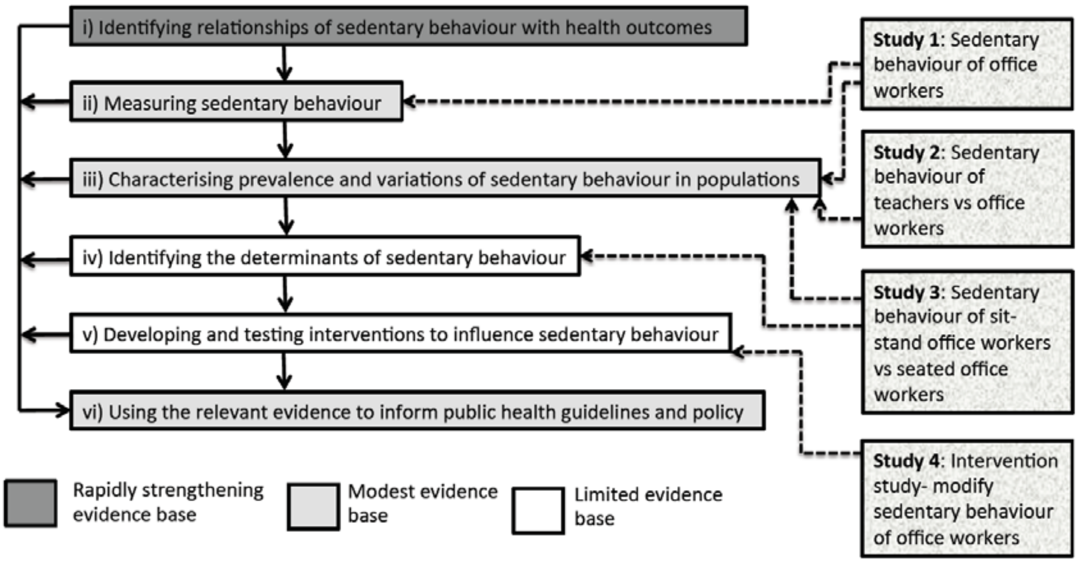
The behavioural epidemiological framework (Sallis, Owen, & Fotheringham, 2000) was developed to classify research categories relating to any health behaviour. Owen et al (2010) have applied the framework specifically to sedentary behaviour research, as illustrated in Figure 1.3. Each phase builds and influences the development of the next phase with all elements of research contributing to the development of public health guidelines and policy. The four studies of this thesis are aligned to this framework, as described below.

The first phase of the framework is identifying the relationships between sedentary behaviours and health outcomes. Over recent years, many large high quality population studies using objective measures of sedentary time have provided evidence of a relationship between sedentary behaviour (exposure and pattern of exposure) and cardiometabolic risk factors (Healy, Dunstan, Salmon, Cerin, et al., 2008; Healy, Mathews, et al., 2011). However, there is an emerging debate regarding this association between sedentary behaviours and cardiometabolic health outcomes. Recent reanalysis of population data, when adjusted for total physical activity (including light activity) rather than total

MVPA, suggests that there is no association between sedentary behaviour and cardiometabolic risk factors (Maher et al., 2014). While this new evidence has not been widely accepted (Lynch et al., 2014), it highlights that the strength of the association between sedentary behaviour and cardiometabolic risk factors may not be as strong as originally proposed.

Phase 2 of the framework, measuring sedentary behaviour, is a growing area of research. Study 1 of this thesis was an observational study that used the International Physical Activity Questionnaire (IPAQ) and accelerometers to evaluate the sedentary time and physical activity of 50 office workers during work hours and during non-work time. The results from Study 1 add to the body of knowledge on measurement of sedentary behaviour (Phase 2) and further contribute to contextual determinants of sedentary behaviour such as occupational sedentary behaviour (Phase 4). Study 2 of this thesis compares sedentary time and physical activity of 34 school teachers with the sedentary time and physical activity of the office workers that completed Study 1. The findings from Study 2 further contribute to the understanding of sedentary behaviour of other occupational groups (Phase 4). Study 3 of this thesis examined a small convenience sample of 8 office workers that were using a sit-stand workstation instead of a regular desk. In this study, comparisons in sedentary time and physical activity were made between the sit-stand office workers and the seated office workers that completed Study 1. The findings from this study contribute to understanding the efficacy and feasibility of using novel interventions such as a sit-stand workstation in larger intervention studies (Phase 5). Study 4 of this thesis was a randomised controlled trial that compared accelerometer determined sedentary time and physical activity of three workplace intervention strategies aimed to reduce sedentary time and improve light intensity activity of office workers during work hours. A secondary aim of Study 4 was to explore if the interventions would also modify self-reported musculoskeletal pain of office workers. Results from this study add to the growing evidence base of sedentary behaviour interventions than can assist in the development of public health guidelines and policy (Phase 6).

Figure 1.3: Behavioural epidemiology framework applied to sedentary behaviour evidence and the relationship of the 4 thesis studies to the phases of the framework (adapted from Owen et al, 2010)



Therefore, the overall aims of this thesis were:

1. To conduct a comprehensive examination of sedentary time and physical activity (amount and pattern of exposure) of office workers during work hours and during non-work periods.
2. To explore the relationship between musculoskeletal pain and sedentary time of office workers.
3. To explore potential correlates of physical activity and sedentary behaviour such as job satisfaction and work productivity.
4. To compare the sedentary time, physical activity (amount and pattern of exposure) and musculoskeletal pain of school teachers and office workers.
5. To compare the sedentary time, physical activity (amount and pattern of exposure) and musculoskeletal pain of a small group of office workers that chose to use a sit-stand workstation with desk bound office workers.
6. To determine if participatory workplace-based interventions could reduce sedentary time and improve light intensity activity of office workers during work hours and during non-work periods.

7. To determine if workplace-based participatory sedentary behaviour interventions would change self-reported musculoskeletal pain, job satisfaction, work productivity and attitude to participation in physical activity.
8. To determine if intervention effects from participatory workplace-based interventions would vary across organisations.

This thesis describes four studies undertaken between 2008 and 2011. The thesis starts with an overall literature review that outlines the measurement of physical activity and sedentary behaviour and the relationship between these behaviours and health. The literature review discusses the important relationship between occupational sedentary behaviour and cardiometabolic and musculoskeletal health. It also describes other potential occupational correlates such as job satisfaction and work productivity to physical activity and sedentary behaviour. The literature review examines the development and implementation of workplace interventions to modify physical activity and sedentary behaviour of office workers and highlights gaps in the literature. Chapters 3-12 present the background, methods and results from Studies 1-4. The final chapter of the thesis summarises the contributions to knowledge drawn from the studies, discusses the implications to practice, the strengths and limitations of the thesis and directions for future research.

2.0 Literature review

2.1 Introduction

The aim of this literature review is to expand the concepts introduced in Chapter 1 of this thesis and to provide supporting evidence for the rationale and development of the four studies undertaken in this thesis. The literature review will also critically appraise the literature in relation to the overall aims of the thesis.

This literature review firstly defines physical activity and sedentary behaviour and then discusses measurement of these behaviours. The relationships between physical activity and sedentary behaviour to health are explored and the development of physical activity and sedentary behaviour guidelines and recommendations are discussed. The overall amount and pattern of physical activity and sedentary behaviour levels in Australia and around the world are examined.

The next section of the literature review discusses the changing nature of work and the resultant changes to occupational physical activity and sedentary behaviour and how occupational sedentary behaviour may impact cardiometabolic and musculoskeletal health. The literature review then discusses how occupational variables may influence the effectiveness of workplace interventions. Finally, the literature review appraises the current approaches to improving workplace physical activity and sedentary behaviour and summarises the gaps in the literature.

2.2 Definitions of physical activity and sedentary behaviour

Physical activity is defined as:

> “any bodily movement produced by skeletal muscles that results in energy expenditure” (Casperson, Powell, & Christenson, 1985, p.126).

Physical activity can be characterised by the type, frequency, duration and intensity of activity (Welk, 2002). Physical activity intensity is typically categorised by energy expenditure presented in metabolic equivalents (METs) with one MET representing the resting energy expenditure during quiet sitting (Ainsworth et al., 2000; McArdle, Katch, & Katch, 2007; Welk, 2002). Light intensity activity ranges from 1.6 – 2.9 METs, moderate intensity activity from 3 - 6 METS and vigorous intensity activity is greater than 6.0 METs (Ainsworth, Haskall, & Leon, 1993; Ainsworth et al., 2000; Pate, O'Neill, & Lobelo, 2008; Pate et al., 1995). There are many potentially important aspects of physical activity such as the pattern of accumulation (Metzger et al., 2008; Troiano et al., 2008; Tucker, Welk, & Beyler, 2011), the type (Blake, Lee, Stanton, & Gorely, 2008; Welk, 2002) and purpose (Aittasalo, Rinne, Pasanen, Kukkonen-Harjula, & Vasankari, 2012; Besser & Dannenberg, 2005; S. G. Brown & Rhodes, 2006) of the activity and domain in which activity occurs (Burton & Turrell, 2000; Caban-Martinez et al., 2007).

Sedentary behaviour is waking behaviour with low energy expenditure (equal to or less than 1.5 METs) in a sitting or recumbent posture (Owen et al., 2011; Proper et al., 2011; Sedentary Behaviour Research Network, 2012). Whilst standing still could be considered sedentary behaviour due to the low energy expended while standing (Reiff, Marlatt, & Dengel, 2012; Speck & Schmitz, 2011), standing may provide other health benefits such as increased incidental activity, improved heart rate and postural variation (Mathiassen, 2006; Pline, Madigan, & Nussbaum, 2006; Toomingas, Forsman, Mathiassen, Heiden, & Nilsson, 2012; Tudor-Locke, Schuna, Frensham, & Proenca, 2013). Sedentary behaviour is thus defined in this thesis by energy expenditure and sitting and recumbent position. Potentially important aspects of sedentary behaviour include the pattern of accumulation (Healy, Dunstan, Salmon, Cerin, et al., 2008) and the type of sedentary behaviour (watching television, using a computer) (Katzmarzyk et al., 2009; Veerman et al., 2012), as well as the domain in which sedentary behaviour occurs (Owen et al., 2011; Pronk, Katz, Lowry, & Payfer, 2012). Therefore, sedentary behaviour is not simply the absence of physical activity but rather, a unique and complex behaviour (Hamilton, Healy, Dunstan, Zderic, & Owen, 2008; Owen et al., 2010)

2.3 Measurement of physical activity and sedentary behaviour

2.3.1 Self-report measures of physical activity and sedentary behaviour

Self-report measures have been used widely to assess many aspects of physical activity and sedentary behaviour such as the type and context of activity. Questionnaires, interviews and diaries are relatively inexpensive and easy to administer, particularly with large populations (Balogh et al., 2004; Carlson et al.; Church et al., 2011; M. Rosenberg et al., 2010; Sallis & Saelens, 2000). However, self-report measures are dependent on the ability of individuals to accurately recall events that have occurred in the past and details, such as frequency and duration of activities, are often required. Using self-report instruments that provide contextual cues, that is, relating activity to work, transport, leisure, can assist in accurate recall (Matthews, 2002).

Physical activity can be measured in terms of overall exposure or total amount of activity, the intensity of the activity, the pattern of exposure of the activity and domain specific activities (work, transport, domestic and leisure) (Welk, 2002). In an early review of self-report measures to assess physical activity, Sallis and Saelens (2000) found relatively high test-retest reliability (correlations coefficients ranging from 0.60-0.89), particularly with short recall periods, however validity was low (correlations coefficients ranging from 0.14-0.36) with measurement of global or overall physical activity. Other limitations of using self-report measures of physical activity are over-estimation of physical activity (Ekelund et al., 2005; Ottevaere et al., 2011; Sebastiao et al., 2012), the difficulties in discriminating between physical activity intensities (light, moderate and vigorous) (Ainsworth, Richardson, Jacobs Jr, Leon, & Sternfeld, 1999; Sallis & Saelens, 2000; Welk, 2002), the tendency to respond in a socially desirable way (Ward, Evenson, Vaughn, Brown Rodgers, & Troiano, 2005; Welk, 2002) and the inability to comprehensively assess the pattern or bouts of activity (Shepherd, 2003).

Sedentary behaviour can be assessed by examining overall sedentary time in a given time period, specific sedentary behaviours such as watching television or sedentary time in specific domains (work, transport, leisure) (Healy, Clark, et al., 2011). Variable reliability has been described in the self-report assessment of sedentary behaviours, however the majority of questionnaires to assess sedentary behaviour have reportedly moderate to high reliability, with reliability most consistent when assessing specific habitual activities such as television viewing (Clark et al., 2009; Healy, Clark, et al., 2011). The validity of questionnaires to assess sedentary behaviour has also been found to be variable with findings suggesting both underestimation and overestimation of sedentary behaviour (Fitzsimons, Kirk, Murphy, & Mutrie, 2012; Healy, Clark, et al., 2011).

Importantly, when assessing the validity of self-report measures to monitor physical activity or sedentary behaviour there is no “gold standard” of comparison. Most validity studies have used accelerometers to compare activity or sedentary time. However, it is debatable whether motion sensors can truly reflect the complex nature of physical activity and sedentary behaviour. Further, accelerometer determined physical activity and sedentary time are derivatives from raw accelerometer counts and may vary depending on the particular brand of accelerometer and the activity cut-points used (Colley & Trembly, 2011; Freedson, Melonson, & Sirard, 1998; Matthews, Ainsworth, Thompson, & Bassett, 2002; Oliver, Schofield, Badlands, & Shepherd, 2010; Straker & Campell, 2012; Wong, Colley, Connar Gorber, & Tremblay, 2011). A detailed description of motion sensors is provided in Section 2.3.2. Nevertheless, accelerometers have been used consistently to validate self-report measures but care should be taken when interpreting the results.

Activity diary or log based self-report provide a detailed record of activity over a given time period and can include description of the type and intensity of the activity or sedentary behaviour. Activity logs generally report the time spent in broad categories of activities such as sitting, standing and walking (Matthews, 2002). The difference between activity diaries and activity logs is that when using an activity log, participants are required to record the individual bouts of activities as they occur in real time whilst diaries are completed after the activities, say at the end of a day (Ainsworth, Irwin, Addy, Whitt-Glover, & Stolarczyk, 1999; Welk, 2002). Both diaries and logs are useful in providing context and details of physical activity or sedentary behaviour but reporting is burdensome for the participant and the act of reporting activity can influence behaviour (Matthews, 2002). In a comprehensive assessment of physical activity or sedentary behaviour, an activity diary or log could be used in conjunction with an objective measure of activity to provide valuable contextual information.

In summary, self-report measures of physical activity and sedentary behaviour can provide a low cost overview of physical activity and sedentary behaviour. Reliability is generally moderate to high but validity is variable. Self-report instruments are ideally used in conjunction with other objective measures to supplement objective findings with context specific information.

2.3.1.1 International Physical Activity Questionnaire – IPAQ

One of the most widely used physical activity questionnaires is the International Physical Activity Questionnaire (IPAQ). It was developed in response to the need for a global measure to assess the prevalence of physical activity and sedentary behaviour in a systemic way with large population groups around the world (www.ipaq.ki.se). Previous physical activity questionnaires, such as the "Active Australia Survey"(Timperio, Salmon, Rosenberg, & Bull, 2004), "Behavioural Risk Factor Surveillance System" (Ainsworth et al., 2006), "Tecumseh Occupational Activity Questionnaire" (Steele & Mummery, 2003) and "Seven Day Recall" (Shepherd, 2003) have focused on participation in activity in one or more domains such as leisure time or occupational physical activity, but do not specify the time spent in each domain of physical activity (Ainsworth, Richardson, et al., 1999; Shepherd, 2003; Tehard et al., 2005). The IPAQ incorporates estimates of occupational, transport, domestic and leisure physical activity. It also has specific questions relating to sitting time. IPAQ has been designed as both a long (27 items) and short (7 items) survey (www.ipaq.ki.se). The long form allows for more detailed analysis of domains of physical activity and sitting.

In 2003, a major international study was conducted to examine the validity and reliability of the IPAQ (Craig et al., 2003). There were testing sites in 14 locations across 12 countries including Australia. Test re-test reliability of the long form IPAQ was found to be very good (correlation coefficients ranging from 0.46-0.96), with recall of vigorous activities generally more accurate than moderate intensity activities. There was also good test-re-test reliability in reporting total sitting time (correlation coefficients ranging from 0.29-0.93). Similarly, the short form IPAQ was found to have good repeatability but with overall lower reliability (Craig et al., 2003; Papathanasiou et al., 2009; Tran, Lee, Au, Nguyen, & Hoang, 2013).

Criterion validity has been assessed by comparing IPAQ determined physical activity (MVPA) with accelerometer derived activity. It was found that there was low to moderate agreement between self-reported and accelerometer derived physical activity (Spearman's coefficient 0.02-0.61) (Craig et al., 2003). Other validity studies of the long form IPAQ using activity monitors and activity logs have suggested good validity for overall physical activity but validity is weaker when estimating moderate intensity activity (Hagstromer, Oja, & Sjostrom, 2006; Macfarlane, Lee, Ho, Chan, & Chan, 2007; Ottevaere et al., 2011). The shorter form IPAQ has been found to have weaker validity with accelerometer determined activity and it generally overestimates MVPA (Ekelund et al., 2005; Hagstromer et al., 2006; Kurtze, Rangul, & Hustvedt, 2008; P. H. Lee, Macfarlane, Lam, & Stewart, 2011).

In relation to sedentary behaviour, the long form of the IPAQ uses three items to assess sitting time (sitting on week days, weekend and during transport). The short form of the IPAQ uses a single item to assess total sitting time of week days only. While sitting is a component of sedentary behaviour, sitting does not reflect total sedentary time, which may also include activities while reclining. A further limitation to using IPAQ to assess sedentary behaviour is that sitting time is not assessed in a specific domain (with the exception of transport) but rather as an overall measure for a week. A small number of studies have examined the validity of the long and short form IPAQ to measure sitting time. Validity has been assessed by comparing sitting time to accelerometer derived sedentary time with low to moderate agreement between self-reported sitting and accelerometer derived sedentary time (Spearman's coefficient 0.14 – 0.63) (Craig et al., 2003; Healy, Clark, et al., 2011; Rosenberg, Bull, Marshall, Sallis, & Bauman, 2008). One of the difficulties in assessing validity of sitting with accelerometer derived sedentary time is that accelerometers will capture all sedentary minutes, not just minutes sitting so that correlations are unlikely to be high.

Despite these limitations, the IPAQ has been used to assess a wide variety of populations groups (Bauman et al., 2011; Colley et al., 2011; Faulkner, Cohn, & Remington, 2006; Fillipas, Cicuttini, Holland, & Cherry, 2010; Tehard et al., 2005) including office workers (Osteras & Hammer, 2006). As the IPAQ assesses self-reported physical activity in four domains, including occupational physical activity and self-reported sitting time, the IPAQ was included in the studies undertaken in this thesis. It was anticipated that the information gained from using the IPAQ would complement the accelerometry results by providing the context of sitting and activity and to illustrate the distribution of physical activity in the four domains (work, transport, domestic and leisure)

The IPAQ was primarily developed as a physical activity surveillance tool (Craig et al., 2003) but it has also been used an outcome measure in a number of studies (Aittasalo et al., 2012; De Cocker, De Bourdeaudhuij, Brown, & Cardon, 2008; Kozey-Keadle, Libertine, Staudenmayer, & Freedson, 2012). The IPAQ was included as a secondary outcome measure in Study 4 to assess changes in self-reported MVPA and sitting time. While accelerometer derived physical activity and sedentary time were the primary outcomes, it was anticipated that any changes to objective measures of physical activity and sedentary time would also be reflected in changes to self-reported measures.

2.3.2 Motion sensors to assess physical activity and sedentary behaviour

There are a number of assessment tools that have been developed to objectively measure physical activity and/or sedentary behaviour. These devices range from inexpensive pedometers, simple uni-axial accelerometers, multi-plane accelerometers, inclinometers and devices that incorporate features of step count, inclinometer and accelerometer. Due to recent technological advances, motion sensors can record and store large amounts of data in a very small device. In the following section, the development and use of motion sensors in research is discussed with particular emphasis on the two accelerometers used in this thesis, the Actical accelerometer (Phillips-Respironics, Oregon, USA) (Studies 1-3) and the Actigraph 3GTX accelerometer (ActiGraph, Pensacola, USA) (Study 4).

2.3.2.1 Pedometers

Pedometers are simple motion sensors that are inexpensive, small and easy to use and have been widely used to measure ambulatory activity. Pedometers are usually attached to the waist to measure the number of steps that a person takes by detecting changes in vertical acceleration (Bassett Jr & Strath, 2002; Montoye, Kemper, Saris, & Washburn, 1996). As pedometers only detect movement in the vertical plane, pedometers cannot measure physical activity in any other planes of movement. While early generation pedometers could not differentiate between intensities of movement, such as speeds of walking or running, as only the gross numbers of steps are recorded (Bassett Jr & Strath, 2002; Tudor-Locke, Williams, Reis, & Pluto, 2002; Welk, 2002), some of the new pedometers, that employ a piezoelectric mechanism have improved step detection accuracy, are able to record steps when positioned in a variety of body positions and can estimate walking speeds through step cadence (De Cocker, De

Meyer, De Bourdeaudhuij, & Cardon, 2012; Giannakidou et al., 2012; Park, Lee, Ku, & Tanaka, 2014). Pedometers cannot assess upper limb or upper trunk movement and would therefore have limited use when the assessment of upper body activity is required. In addition, as pedometers typically only measure number of steps over a period of time, a pedometer has limited potential to assess the pattern of accumulation of steps.

Test-retest reliability is reported as good but there is variability between different brands of devices (Bassett Jr et al., 1996; Bassett Jr & Strath, 2002; Park et al., 2014). In terms of validity, there is a strong correlation between pedometer and accelerometer measured physical activity and an inverse relationship between pedometer steps and self-reported sitting (Bassett Jr et al., 2000; Tudor-Locke, Ainsworth, Thompson, & Matthews, 2002; Tudor-Locke, Williams, et al., 2002).

Pedometers have been used recently in population studies to assess ambulatory activity (Bassett Jr, Wyatt, Thompson, Peters, & Hill, 2010; George et al., 2013; McCormack, Milligan, Giles-Corti, & Clarkson, 2003; M. Rosenberg et al., 2010) and increasingly as a motivational and self-monitoring tool in intervention studies (Ainsworth et al., 2012; Aittasalo et al., 2012; Carr et al., 2008; Chan, Ryan, & Tudor-Locke, 2004; De Cocker et al., 2008; Freak-Poli, Wolfe, Backholer, de Courten, & Peeters, 2011). Some workplace activity programmes using pedometers have been particularly successful in improving physical activity in sedentary workers (Aittasalo et al., 2012; Freak-Poli et al., 2011; Gilson et al., 2009). However, a recent systematic review of workplace pedometer interventions to increase physical activity (Freak-Poli, Cumpston, Peeters, & Clemes, 2013) found that due to the limited number and low quality of workplace pedometer trials, it was not possible to conclude that workplace pedometer interventions were effective at increasing physical activity and health outcomes.

2.3.2.2 Accelerometers

Accelerometers are small motion sensors that can be attached to the body (hip, upper arm, wrist or ankle) to record changes in acceleration. Rates of acceleration are detected by piezoresistive elements and then converted to readable information by a microprocessor within the device (Keim, Blanton, & Kretch, 2004; Welk, 2002). Uniaxial accelerometers detect movement in one plane (typically vertical) and triaxial accelerometers can detect movement in three planes. The advantage of using accelerometers is the ability to simultaneously record the amount of activity (counts) in a given time period (epoch) and therefore assess pattern of activity intensity over time. Accelerometers have been found to have acceptable reliability for research (Welk, Schaben, & Morrow Jr, 2004) but reliability is variable between different devices (Matthews, 2005; Trost, McIver, & Pate, 2005). One of the challenges in using motion sensors to assess activity is the validity of the particular device to truly reflect the activity being measured, particularly in free-living conditions. Most validity studies of accelerometers estimate energy expenditure from activity counts in laboratory and field studies using indirect calorimetry and double labeled water and then derive regression equations to equate activity to energy expenditure. Under laboratory conditions with a limited set of activities, correlation between energy expenditure and activity counts is high and generally greater than in field studies (Bassett Jr et al., 2000; Crouter & Bassett Jr, 2008; Dinger & Behrens, 2006; Nichols, Morgan, Chabot, Sallis, & Calfas, 2000; Swartz et al., 2000; Ward et al., 2005). However, it is important to note that energy expenditure is not a direct measure of physical activity, nevertheless it has been used widely to reflect physical activity intensities (Ainsworth et al., 1993; Ainsworth et al., 2000).

Participants in the observational studies (Studies 1-3) of this thesis wore the Actical (Phillips-Respironics, Oregon, USA) accelerometer to assess sedentary time and physical activity. It is described by the manufacturer as “omnidirectional” and detects movement primarily in the vertical plane but also senses movement in other planes. It was anticipated that the “omnidirectional” nature of the accelerometer would be useful in detecting incidental movement associated with office work. The device is small (2.8 × 2.7 × 1.0 cm), light (17 g) and waterproof so that it does not need to be removed for swimming or surface water sports.

The Actical accelerometer has shown good intra-instrument and inter-instrument reliability in laboratory studies (Eslinger & Tremblay, 2006). The validity of the Actical accelerometer to measure energy expenditure in free-living conditions has been assessed using indirect calorimetry (Heil, 2006). The Actical accelerometer has been found to be a valid measure of moderate and vigorous physical activity when compared to treadmill walking and running at pre-determined speeds (Colley & Trembly, 2011). The Actical accelerometer has also been found to be a valid measure of sedentary time in free-living conditions when compared to an activPAL™ (PAL Technologies Ltd, Glasgow, Scotland) inclinometer (Oliver et al., 2010). It has been used in large population studies (Carson et al., 2014; Colley et al., 2011; Kayes et al., 2009; Rand, Eng, Tang, Jeng, & Hung, 2009) and recently to assess sedentary time in office workers (Oliver et al., 2010).

The ActiGraph (ActiGraph, Pensacola, USA) accelerometer is one the most widely used accelerometers in population research and has been used in the US National Health and Nutritional Examination Survey (NHANES) studies that are discussed in Section 2.8 of this literature review (Metzger et al., 2008; Troiano et al., 2008; Tucker et al., 2011). The early generation ActiGraph accelerometers were uni-axial with later versions providing tri-axial output. In Study 4, participants wore the ActiGraph GT3X to assess sedentary time and physical activity. The ActiGraph GT3X is a tri-axial accelerometer that also has an inclinometer function incorporated into the unit. It is small (3.8 × 3.7 × 1.8 cm) and weighs 28g. There are limited reported studies that have used this model of accelerometer. One recent study has used the ActiGraph GT3X to assess time spent in different postures in free-living conditions with sedentary adults of different weight categories (Barwais, Cuddihy, Rachele, & Washington, 2013). While this study used the inclinometer function of the accelerometer to classify postures, the ActiGraph GT3X inclinometer function has been found to misclassify sitting and standing (Clemes et al., 2012; McMahon, Brychta, & Chen, 2010).

Subsequent to the data collection in Study 4, ActiGraph released a newer model of the GT3X. The GT3X-plus records raw data, typically at 30Hz, for each axis and has been used to assess sedentary behaviour of older adults (Aguilar-Farias, Brown, & Peeters, 2014) and to collect data in the latest NHANES population research (see Section 2.8). A recent study has compared inter-monitor agreement between the most recent generations of ActiGraph accelerometers in laboratory-based standardised activity sessions. It was found that there was strong agreement (Inter-class correlations between 0.989 - 0.981) in vertical axis activity counts, vector magnitude counts (GT3X and GT3X-plus) and time in MVPA between the GT1M, GT3X and GT3X-plus ActiGraph models (Robusto & Trost, 2012). Given that accelerometer studies over recent years have used a variety of ActiGraph accelerometers (Camhi, Sisson, Johnson, Katzmarzyk, & Tudor-Locke, 2011; Kozey-Keadle et al., 2012; Thorp et al., 2012), the findings from this study suggest that accelerometer determined MVPA data between ActiGraph models is comparable. However, light intensity activity and sedentary time were not assessed by Robustio and Trost (2012) so it is unclear whether the same relationship exists for lower intensity activities.

Accelerometer activity cut-points were developed to categorise activity counts into activity intensities, so that activity in a particular range of activity counts could be classified as sedentary, light, moderate or vigorous. These activity cut-points are important in understanding and giving meaning to accelerometer count data. Activity cut-points were derived from studies that compared accelerometer counts to energy expenditure (oxygen consumption), activity logs or MET determined activities (treadmill walking). A summary of selected papers that describe activity count cut-points is shown in Table 2.1. Freedson et al (1998) used an early version of the ActiGraph accelerometer to establish cut-points for light (< 1952 counts/minute), moderate (1952-5724 counts/minute) and vigorous (hard) (>5725 counts/minute) activity in a laboratory based study. As the focus of research shifted to examining low intensity activity and sedentary time, Matthews et al (2008) was the first to use the sedentary cut-point of 100 counts/min based on the findings of other researchers (Healy et al., 2007; Treuth, Schmitz, & Catellier, 2004). Troiano et al (2008) used the weighted average of cut-points derived from four different studies (Brage, Wedderkopp, Franks, Andersen, & Froberg, 2003; Freedson et al., 1998; Leenders, Sherman, Nagaraja, & Kien, 2001; Yngve, Nilsson, Sjostrom, & Ekelund, 2003) and these cut points were used in the NHANES data analysis (Metzger et al., 2008).

Activity count cut-points are specific to the device so that the Actical accelerometer activity cut-points vary from the ActiGraph cut-points. In order to compare and be consistent with research findings Straker and Campbell (2012) developed ActiGraph translated cut-points than can be applied when using an Actical accelerometer. The translated cut-points were derived from regression equations from data obtained by subjects wearing the Actical and the ActiGraph GT3X accelerometers simultaneously under free-living conditions. These translated cut-points were used for analysis in Studies 1-3.

For Study 4, the Actigraph GT3X was used to assess sedentary time and physical activity at baseline and following the intervention period. It was anticipated that assessing activity in planes other than the vertical would be useful to detect small changes, such as postural and incidental movements that may have otherwise been overlooked by assessing only the vertical plane of movement. However, to date, there are no published or manufacturer recommended activity count cut-points for adults in the frontal and lateral axes of movement, only for the vertical axis, and therefore analysis was only conducted on the vertical plane data. The activity count cut-points for the vector magnitude sum of the three axes in the ActiGraph GT3X model for children and the GT3X-plus in adults are being developed (Aguilar-Farias et al., 2014; Hanggi, Phillips, & Rowlands, 2013) and the cut-points for each axis may be developed in the future, although analysis is now moving away from epoch count data to raw data (Aguilar-Farias et al., 2014).

Table 2.1: Summary of selected accelerometer activity one minute epoch count intensity cut-point recommendations for adults

Author	Accelerometer	Method	Cut-points derived (counts/min)
Freedson et al (1998)	CSA monitor (predecessor of ActiGraph)	Laboratory conditions; Oxygen consumption; spirometry	Light: <1952 Moderate: 1952-5724 Hard: 5725-9498 Very hard: >9498
Troiano et al (2008)	ActiGraph	Weight average from 4 studies*	Moderate: 2020-5999 Vigorous: >5999
Matthews (2005)	ActiGraph	Review study	Sitting: ≤ 50
Matthews et al (2008)	ActiGraph	Derived from 2 studies^	Sedentary<100
Colley and Tremblay, (2011)	Actical	Laboratory conditions; treadmill METs	Moderate: 1536-3959 Vigorous: > 3960
Wong et al (2011)	Actical	Free-living; analysis of Actical and step data	Sedentary: < 100
Straker and Campbell (2012)	Actical/ ActiGraph	Free-living; 2 days wearing both accelerometers	Actical translated Sedentary: <91 Light: 91-1766 Moderate: 1767-5181 Vigorous: > 5182

*(Brage et al., 2003; Freedson et al., 1998; Leenders et al., 2001; Yngve et al., 2003)
^(Healy et al., 2007; Treuth et al., 2004)

2.3.2.3 Posture monitors

Accelerometers have the ability to measure intensity of activity, however, an accelerometer cannot distinguish between activity occurring in sitting or standing. A number of studies have examined the influence of posture of musculoskeletal pain in office workers and call centre workers and have used a thigh-mounted inclinometer to differentiate sitting and standing positions (Balogh et al., 2004; Mork & Westgaard, 2007; Toomingas et al., 2012). However, the studies above did not differentiate between standing and walking.

Therefore postures reported as “non-seated” may be standing or walking (Toomingas et al., 2012). Some of the newer accelerometers have an inclinometer function incorporated into the device but, as mentioned above, the inclinometer function in the ActiGraph GT3X accelerometer appears to misclassify postures (Clemes et al., 2012; McMahon et al., 2010).

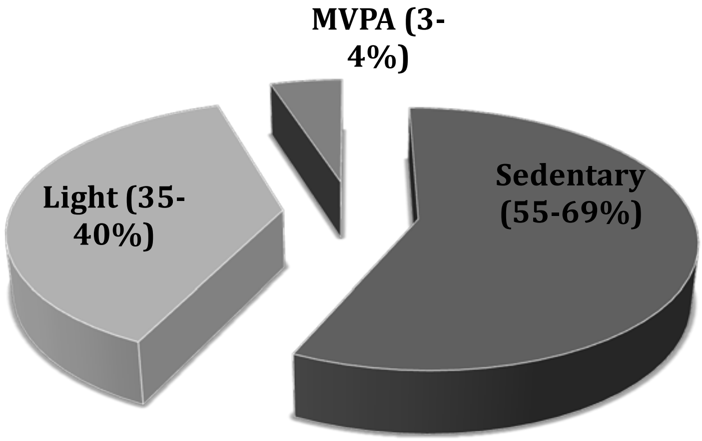
More recently, the activPAL™ (PAL Technologies Ltd, Glasgow, Scotland) device, a small accelerometer based monitor that is attached to the mid-thigh to assess sitting, standing and lying postures, has become popular. It has been found to be a valid and reliable measure of sitting, standing and lying postures as well as walking (Grant, Ryan, Tigbe, & Granat, 2006; Ryan, Grant, & Tigbe, 2006) and is increasingly being recognised as the most accurate monitor to assess sitting time in free-living conditions (Kozey-Keadle, Libertine, Lyden, Staudenmayer, & Freedson, 2011; Lyden, Kozey-Keadle, Staudenmayer, & Freedson, 2012; Ryde, Gilson, Suppini, & Brown, 2012). Importantly, unlike typical accelerometers, the activPAL™ can detect sit-stand transitions, which is particularly relevant when implementing strategies to encourage breaks and reduce sitting.

2.4 Exposures to MVPA, light intensity activity and sedentary time

The results from the large population accelerometer studies indicate that typically the majority of the day, well over 90% of waking hours, is spent in sedentary or light activities (Colley et al., 2011; Healy, Wijndaele, et al., 2008; Matthews et al., 2008). Accelerometer derived time in light intensity activity is 35-40% of waking hours or 6 hours per day (Colley et al., 2011; Healy et al., 2007; Tudor-Locke, Brashear, Johnson, & Katzmarzyk, 2010). MVPA contributes only 3-4% of waking hours or about 30 minutes per day (Colley et al., 2011; Healy, Wijndaele, et al., 2008; Troiano et al., 2008; Tudor-Locke et al., 2010). Figure 2.1 illustrates the proportion of the day spent in sedentary, light and MVPA. Importantly, there appears to be a reciprocal relationship between sedentary time and light activity (Healy et al., 2007; Healy, Wijndaele, et al.,

2008) so that as sedentary time increases, there is a corresponding reduction in light activity.

Figure 2.1: Accelerometer measured time spent in sedentary, light and MVPA



According the Australian Bureau of Statistics (ABS) (2013) 29% of Australians report more than 5 hours per day of leisure time sedentary behaviour. Further, IPAQ derived sitting time from 49,493 adults in 20 countries found that on average, sitting time was 5-6 hours per day (Bauman et al., 2011). Objective measures of sedentary time indicate that adults are sedentary for 55-69% (8-9.5 hours) of waking hours (Colley et al., 2011; Matthews et al., 2008; Tudor-Locke et al., 2010).

2.5 Relationship of physical activity to health

Low levels of physical activity, typically MVPA, have been linked to the development of many chronic diseases such as Type 2 diabetes, obesity, heart disease, some forms of cancer and depression (Bassuk & Manson, 2010; Chomistek et al., 2013; Davies, Vandelanotte, Duncan, & van Uffelen, 2012; Duclos et al., 2013; Ford et al., 2010; Friedenreich, Neilson, & Lynch, 2010; Lakerveld et al., 2011; Magne et al., 2011; Parent, Rousseau, El-Zein, & Latreille, 2011; Vallance et al., 2011). In a landmark series of studies undertaken in London during the 1950-60's, Morris et al (1966), found that bus conductors had a lower incidence of ischemic heart disease, when compared to bus drivers, suggesting that physical activity may prevent heart disease (Morris, Heady, Raffle, Roberts, & Parks, 1953; Morris et al., 1966).

In a series of studies examining the health of British civil servants over 25 years, it was found that increased leisure time physical activity reduced mortality, cardiovascular disease risk and some forms of cancer (Davey Smith, Shipley, Batty, Morris, & Marmot, 2000; Marmot et al., 1991). In a similar longitudinal study over 16 years, it was found that individuals that were more physically active (estimated from self-reported participation in leisure sports, walking and stair climbing) had significantly lower mortality (Paffenbarger, Hyde, Wing, & Hsieh, 1986). Further, the adoption of a healthy lifestyle, which included participation in physical activity (leisure sports, walking and stair climbing), reduced death rates in older men (Paffenbarger et al., 1993). These early longitudinal studies highlighted the important relationship between participation in physical activity and the reduction in risk factors for poor health and recognised that physical activity can potentially impact health.

Recent epidemiological studies have suggested that participation in 30 minutes per day of MVPA can prevent many cardiometabolic diseases (Archer & Blair, 2011; Bassuk & Manson, 2010; Li, Loerbroks, & Angerer, 2013). Accelerometer derived levels of physical activity from large population studies indicate that adults typically participate in less than 30 minutes per day of MVPA (Colley et al., 2011; Healy, Wijndaele, et al., 2008; Troiano et al., 2008; Tudor-Locke et al., 2010) and as discussed in section 2.8, only a very small proportion of adults are achieving health recommended levels of physical activity in bouts of 10 or more minutes.

The link between physical activity and health is increasingly important because in modern times, as the developed world has moved from the agricultural and industrial age to the 'technological' age, there has been a corresponding reduction in physical activity at work and activities of daily living are less active (Armstrong, Bauman, & Davies, 2000; Borodulin, Laatikainen, Juolevi, &

Jousilahti, 2007; Brownson, Boehmer, & Luke, 2005; Matthews et al., 2008). Egger and colleagues (2001) used accelerometers to compare activity levels of actors simulating life in the early 19th century as early Australian settlers with the activity levels of modern office workers. It was found that the actors in the historical group had activity levels up to 2.3 times greater than the office workers (Egger et al., 2001). In a similar study, Bassett and colleagues (2004) used pedometers to examine the step count of an Old Order Amish community to assess the impact of modern technology. The Amish community lifestyle has not changed greatly in the last 150 years. It was found that the Amish recorded a high average step count of 18,425 steps/day for men and 14,196 for women. In contrast, contemporary healthy adults in the USA only take between 5000 and 13,000 steps/day (Bassett Jr et al., 2010; Tudor-Locke & Bassett, 2004). These studies demonstrate that in the modern technological age, participation in physical activity has reduced.

2.6 Relationship of sedentary behaviour to health

Sedentary behaviour, such as prolonged sitting, is increasingly being recognised as an important contributor to poor health. Large population surveillance studies have examined the association between sitting and morbidity and mortality. Hu et al (2003) assessed the relationship between self-reported prolonged TV viewing and the development of diabetes. The study followed 50,277 women over a six year period. It was found that the amount of TV watching and sitting at work or at home was positively associated with the risk of obesity, and that the amount of TV watching was also significantly associated with the development of diabetes. It was found that participation in self-reported physical activity reduced the risks of developing obesity and diabetes. This study highlighted the importance of not only encouraging physical activity but also reducing sedentary behaviour.

Healy et al (2008) examined the association between TV watching and metabolic risk in 4064 healthy adults. It was found that there was a positive, dose-response relationship between self-reported TV watching with a number of metabolic risk factors including waist circumference, systolic blood pressure and blood glucose levels. Katzmarzyk et al (2009) in a prospective study of 17,013 Canadian adults over a 12 year period using a self-reported measure of sitting and physical activity, found a positive dose-response relationship between sitting and mortality from all causes and cardiovascular disease. Importantly, this study suggested that sitting risk was potentially independent of participation in leisure time physical activity. In a similar Australian study, Dunstan et al (2010) examined the association between self-reported TV viewing and mortality of 8,800 adults over 6.6 years. The findings were consistent with the previous studies that TV watching increased the risk of death from all causes and cardiovascular disease, independent of participation in physical activity.

Most recently, van der Ploeg (2012) reported findings from one of the largest Australian population studies – "45 and Up Study". The paper describes a dose-response relationship of prolonged sitting and all-cause mortality in 222,497 participants aged over 45 years. Further, George et al (2013), also using the 45 and Up Study data, found that men who reported in excess of 4 hours/day of sitting were at greater risk of developing chronic disease (heart disease, diabetes, cancer, elevated blood pressure) and those that reported sitting for greater than 6 hours/day were at greater risk of developing diabetes. The results from van der Ploeg (2012) and George et al (2013) indicate that there is a dose-response relationship between prolonged sitting and all-cause mortality and chronic disease, potentially independent of participation in physical activity. This suggests that health campaigns should not only promote participation in physical activity but also encourage reduced sitting times.

One of the weaknesses of the population studies described above is the lack of an objective measure of sitting or sedentary behaviour. Matthews et al (2008) was one of the first to examine accelerometer derived sedentary time. Using the NHAMES (2003-2004) data, it was found that US adults were sedentary (less than 100 accelerometer counts/minute) for 55% of wear time (waking hours). Similarly, further analysis of the NHANES (2005-2006) data, which included accelerometer analysis of sedentary and light intensity activity, found that US adults were sedentary for 57% of waking hours and participated in low or light activity for 40% of waking hours with MVPA contributing only 3% (Tudor-Locke et al., 2010). Accelerometer data from the Canadian Health Measures Survey (CHMS) showed that Canadian adults were sedentary for 69% of wear time (Colley et al., 2011), considerably higher than the US data. However, the CHMS used Actical accelerometers whereas the NHANES used ActiGraph accelerometers, so that differences in sedentary time may be a product of the different devices used.

Healy et al (2008) described the associations between objectively measured sedentary time and physical activity and metabolic risk factors in Australian adults. 168 participants were drawn from the Australian Diabetes, Obesity and Lifestyle (AusDiab) Study. AusDiab was a cross-sectional observational study to assess the development of diabetes and kidney disease. Activity was assessed using an ActiGraph accelerometer attached to the hip and worn for 7 consecutive days. Blood glucose and cholesterol and waist circumference were also measured. It was found that waist circumference and clustered metabolic risk scores were associated with sedentary time and light intensity activity independent of MVPA. This study was one the first to link accelerometer determined sedentary time and physical activity with specific health risks.

Further Healy et al (2008) examined the relationship between breaks in sedentary time and metabolic risk factors. A break in sedentary time was defined as interruption to sedentary time that lasted at least 1 minute with an intensity of 100 or greater activity counts/minute. Using the same AusDiab data, it was found that the total number of breaks in sedentary time were associated with significantly lower waist circumference, BMI, triglycerides and 2 hour plasma glucose. Importantly, these findings were independent of total sedentary time and MVPA. This study demonstrated for the first time that interrupting sedentary time has an association with metabolic risk factors. Similarly, Healy et al (2011) examined the NHANES (2003-2004 and 2005-2006) accelerometry data of adults (4757 participants) and found again that breaks in sedentary time were positively associated with waist circumference and inflammatory biomarkers, independent of total sedentary time and MVPA. Recently Carson et al (In Press) examined the CHMS accelerometer data and found that sustained sedentary time (≥ 20 minutes) was associated with increased insulin levels independent of MVPA. Further, an additional 10 breaks in sedentary time/day was associated with beneficial associations with waist circumference and blood glucose and cholesterol levels, independent of total sedentary time and MVPA. These studies highlight the important health implications of prolonged, uninterrupted sedentary time.

With the increasing availability of large population data that assesses sedentary behaviour Chau et al (2013) conducted a meta-analysis of the relationship between sitting and all-cause mortality. Of the six studies included in the analysis, five studies assessed sitting using self-report measures and one study used accelerometer derived measures of sedentary time. All the studies adjusted for participation in MVPA. It was found that for every additional hour of daily sitting there was a 2% increase risk of all-cause mortality after adjusting for MVPA. The relationship between sitting and all-cause mortality was found not to be linear, as the risk increased to 5% for sitting times in excess of 7 hours per day. The findings from this study may assist in providing a threshold for daily sedentary exposure.

2.7 Relationship of light intensity physical activity to health

Using the AusDiab data, Healy et al (2007) determined that there was a significant association between higher levels of light activity and lower 2 hour plasma glucose, independent of MVPA. Further Camhi et al (2011), using NHANES 2005-2006 data, found that greater 'lifestyle activity' (accelerometer counts 760-2019 counts/minute) that equates roughly to light intensity activity (accelerometer counts 100-1952 counts/minute), was associated with lower odds of elevated blood cholesterol and increased waist circumference. These results were independent of participation in MVPA. These findings highlight the important health implications of promoting light intensity activity.

Further, there have been a number of recent laboratory studies that have also explored the health benefits of light activity. Swartz et al (2011) examined the energy expenditure of interrupting 30 minutes of sedentary time (desk work) with treadmill walking in bouts of 1-5 minutes in healthy subjects. For walking 2 minutes every hour, the extrapolated results for an 8 hour working day, indicate that a subject would expend on average an additional 296 kilocalories per week when compared to just sitting. In a similar study, Dunstan et al (2012) examined the effect of short bouts of treadmill walking on glucose metabolism in overweight and obese subjects. It was found that interrupting sitting every 20 minutes with 2 minutes of treadmill walking (light or moderate intensity) improved glucose metabolism. Both these studies indicate that the addition of short bouts of light activity can have a positive impact on health.

In considering that only a very small proportion of the day is spend in MVPA, and the known adverse health effects of prolonged sedentary behaviour, health promotion interventions should increasingly focus on the potential health benefits from encouraging replacing sedentary behaviour with light intensity activity.

2.8 Physical activity guidelines

The recognition that participation in MVPA can impact health led to the development of recommendations for physical activity to maintain health (Welk, 2002). The US Center for Disease Control and Prevention and the American College of Sports Medicine recommended that adults should:

> "accumulate 30 minutes or more of moderate-intensity activity on most, preferably all, days of the week" (Pate et al., 1995,p 404).

Similarly, National Physical Activity Guidelines for Australian adults recommended participation in at least 30-60 minutes of moderate intensity physical activity on most, if not all days of the week (Australian Government Department of Health and Aging, 2005; Commonwealth of Australia, 2014a).

In Canada, the United States and Britain as well as by the World Health Organization (WHO) there has been revision of physical activity guidelines. The newer guidelines recommend that adults should participate in 150 minutes/week of MVPA in bouts of 10 or more minutes (Tremblay, Warburton, et al., 2011; 2008; 2010). The introduction of accumulation of MVPA in bouts of 10 or more minutes was to provide a realistic and flexible option to achieving 30 minutes of MVPA every day in inactive populations where time to participate in MVPA was often reported as a barrier to participation in physical activity (Murphy, Blair, & Murtagh, 2009; Trost, Owen, Bauman, Sallis, & Brown, 2002).

Early physical activity population surveillance studies used physical activity surveys to assess self-reported participation in MVPA. “Active Australia” was a national physical activity survey of Australian adults conducted in 1997 and repeated in 1999 (Armstrong et al., 2000). Active Australia defined “sufficient” physical activity to be beneficial to health as participation in 150 minutes of moderate intensity physical activity over one week or participation in vigorous intensity leisure time physical activity for 60-90 minutes over one week. It was found that 62% in 1997 and 57% in 1999 of Australians were participating in ‘sufficient’ physical activity to provide health benefit. In Western Australia (WA), a large population physical activity telephone survey of WA adults was conducted 1999, 2002, 2006 and 2009. The WA survey considered “sufficient physical activity” to be the accumulation of 150 minutes of moderate intensity physical activity on 5 or more sessions or the accumulation of 60 or more minutes of vigorous intensity physical activity over one week. It was found that the proportion of WA adults participating in sufficient physical activity ranged from 54-60% between 1999-2009 (McCormack et al., 2003; Rosenberg et al., 2010). Further, recent data from the ABS indicate 60% of adults are participating in less than 30 minutes of physical activity per day (Australian Bureau of Statistics, 2013). This Australian data highlighted that between 40-60% of Australians were not achieving health recommended levels of physical activity.

The use of accelerometers in population research has led to more accurate estimates of population physical activity accumulation and pattern. In a landmark Finnish study, Hagstromer and colleagues (2007) were one of the first groups to describe the objectively measured physical activity of a large population. The results from 1114 adults who wore an accelerometer for 7 days, showed that 52% of the participants accumulated 30 minutes/day of moderate intensity physical activity but only 1% achieved 30 minutes of moderate activity in bouts lasting more than 10 or more minutes. Accelerometer determined accumulation of 30 minutes/day of MVPA includes every minute of activity that exceeds a moderate activity accelerometer cut point (in this case 1952 counts/minute (Freedson et al., 1998)). The assessment of 10 minute bouts of continuous moderate or vigorous activity is likely to indicate intentional, rather than incidental participation in MVPA. Hagstromer et al (2007) highlighted the discrepancies between self-reported and objectively measured overall and pattern of exposure of physical activity.

NHANES is a USA national health survey and health assessment conducted regularly since the 1960's. From 2003, the use of a physical activity monitor was added to the NHANES due to the limitations of self-reported measures of physical activity (Sallis & Saelens, 2000; Shepherd, 2003; Welk, 2002) and to assess the pattern of exposure of physical activity. The ActiGraph AM-7164 accelerometer was first used and participants wore it on their right hip during waking hours (www.cdc.gov/nchs/nhanes). From 2009, the triaxial ActiGraph GT3X-plus accelerometers have been used and are attached to the wrist instead of the hip (Center Disease Control, 2011). Using the wrist mounted accelerometer records a different pattern of movement due to the larger movements that occur in the upper limb, such as arm swing and hand gestures. However, the use of a wrist accelerometer may improve wear time of participants (Mannini, Intille, Rosenberger, Sabatini, & Haskell, 2013).

Troiano et al (2008) reported the findings of NHANES accelerometer data of 4867 participants that had four or more valid days of data. It was found that only 3.5% of US adults obtained 30 or more minutes of moderate intensity activity in bouts of 10 or more minutes. Further, examination of accelerometer data from the NHANES 2005-2006 found that less than 10% US adults were achieving Physical Activity Guidelines for Americans (150 minutes/week moderate intensity activity, 75 minutes/week vigorous intensity activity or a combination of MVPA in bouts of 10 or more minutes)(Tucker et al., 2011). These two studies further highlight the discrepancy between self-reported and accelerometer determined assessment of MVPA.

The CHMS has been used to assess self-reported physical activity levels of Canadians. In 2007-2009, the addition of Actical accelerometers was used for the first time to objectively measure physical activity levels of a large population in Canada. The CHMS reported that self-reported levels of physical activity were improving, despite the rising levels of obesity (Bryan & Katzmarzyk, 2009; Craig, Russell, Cameron, & Bauman, 2004). The results of the accelerometry data from 2832 adult Canadians with at least 4 days of accelerometer data were in contrast to the self-reported measures of physical activity, and showed that only 15% of adults accumulated 150 minutes of MVPA per week in bouts of 10 or more minutes, again highlighting the discrepancies between self-reported and accelerometer determined physical activity (Colley et al., 2011).

The findings from the NHANES and CHMS studies vary in the proportion of the population achieving health recommended levels of physical activity (range 3.5-15%). This may be due to different accelerometers (Actical and ActiGraph) used in each study or differences in the populations assessed. Therefore, there appears to be large differences in self-reported and accelerometer derived accumulation and pattern of accumulation of physical activity in population studies.

2.9 Sedentary behaviour guidelines

Even though there is debate about the association between sedentary behaviour and cardiometabolic risk factors, independent of participation in physical activity (Lynch et al., 2014; Maher et al., 2014), there is a substantial body of evidence to suggest that sedentary behaviour is a distinct health risk and public health policies and interventions are beginning to address ways to modify sedentary behaviour. There is growing discussion about the development of 'sedentary guidelines'. It has been argued that recommendations to reduce sedentary behaviours could be incorporated into the existing health recommendations that promote the benefits of participation in MVPA (Hamilton et al., 2008; Tremblay, LeBlanc, et al., 2011; Tremblay, Warburton, et al., 2011). In the UK and New Zealand, current physical activity guidelines encourage reduced sitting time but there are no specific sedentary behaviour recommendations (www.gov.uk, www.health.govt.nz).

In 2014, new Australian Physical Activity and Sedentary Behaviour Guidelines were published. The guidelines promote participation in 150-300 minutes per week of moderate intensity activity or 75 minutes per week of vigorous intensity activity and in addition present sedentary behaviour recommendations. It was the first time that Australian government sedentary behaviour guidelines were specifically addressed. It was recommended that Australian adults:

> "Minimise the amount of time spent in prolonged sitting" and "Break up long periods of sitting as often as possible" (Commonwealth of Australia, 2014a).

Importantly, these guidelines also recognise the contribution of occupational sedentary behaviour, for example, by encouraging incidental activity at work and promoting participation in walking work meetings (Commonwealth of Australia, 2014b). The Australian Physical Activity and Sedentary Behaviour Guidelines were developed from the integration of the most recent Australian and international population research and guidelines (Australian Bureau of Statistics, 2013; Commonwealth of Australia, 2014b). Sedentary behaviour guidelines may assist in implementing important future research initiatives to reduce workplace sedentary behaviour by providing organisations with the evidence and support to implement workplace sedentary behaviour interventions.

2.10 Changing work demands – declining rates of occupational physical activity

In the first half of this literature review, physical activity and sedentary behaviour were defined and the general relationships between these behaviours and health were discussed. The current health recommended guidelines for physical activity and sedentary behaviour, and the overall amount and pattern of exposure of physical activity and sedentary behaviour were evaluated.

The focus of the second half of this literature review is the changing nature of work and the health implications of *occupational* sedentary behaviour. Further, the relationship between physical activity, sedentary behaviour and musculoskeletal pain is explored. Other potential occupational correlates to physical activity and sedentary behaviour are then discussed. This literature review then critically appraises the interventions that have explored ways to reduce occupational sedentary exposure and work-related musculoskeletal pain. Finally, the potential influences to physical activity and sedentary behaviour of physical and psychosocial features of an organisation are discussed.

Advancements in technology have resulted in a shift of more of the workforce into less physically active employment. Brownson (2005) examined US historical national data from the Behavioural Risk Factor Surveillance System, the National Health Interview Survey, NHANES, Bureau of Labor Statistics and the U.S. Census Bureau over a 50 year period. It was found that there was a declining proportion of the labour force in high activity occupations since the 1970's. Between 1950-2000 there was a relative reduction of 25% of the US workforce in high activity occupations. There was also a concurrent reduction in active transport (69% relative reduction), such as, walking to work (71% relative reduction). Brownson (2005) also found that household duties were less active due to the development of many domestic labour saving devices (Brownson et al., 2005). A similar trend has been demonstrated with Canadian and Finnish population groups (Borodulin et al., 2007; Juneau & Potvin, 2010). Importantly, Church et al (2011) using NHANES data from the last 50 years and employment data, extrapolated that the changing nature of work in the United States over that time resulted in a reduction of more than 100 calories per day in energy expenditure during work hours.

ABS data of employment categories has been modified considerably over the last 40 years making comparison of the physical nature of employment between the years difficult. Nevertheless, there does appear to be similar trends in Australia to a less active workforce (Australian Bureau of Statistics, 1985, 2006). A recent report from the ABS (2012) describes the changes in the Australian workforce over the last 50 years. During the 1960's, occupations were predominately trades and lower skilled jobs, blue-collar work. The most common occupations in 1966 were tradesmen, production process workers and labourers (44%), farmers, fishermen and timber workers (12%) and clerical (9%). In contrast, in the last 20 years there has been a substantial reduction in blue-collar work with a corresponding rise in white-collar workers, so that by 2011 the most common occupations were professionals (22%), clerical and administration (15%) (Australian Bureau of Statistics, 2012b).

2.11 Relationship between occupational and leisure activity

Early research, using self-report measures, suggested that lower occupational physical activity was "compensated" by correspondingly greater leisure activity (Burton & Turrell, 2000; Steele & Mummery, 2003). This idea was derived from findings that, blue-collar workers were less likely to report participation in leisure time physical activity compared to white-collar workers (Burton & Turrell, 2000; Kaplan & Keil, 1993; Salmon, Owen, Bauman, Schmitz, & Booth, 2000). Kirk and Rhodes (2011) conducted a review that examined this complex relationship between occupational physical activity and leisure time physical activity and found that there were few high quality studies, with 60 of the 62 eligible studies using self-report measures of physical activity. The authors concluded the evidence was inconclusive, however, the majority of studies did support the notion that white-collar workers appeared to have greater leisure time physical activity compared to blue-collar workers. The use of occupational grade (white-collar/blue-collar) can be a confounding issue in relation to physical activity as white-collar workers may have a higher socio-economic status that can also influence participation in leisure time physical activity (Hillsdon, 2011).

Steele and Mummery (2003) used pedometers to assess the differences in occupational physical activity between occupational groups and found that blue-collar workers participated in more occupational activity than white-collar or professional workers. While these results compared different occupational groups, there was no assessment of non-work activity. Schofield et al (2005) also used pedometers but compared physical activity of different occupational groups (office workers, retail, university academic, university allied, nurse/aid and blue collar) at work and during non-work periods. Similarly to Steele and Mummery (2003), it was found that occupational physical activity varied between occupational groups but importantly, this study was one of the first to show that there was very little difference in non-work activity between occupational groups suggesting that employees in low activity occupations such as office workers, were not more active outside of work hours than workers in high activity occupations. However, this study was small, with low numbers in some occupational groups and therefore may not be representational of the wider population and pedometers, rather than more sensitive motion sensors, were used.

More recently, Tigbe et al (2011) used activPAL™ motion sensors to assess the physical activity of walking postal workers and non-walking/administrative postal workers during working hours and non-work periods. Importantly, it

was found that there was no difference in activity levels between the two groups of postal workers during non-work time. There was no evidence that non-ambulatory post workers were compensating for their low occupational activity by increased activity in non-work periods. Similarly, Clemes et al (2014) found that for office workers, there was a positive association between sedentary time at work and sedentary time during non-work periods.
While early research based mainly on self-reported measures of physical activity indicated that low occupational physical activity may be compensated by participation in high non-work or leisure activity, more recent studies, using objective measures of physical activity, suggest that workers in low activity work do not have greater non-work activity when compared to other workers. Therefore, workers in low activity occupations, such as office workers, may be at particular risk of not achieving sufficient physical activity to maintain good health and prevent many chronic diseases.

2.12 Quantification of occupational sedentary exposure of office workers

Throughout this thesis, the generic term "office workers" is used. Office workers represent a large proportion of the modern workforce – according to the ABS, in 2011 nearly 70% of Australian workers were white-collar workers (managers, professionals, community and personal service workers, clerical and administrative workers and sales workers) with 37% of workers classed as professionals, clerical and administrative workers (Australian Bureau of Statistics, 2012b). For the studies conducted as part of this thesis, office workers were defined as workers that worked in an office (not in manufacturing or a factory) and were required to sit to complete work tasks and therefore sitting was required for most of the working day. The only exceptions were the office workers that were using a 'sit-stand' workstation that is described in Chapter 8 of this thesis.

In light of the evidence of the risks associated with prolonged sitting, a number of recent studies have examined the sedentary behaviour of office workers.

Ryan et al (2011) was one of the first to objectively measure sedentary behaviour, specifically sitting time using the activPAL™ device. 83 office workers wore the activPAL™ for 7 days during working hours. Total sitting time, number of sitting events and adherence to recommendations to sit for no longer than 20, 30 or 55 minutes were assessed. It was found that office workers were sitting for 66% of working hours with 52% of sitting time in bouts of greater than 30 minutes. This study not only examined total work sitting time but also investigated breaks in sitting time. However, the study only examined sitting time at work and did not explore sitting in non-work periods.

Toomingas et al (2012) used inclinometers to assess the sitting time and frequency of bouts of sitting in 140 call centre workers. It was found that participants were sitting for 75% of working hours, had 10 breaks in sitting per hour with the average bout of sitting lasting 11 minutes. This study again examined aspects of work sitting frequency and duration but did not examine sitting outside of work hours.

Thorp et al (2012) examined physical activity and sedentary time, as well as sustained bouts of sedentary time (bouts ≥ 20 minutes and bouts ≥ 30 minutes) of office workers, call centre and customer services workers using Actigraph GT1M accelerometers, both at work and during non-work hours. Office workers were sedentary for 76% of work hours with 21% of working hours in sedentary bouts greater than 30 minutes. Thorp et al (2012) was one of the first studies to not only explore sedentary time but also physical activity of office workers and compared activity levels at work and during non-work periods.

Clemes et al (2014) examined the physical activity and sedentary behaviour of a group of 170 office workers at work and during non-work periods using Actigraph GT1M accelerometers. In addition, Clemes et al (2014) examined the relationship between sedentary behaviour at work and outside of work hours. Office workers were sedentary for 71% of work hours and for 63% of non-work hours. There was a strong positive relationship between sedentary time at work and sedentary time during non-work time.

The occupational sedentary time varied between the four studies but this variation could be a product of the different devices, protocols and work practices that were used in each study.

At the time when Study 1 was conducted, there was no study that had objectively examined four important aspects of physical activity and sedentary behaviour of office workers:

1. The relationship between occupational physical activity and non-work or leisure time physical activity.
2. The contribution of occupational sedentary time to overall sedentary exposure.
3. The pattern of accumulation and breaks in sedentary time at work and during non-work periods.
4. The contribution and pattern of exposure to light intensity activity and MVPA at work and during non-work periods.

Therefore, **GAP 1 in the research: The need for comprehensive quantification of physical activity and sedentary behaviour of contemporary office workers using accelerometry.**

Further, at the time when Study 2 was developed, there was limited research that compared the physical activity and sedentary behaviour of different occupational groups (Jans, Proper, & Hildebrandt, 2007; Schofield et al., 2005; Steele & Mummery, 2003). In order to better understand similarities and differences in physical activity and sedentary behaviour of office workers and other workers, **GAP 2 in the research was identified: The need to explore the physical activity and sedentary behaviour of office workers compared to other occupational groups.**

2.13 Occupational sedentary behaviour and risk to poor health

The overall amount of daily sedentary behaviour can be divided into four domains – occupational, leisure, domestic and transport. There is some evidence that transport related sedentary behaviour may predict cardiovascular mortality in men (Warren et al., 2010). There is also growing evidence that leisure time sedentary behaviour is associated with cardiovascular disease, cardiometabolic disorders and all-cause mortality (Chau et al., 2014; G. Hu et al., 2007; Stamatakis et al., 2013). As adults spend a large proportion of the day at work (8 hours per day for fulltime workers (Australian Bureau of Statistics, 2012a)), the contribution of occupational sedentary exposure and the potential health implications of excessive occupational sedentary exposure are particularly important.

There is emerging evidence that occupational sedentary behaviour is associated with some cardiometabolic risk factors. A number of studies have explored the association between occupational sedentary behaviour, such as sitting, and health. Mummery et al (2005) found that self-reported occupational sitting time was independently associated with being overweight and obese in men, suggesting that occupational sedentary behaviour may be a factor associated with health risks. However, in a comprehensive review of the health risks associated with occupational sitting, van Uffelen et al (2010) found that of 43 eligible papers only a few were of sufficient quality and many did not control for physical activity or leisure time sitting. The authors did not find conclusive evidence supporting a positive causal relationship between occupational sitting and health risks.

Chau et al (2012) examined the association between occupational sitting, physical activity and obesity. It was found that sitting for most of the time at work was associated with increased risk of obesity independent of participation in physical activity. However, even though this large (10,785 participants) study used objective measures of Body Mass Index (BMI), the sitting time and physical activity data was based on self-report. Similarly, Stamatakis et al (2013) examined the relationship between occupational sitting and mortality and found that for women, sitting occupations were associated with an increased risk for all-cause and cancer mortality (Stamatakis, Chau et al. 2013). This longitudinal study used self-reported data of occupational activity (sitting, standing or walking) and death records over a 12.9 year period.

Presently, there is limited research of sufficient quality to conclusively link occupational sedentary behaviour or sitting to poor cardiometabolic health. However, from the current evidence it appears that there may be an increased risk of poor cardiometabolic health or death from excessive exposure to occupational sitting or sedentary behaviour. In addition, occupational sedentary behaviour may also be associated with other types of health such as, an increased risk of musculoskeletal disorders.

2.13.1 Cardio-metabolic Health - Body Mass Index and waist girth

As discussed in detail in the following sections of this literature review, promotion of physical activity and the reduction of sedentary behaviour may lower mortality and cardio-metabolic morbidity risks (Anderson, Schnohr, Schroll, & Hein, 2000; Dunstan et al., 2010; George et al., 2013; Katzmarzyk et al., 2009; Paffenbarger et al., 1986). Whilst cardio-metabolic health outcomes were not a focus of this thesis, BMI and waist girth were assessed in the observational study (Study 1) and were used as a secondary outcome measure in the intervention study (Study 4).

The BMI scale of "normalcy" of body weight is used widely as an indicator of health risk (Ardern, Katzmarzyk, Janssen, & Ross, 2003; de Koning, Merchant, Pogue, & Anand, 2007; Janssen, Katzmarzyk, & Ross, 2004; McArdle et al., 2007; Okosun et al., 2004; Zhu et al., 2004). There are however, a number of limitations to solely using BMI as a health indicator. There is ethnic variability in body fat distribution, which can also influence health, and BMI does not account for this (P. Brown, 2009; Misra, Wasir, & Vikram, 2005; Mooney, Baecker, & Rundle, 2013). Importantly, abdominal obesity – fat distributed centrally - is also strongly associated with cardiovascular, metabolic disorders and increased mortality (Janssen et al., 2004; Okosun et al., 2004). Further, recent sedentary behaviour population and intervention studies have reported significant changes in waist girth, rather than BMI (Healy, Mathews, et al., 2011; Steeves, Bassett, Fitzhugh, Raynor, & Thompson, 2012). Therefore, BMI was used in the description of all participants, with waist girth and BMI as secondary outcome measures in the intervention study (Study 4).

2.13.2 Measurement of musculoskeletal pain

The Nordic Musculoskeletal Questionnaire was developed out of the need for a standardised instrument to assess musculoskeletal pain in the occupational and ergonomic fields (Kuorinka et al., 1987). The original questionnaire assessed the distribution of musculoskeletal pain and asked questions relating to low back and shoulder pain, specifically the frequency, duration and need for medical care and lifestyle modifications due to the pain. Over time the questionnaire was modified and a standardised form was developed (Dickinson et al., 1992) and later an extended version was developed (Dawson, Steele, Hodges, & Stewart, 2009).

The test-retest reliability is reported as high using both percentage of disagreement between measurement occasions (Kuorinka et al., 1987) and later the more rigorous Kappa co-efficient (Dawson et al., 2009). The Nordic Musculoskeletal Questionnaire has been used with a number of different occupational groups (Choobineh, Tabatabaei, & Mokhtarzadeh, 2007; Dovrat & Katz-Leurer, 2007; Macdonald & Waclawski, 2006; Meijsen, Hanneke, & Knibbe, 2007; Trinkoff, Lipscomb, Geiger-Brown, & Brady, 2002) including office workers (Janwantanakul, Pensri, Jiamjarasrangsri, & Sinsongsook, 2008). It has been used in research with office workers as both a surveillance instrument (Balogh et al., 2004; Griffiths, Mackey, Adamson, & Pepper, 2012; Harcombe & McBride, 2009; Widanarko et al., 2011) and an outcome measure (L. L. Andersen et al., 2010; Blagsted et al., 2008).

The advantages of using the Nordic Musculoskeletal Questionnaire are that it has been used widely and consistently, particularly with office workers and as it is a standardised test, results between studies are comparable. In this thesis the Nordic Musculoskeletal Questionnaire was used to identify and measure the distribution of musculoskeletal pain and the impact of musculoskeletal pain on work and leisure activities and need for medical assistance (Studies 1-3). It was also used as an outcome measure to assess if workplace interventions to reduce sedentary behaviour also modified the distribution and impact of musculoskeletal symptoms (Study 4).

2.13.3 Occupational physical activity and musculoskeletal pain

Musculoskeletal pain is one of the most prevalent occupational health problems (Andersen, Haahr, & Frost, 2007; Janwantanakul et al., 2008). Musculoskeletal pain is likely to influence participation in physical activity. In addition, physical activity and sedentary behaviour may also contribute to the development of musculoskeletal pain.

Physical activity has been suggested as both a risk factor, for example from excessive loads and repetitive movements, to the development of musculoskeletal pain; but also as a preventative factor to the development of musculoskeletal pain, for example participation in aerobic and stretching exercise classes to reduce musculoskeletal pain (Andersen et al., 2008; Andersen et al., 2011; Blagsted et al., 2008). Therefore, the relationship between physical activity and musculoskeletal pain has been described as 'U-shaped' (Heneweer, Vanhees, & Picavet, 2009), where very high physical activity and very low physical activity or sedentary behaviour may both potentially increase the risk of musculoskeletal symptoms.

There is limited evidence that the presence of musculoskeletal pain alters the amount or the pattern of accumulation of physical activity. In a recent review that examined the relationship between patients with chronic low back pain and physical activity, there was no conclusive evidence that individuals with low back pain were less active than those without pain (Griffin, Harmon, &

Kennedy, 2012). However, the review found that only three of the seven papers included in the review used activity monitors to measure physical activity (Ryan et al., 2009; Spenkelink, Hutten, Hermens, & Greitemann, 2002; van Weering, Vollenbroek-Hutten, & Hermens, 2011) and that there were low numbers of participants in the included studies (Griffin et al., 2012) suggesting that further research with objective measures of physical activity is required.

2.13.4 Occupational sedentary behaviour and musculoskeletal pain

There has been very little research that has explored the relationship between occupational sedentary behaviour and musculoskeletal pain. Roffey et al (2010) conducted a review of the causal relationship between occupational sitting and low back pain but found very few high quality studies, with most research being cross-sectional so that a causal link could not be assessed. Based on the few high quality studies, a causal relationship between occupational sitting and low back pain was not demonstrated.

To date, while there does not appear to be good evidence for a causal relationship between occupational sedentary behaviour and musculoskeletal symptoms, there is a high prevalence of musculoskeletal complaints amongst sedentary workers (Cho et al., 2012). A small number of studies have examined the impact of reducing sedentary time or sitting on musculoskeletal complaints (Andersen et al., 2010). For example, the introduction of sit-stand workstations reduced self-reported musculoskeletal pain in healthy office workers (Davis et al., 2009; Hedge & Ray, 2004), however some workers have reported increased musculoskeletal pain when using a sit-stand workstation, particularly pain in the lower limb (Healy et al., 2013). Therefore, **GAP 3 in the research was identified: There is a paucity of literature that describes the association between objectively measured physical activity and sedentary behaviour and musculoskeletal pain of office workers.**

2.14 Potential correlates to occupational physical activity and sedentary behaviour

The main focus of this thesis was the exploration of sedentary behaviour and physical activity of office workers. However, a secondary aim was to examine a number of potential correlates of occupational sedentary behaviour and physical activity.

2.14.1 Job satisfaction

When considering the potential correlates of sedentary behaviour and physical activity, particularly with respect to office workers, it was anticipated that work factors such as job satisfaction might be related to participation in occupational activity. It may also be that occupational physical activity or sedentary behaviour may be related to the job satisfaction of workers. Studies have examined the impact of job satisfaction and mental health (Bogg & Cooper, 1995), self-reported stress and cardiovascular symptoms (Heslop et al., 2002) and the influence of the physical work environment on job satisfaction (Klitzman & Stellman, 1989). However, there does not appear to be any studies that have assessed whether there is an association between job satisfaction and activity levels or sedentary behaviour of office workers.

The Warr-Cook-Wall job satisfaction survey (Warr, Cook, & Wall, 1979) has been used widely with a number of different population groups including office workers (Dollard, Winefield, Winefield, & de Jonge, 2000; French et al., 2005; Goetz et al., 2011; Haynes, Wall, Bolden, Stride, & Rick, 1999). It has been shown to have good internal reliability (Warr et al., 1979). The relationship between job satisfaction and activity was assessed in the observational study (Study 1) and job satisfaction was assessed as a secondary outcome measure in the intervention study (Study 4).

2.14.2 Work productivity

As discussed in detail in sections 2.5-2.6 both insufficient physical activity and sedentary behaviour may both have associations with cardiometabolic disorders. Poor health of workers has the potential to negatively impact work productivity (Brown & Roberts, 2011). Brown et al (2012) examined the relationship between accelerometer determined sedentary behaviour and physical activity on presenteeism (loss of 'on the job' productivity) in 157 office workers. No relationship was found between employee presenteeism and sedentary behaviour and physical activity. Brown et al (2012) examined one aspect of productivity (presenteeism) of office workers, however, there does not appear to be any studies that have explored the relationship between overall self-reported work productivity and physical activity and sedentary behaviour.

A modified version of the Health and Work Performance Questionnaire (HPQ) used in this thesis selected a global assessment of self-reported productivity. The HPQ has been used in large population studies with a variety of population groups including office workers (Holden, Scuffham, Hilton, Vecchio, & Whiteford, 2010; Kessler et al., 2004; Tsutsumi, Nagami, Yoshikawa, Kogi, & Kawakami, 2009). It has been found to have good reliability and validity when assessed by systematic review (Schultz & Edington, 2007). As productivity of office workers is task specific, the general self-rated productivity measure provided in the HPQ was thought to be sufficient to give an overall rating of productivity. The aim of using the productivity index was firstly to assess whether characteristics of work such as productivity, are associated with physical activity and sedentary behaviour (Study 1) and secondly, whether participation in workplace activity programmes impact positively or negatively on work productivity (Study 4).

2.14.3 Readiness for physical activity

Physical activity has often been examined within the psychological framework of behaviour modification. The Transtheoretical Model (Prochaska & DiClemente, 1983; Prochaska & Velicer, 1997) of behavioural change has been applied to physical activity in order to explain and predict how and when individuals change their behaviour through a series of five stages. Precontemplation is the stage where individuals are not intending to modify their behaviour in the foreseeable future. Contemplation stage is where individuals are seriously considering changing their behaviour but have not made a commitment to change. Preparation is the stage when individuals intend to change their behaviour in the next 30 days and have already made some small behavioural steps to achieving change. Action stage is where the behaviour change has been achieved but for less than 6 months. Maintenance is where the behaviour has been sustained for greater than 6 months (Prochaska & DiClemente, 1983; Sarkin, Johnson, Prochaska, & Prochaska, 2001). The underlying assumption is that individual's progress through various defined stages in order to change a behaviour.

Determining the stage of readiness for physical activity is suggested to assist in developing tailored interventions and progression through the stages of readiness may also be used as an outcome measure for physical activity interventions. Titze et al (2001) found that following a workplace physical activity intervention, office workers had a significant improvement in their readiness to participate in physical activity, even though improvement in self-reported physical activity was marginal (Titze, Martin, Seiler, Stronegger, & Marti, 2001). Therefore, assessment of stage of behaviour change may be able to demonstrate a change in readiness for physical activity even if no actual change in physical activity has been detected (Marshall & Biddle, 2001; Nigg et al., 2011; Titze et al., 2001).

To date, there does not appear to be research that has examined the relationship between objectively measured occupational physical activity (MVPA and light intensity activity) or sedentary behaviour and the stages of behavioural change in office workers. The validity of the stages of behavioural change in physical activity has only been assessed against self-reported measures of activity (Haas & Nigg, 2009; Marshall & Biddle, 2001; Plotnikoff, Costigan, Karunamuni, & Lubans, 2013). Further, one of the weaknesses of the stages of behavioural change in physical activity research is that it has focused on MVPA rather than light activity or sedentary behaviour (Schumann, Estabrooks, Nigg, & Hill, 2003).

The Readiness for Physical Activity Survey (Marcus, Selby, Niaura, & Rossi, 1992) was included as an outcome measure in the intervention study of this thesis (Study 4) as progression through the stages of change of readiness to participate in physical activity may detect motivational changes in response to an intervention that may otherwise not be detected. Conversely, it may be that interventions that modify the environment or task with the aim of increasing physical activity may objectively cause an increase in physical activity but motivational readiness for physical activity may be unchanged. Further, the use of an objective measure of physical activity and sedentary time may contribute to assessing the legitimacy of the Readiness for Physical Activity Survey to reflect changes in physical activity and sedentary time. In addition, it may be possible to determine whether progression through the stages is consistent with objectively measured activity changes.

Therefore, **GAP 4 in the research was identified: There is a paucity of literature that has examined potential correlates to occupational physical activity and sedentary behaviour such as job satisfaction, work productivity and stage of readiness to participate in physical activity.**

2.15 Workplace interventions to improve physical activity and sedentary behaviour of office workers

The workplace has been used as a convenient venue for health promotion programmes for office workers (Pressler et al., 2010). A number of different health behaviours have successfully been targeted such as smoking cessation, reducing alcohol consumption and the prevention of cardiometabolic diseases by the promotion of healthy eating and participation in physical activity (L. M. Anderson et al., 2009; Cahill, Moher, & Lancaster, 2008; Dishman, Dejoy, Wilson, & Vandenberg, 2009; Ovbiosa-Akinbosoye & Long, 2011).

Early health promotion programmes for office workers that have targeted physical activity have encouraged participation in physical activity during work breaks, before and after work and increased use of active transport with the goal of improving health by increasing physical activity (Engbers, van Poppel, & van Mechelen, 2007; Osteras & Hammer, 2006; Yancey et al., 2004). However, although these studies were implemented at the workplace, the primary aim was to improve physical activity in non-productive work time rather than occupational physical activity occurring as part of work tasks.

With the growing awareness that reduced occupational physical activity may significantly contribute to poor health, some workplace studies have specifically targeted increasing occupational physical activity. For example, a number of interventions have encouraged the use of stairs as a means of increasing workplace physical activity (Badland & Schofield, 2005; Engbers et al., 2007) and recently, a work-based pedometer challenge that encourages workers to increase incidental activity at work by promoting 'active e-mails' or 'moving mobile calls' (Gilson et al., 2013). However, the success of this approach to physical activity interventions has been variable (Conn, Hafdahl, Cooper, Brown, & Lusk, 2009; Dishman, Oldenburg, Neal, & Shephard, 1998) and is dependent on the motivation of the individual to participate in such a programme, the ability to modify work conditions such as extended lunch breaks and flexible working hours in order to participate in the programme and on the willingness of an organisation to support a workplace physical activity intervention.

With the recognition that sitting is an important risk factor to poor health, there has been a shift of emphasis from occupational physical activity interventions to workplace interventions to reduce sitting. A review of interventions to reduce sitting in the workplace found that there were very few studies that specifically addressed reducing occupational sitting time and there were no studies with objective measures of sitting (Chau et al., 2010). Since the publication of that review, a number of studies that target workplace sitting have reported intervention effects using objective measures of sitting (Alkhajah et al., 2012; Healy et al., 2013; Neuhaus et al., 2014). For example, Evans et al (2012) assessed the change in sitting pattern after the introduction of break-prompting software using activPAL™ and found that even though total sitting time did not change, there was a significant reduction in the number and duration of prolonged sitting bouts.

Another approach to reducing sitting time has been to introduce 'sit-stand' workstations into the workplace. Gilson et al (2012) installed a sit-stand workstation as a 'hot desk' for university employees. There was no significant change to sedentary time as measured by a 'SenseWear' activity monitor in the small group of participants and the frequency of use of the sit-stand desk was variable within the group. One of the limitations of using a 'hot desk' is that it is dependent on the motivation of the individual to move from their regular desk to a new workstation that may require additional time to log on/off a computer and to negotiate with other workers to use the sit-stand workstation (Tudor-Locke et al., 2013).

A number of studies have incorporated a sit-stand computer stand onto a standard desk (Alkhajah et al., 2012; Healy et al., 2013; Neuhaus et al., 2014). Healy et al (2013) used the integrated sit-stand desktop computer stand as part of a programme that encouraged more standing and more sit-stand transitions as well as increased number of steps. Following the intervention period, activPAL3™ recorded sitting was reduced by 2 hours/day during work hours and there were an increased number of sit-stand transitions as well as reduced prolonged sitting time. The success of this intervention may be due in part to the sit-stand computer stand being integrated into the regular desk so that participants were not required to change their workstation. Further, the introduction of the desktop sit-stand computer stand was part of large intervention approach that included individual health coaching.

Straker et al (2013) assessed sitting time on a single day (measured by an inclinometer) in 90 call centre workers in Sweden that were provided with a sit-stand workstation. It was found that the proportion of time spent sitting was 5.3% lower for workers using the sit-stand workstation when compared to workers that were seated at a desk (41 workers). The sit-stand workers observed in Straker et al (2013) did not participate in a behavioural modification programme, which may explain why the reduction in sitting time from using a sit-stand workstation was smaller when compared to sit-stand workers in Healy et al (2013). Neither Healy et al (2013) or Straker et al (2013) reported potential flow-over effects into non-work periods.

At the time of the development of Study 3 of this thesis, there was limited evidence of the efficacy of using a sit-stand workstation in free-living conditions. Therefore, **GAP 5 in the research: The need to examine the physical activity and sedentary behaviour of office workers using a sit-stand workstation in free-living conditions.**

The concept of modifying the office workstation to encourage movement has been advanced by the use of an 'Active Workstation'. The Active Workstation was first reported by Edelson and Danoff (1989). It was found in laboratory conditions that walking on a treadmill while typing did not impair typing performance and it improved self-reported measures of stress. Other studies have found that the introduction of an Active Workstation did reduce productivity of some work tasks (John, Bassett Jr, Thomas, Fairbrother, & Baldwin, 2009; Ohlinger, Horn, Berg, & Cox, 2011; Straker, Levine, & Campell, 2009). Further, it has been suggested that the use of an Active Workstation could assist in the reduction of obesity of office workers by increasing the energy expenditure of office work by walking and working during work hours (Koepp et al., 2013; Levine & Miller, 2007; Thompson, Foster, Eide, & Levine, 2008; Tudor-Locke et al., 2013).

Only a small number of studies have examined the efficacy of using an Active Workstation in free-living conditions. In a study of overweight/obese office workers, it was found that the introduction of an Active Workstation significantly improved daily step count, waist circumference and blood cholesterol over a 9 month period (John et al., 2011). Similarly, Koepp et al (2013) found that 1 year following the introduction of an Active Workstation in a group of 36 office workers of mixed BMI, there was a significant reduction in weight and increased physical activity/reduced sedentary time with no impact on work performance. Therefore, Active Workstations have the potential to improve occupational physical activity and sedentary behaviour of office workers with minimal change to work tasks.

Both sit-stand workstations and Active Workstations have been found to reduce occupational sedentary behaviour of office workers (Alkhajah et al., 2012; Healy et al., 2013; John et al., 2011; Koepp et al., 2013; Neuhaus et al., 2014). Active Workstations have a greater potential to increase energy expenditure when compared to sit-stand workstations (Tudor-Locke et al., 2013), however the cost of a sit-stand workstation or an elevated computer stand attached to a regular desk is considerably less than the installation of an Active Workstation. In addition, the use of an Active Workstation (treadmill walking or cycling while completing office work tasks) is a novel skill, and may require additional training or may not be suitable for all workers. Further, to date, there does not appear to be any research that has directly compared the efficacy of reducing sedentary behaviour or other health outcomes such as musculoskeletal symptoms, between sit-stand workstations and Active Workstations. In order to assess the efficacy of an Active Workstation to reduce sedentary behaviour of office workers, some participants that took part in Study 4 of this thesis had access to an Active Workstation as part of a multi-component participatory workplace intervention. While Study 4, did not install sit-stand workstations in the workplaces that participated in the study, Study 4 did examine the impact of modifying work tasks, including the use of the Active Workstation, on musculoskeletal symptoms.

2.16 Participatory approach to intervention development for office workers

One of the challenges when conducting workplace interventions is matching the intervention to the specific needs of the workers. Participatory ergonomics was introduced as a means to improve the process of setting and achieving occupational health goals (Kuorinka & Patry, 1995). Participatory ergonomics is defined as:

> “the workers’ active involvement implementing ergonomic knowledge and procedures in their workplace. This worker effort is supported by their supervisors and managers, in order to improve their working conditions and product quality” (Nagamachi, 1995, p371).

Key features of participatory ergonomics include participation in decision making, support of the organisation, understanding of ergonomic methods and tools and job design concept (Nagamachi, 1995). Participatory ergonomics engages employees, team leaders or managers and uses ergonomics principles to achieve a desired workplace goal. Participatory practices aim to develop a sense of ownership and ability to change by involving all levels of employees in working together to achieve a common goal (Rivilis et al., 2008).

Participatory ergonomics has been used in the management of musculoskeletal pain, manual handling tasks, office design, risk management and reducing injury or sickness rates (Brenner & Ostberg, 1995; Driessen et al., 2011; Loisel et al., 2001; Straker, Burgess-Limerick, Pollock, & Egeskov, 2004; van Eerd et al., 2010). At the time of conducting the studies in this thesis it did not appear that, the participatory approach had been applied to the development of interventions aimed at workplace physical activity and sedentary behaviour. Therefore, **GAP 6 in the research was identified: There does not appear to be any workplace intervention studies aimed at reducing sedentary behaviour and increasing physical activity of office workers that applied a participatory approach to intervention development.**

2.17 Workplace interventions to reduce and prevent musculoskeletal pain

While the change in pattern of employment from more physically demanding jobs to less physically demanding jobs reduced the exposure of many risks such as heavy loads and repetitive lifting, new risks have emerged. In the 1980’s, with the increased use of desktop computers in the workplace, overuse disorders, “repetitive strain injury”, and musculoskeletal complaints associated with prolonged computer use became more prevalent amongst office workers

(Attwood, 1989; National Occupational Health and Safety Commission, 1986; Westgaard & Winkel, 1996). Office workers report high levels of musculoskeletal complaints, in particular upper limb, neck and low back pain (Harcombe & McBride, 2009; Huysmans, 2012; Widanarko et al., 2011). Workplace posture, prolonged computer keyboard and mouse use, high workload and stress are all thought to contribute to the development of musculoskeletal symptoms in office workers (Chiu et al., 2002; Cho et al., 2012; Hannan, Monteilh, Gerr, Kleinbaum, & Marcus, 2005; Hush, Michaleff, Maher, & Refshauge, 2009; Huysmans, 2012; Jensen, 2003; Kiss, Meester, Kruse, Chavee, & Braeckman, 2012).

A number of workplace interventions and guidelines have been developed to reduce and prevent musculoskeletal pain associated with office work (Cagnie, Danneels, Tiggelen, De Loose, & Cambier, 2007; Griffiths, Mackey, & Adamson, 2007; Lee et al., 1992). Intervention approaches include ergonomics training, workstation adjustment, the provision of new chairs or other equipment, break guidelines (Brewer et al., 2006; Robertson et al., 2009) and targeted physical activity programmes that promote upper limb and neck exercises (Andersen et al., 2008; Blagsted et al., 2008)

There have been a number of physical activity programmes that have used specific upper limb and neck muscle strength training programmes to successfully reduce musculoskeletal symptoms. For example, Sjogren et al (2005) found that a specific exercise programme reduced headache symptoms in office workers. Similarly, Andersen et al (2011) and Blagsted et al (2008) found that short bouts of resistance training reduced neck and shoulder pain and tenderness in healthy adults. Other physical activity interventions have employed programmes that increased overall physical activity by participation in aerobic and stretching exercise classes provided at the workplace, encouraging the use of stairs and increased leisure time physical activity to successfully reduce or prevent musculoskeletal disorders of office workers (Andersen et al., 2008;. Andersen et al., 2011; Blagsted et al., 2008; Proper et al., 2003).

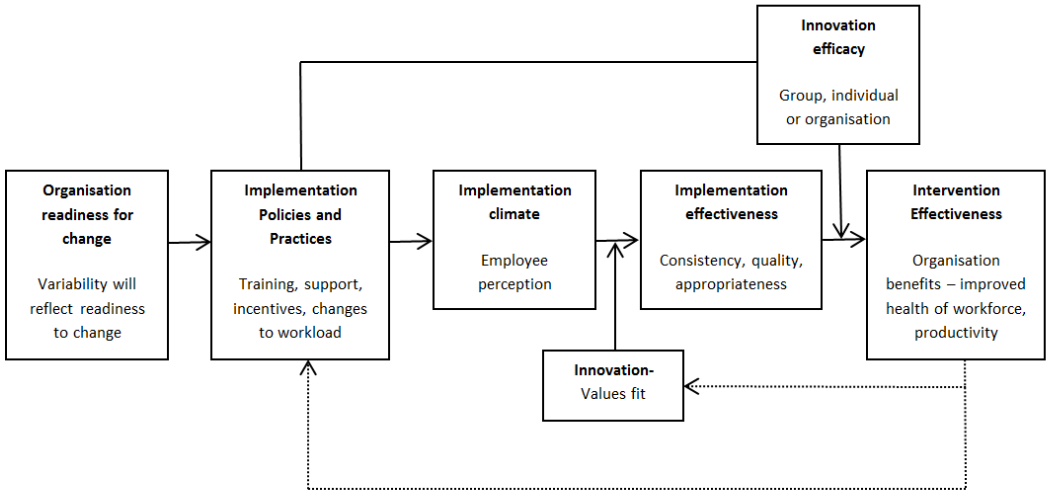
Therefore, both targeted strength training programmes and increased participation in general physical activity programmes have the potential to modify musculoskeletal symptoms of office workers. However, as identified in **GAP 7 in the research: There is paucity of research that examines whether workplace interventions to reduce sedentary behaviour will change musculoskeletal pain.**

2.18 Physical and psychosocial features of an organisation that may influence effectiveness of workplace interventions

The success of implementing health promotion programmes in the workplace may be influenced by the physical and psychosocial features of the organisation (O'Driscoll & Cooper, 2002; Shaw, Main, & Johnson, 2011). A number of different organisational factors have been found to influence the implementation of health programmes such as endorsement of the programme by employees and managers, marketing, workplace facilities, flexibility of working hours, job demands, policy factors and incentives (Crump, Earp, Kozma, & Hertz-Picciotto, 1996; McLellan, MacKenzie, Tilton, Comi, & feng, 2009; Taitel, Haufle, Heck, Loeppke, & Fetterolf, 2008).

Weiner et al (2009) developed a model to determine the effectiveness of implementing workplace health promotion programmes. This model is based on implementation theory which explains why interventions are successful in some organisations but not in others. The determinants of implementation effectiveness as described by Weiner et al (2009) are illustrated below (Figure 2.2).

Figure 2.2: Determinants of implementation effectiveness (Adapted from Weiner et al, p.295, 2009)



The readiness of an organisation for change may influence the ability to participate in work-based programmes. The organisational support, training, incentives to participate in programmes and flexibility to enable employee participation may also influence the implementation effectiveness. The innovation effectiveness is the benefit that the organisation realises from the innovation (intervention) such as improved health of employees, increased productivity. The ultimate success of an intervention will feedback to future innovations and may influence the development of policies. This model incorporates the challenges to implementing health promotion programmes within an organisation such as leadership support, employee support and training.

One of the aims of using a participatory approach to intervention development was to provide employee input in the intervention study (Study 4) and to reduce some of the barriers to participation in the study. Recently, it has been found that in addition to providing desktop sit-stand computer stands to office workers, engaging management and providing individual coaching to participants was more successful in reducing sitting times of office workers than the sole provision of a desktop sit-stand computer stand (Neuhaus et al., 2014). This study highlights the potential benefits of organisational and employee support to implementing sedentary behaviour interventions. To date, the studies that have examined interventions to reduce sedentary behaviour or sitting of office workers have reported findings from single organisations (Alkhajah et al., 2012; Evans et al., 2012; Gilson et al., 2013; Gilson, Suppini, et al., 2012; Healy et al., 2013; John et al., 2011). Therefore, GAP **8 in the research: At the time of conducting the studies for this thesis, there did not appear to be any studies that had assessed whether interventions aimed at reducing sedentary behaviour were successful in different organisations.**

2.19 Conclusion

This literature review has examined the key issues associated with the studies presented in this thesis. It has identified eight gaps in the literature that were the foundation for the development of the studies in this thesis. The gaps in the literature were as follows:

1. The need for comprehensive quantification of physical activity and sedentary behaviour of contemporary office workers using accelerometry.
2. The need to explore the physical activity and sedentary behaviour of office workers compared to other occupational groups.
3. There is a paucity of literature that describes the association between objectively measured physical activity and sedentary behaviour and musculoskeletal pain of office workers.
4. There is a paucity of literature that has examined potential correlates to occupational physical activity and sedentary behaviour such as job satisfaction, work productivity and stage of readiness to participate in physical activity.
5. The need to examine physical activity and sedentary behaviour of office workers using a sit-stand workstation in free-living conditions.
6. There does not appear to be any workplace intervention studies aimed at reducing sedentary behaviour and increasing physical activity of office workers that applied a participatory approach to intervention development.

7. There is a paucity of research that examines whether workplace interventions to reduce sedentary behaviour will change musculoskeletal pain.
8. At the time of conducting the studies for this thesis, there did not appear to be any studies that had assessed whether interventions aimed at reducing sedentary behaviour were successful in different organisations.

3.0 Study 1 - Introduction: What is the overall amount and pattern of exposure to sedentary time and physical activity, musculoskeletal pain and work factors of Australian office workers at work and during non-work hours?

Both the overall amount of sedentary behaviour and the pattern of exposure to sedentary behaviour have been suggested as important risk factors in terms of physiology and health consequences (Dunstan, Howard, Healy, & Owen, 2012; Hamilton et al., 2008; Healy, Dunstan, Salmon, Cerin, et al., 2008; Healy, Mathews, et al., 2011; Healy, Wijndaele, et al., 2008; Owen et al., 2011; Thorp, Owen, Neuhaus, & Dunstan, 2011). Over the last 50 years, with the rapid integration of technology into many aspects of daily living, the prevalence of sedentary behaviour is increasing (Borodulin et al., 2007; Brownson et al., 2005; Matthews et al., 2008; Proper et al., 2011). This may be due in part to the shift towards reduced MVPA in occupations traditionally requiring MVPA and the increasing percentage of workers in low activity occupations (Australian Bureau of Statistics, 2012b; Chau, Merom, et al., 2012; Kirk & Rhodes, 2011; Straker & Mathiassen, 2009). Therefore, occupational sedentary behaviour, the overall proportion of sedentary time and the pattern of exposure of sedentary time during work hours, may be an important contributor to overall sedentary exposure.

The focus of the first study in this thesis was to examine the sedentary time and physical activity of modern office workers. While it can logically be assumed that office workers are sedentary at work due the nature of office work, essentially sitting at desk and completing computer, telephone or paper tasks, when this study was initiated (2008) there were no reports of objectively measured sedentary time and physical activity of office workers and few reports from studies based on self-report measures.

Early studies using self-report measures examined the relationship between physical activity at work and leisure time physical activity. It was found that workers in low activity occupations reported high levels of leisure time physical activity, suggesting that these workers may be compensating for low occupational physical activity (Burton & Turrell, 2000; Salmon et al., 2000). Findings from more recent studies, using objective measures of physical activity, suggest that there is very little difference in activity levels during non-work periods between workers with low occupational physical activity and workers with higher occupational physical activity (Clemes, Patel, et al., 2014; Kirk & Rhodes, 2011; Tigbe et al., 2011).

Recently, a number of studies have examined the occupational sedentary behaviour and physical activity of office workers. Ryan et al (2011) used activPAL™ , to assess sitting time and frequency of breaks from sitting in a group of university based office workers. It was found that 66% of the working day was spent sitting and that office work was characterised by bouts of prolonged sitting, with 25% of sitting time occurring in bouts in excess of 55 minutes. While this study comprehensively examined sitting time, it did not measure light intensity activity or MVPA and it did not assess sedentary time or physical activity outside of work hours. Similarly, Toomingas et al (2012) using inclinometers found that 75% of the working day was spent sitting in a group of call centre workers with 9% of working hours consisting of prolonged bouts (60 or more minutes) of sitting. This study did not examine the pattern of sitting during work hours, nor did it differentiate activity levels during non-sitting periods. Thorp et al (2012) used Actigraph accelerometers to assess sedentary time and physical activity of office workers and found that office workers were sedentary for 76% of their working hours. Again, this study found that office workers experienced high sedentary exposure at work, however the pattern of exposure of sedentary time and physical activity was not fully explored. Most recently, Clemes et al (2014) used Actigraph accelerometers to measure physical activity and sedentary behaviour of office workers at work and during non-work periods and also to examine the relationship between work and non-work sedentary time and physical activity. Office workers were found to be sedentary for 71% of work hours and 63% of non-work hours and it was found that office workers that were sedentary at work, were also sedentary in non-work periods. While this study examined work and non-work sedentary time and physical activity, it did not explore the pattern of exposure of sedentary time and physical activity.

Physical activity has been suggested as both a risk factor to the development of musculoskeletal pain but also as a preventative factor to the reduction of musculoskeletal symptoms (Heneweer et al., 2009). Currently, there is no consistent evidence of a relationship between either excessive physical activity (Griffin et al., 2012; Lin et al., 2011; Ryan et al., 2009) or low level activity or sitting and musculoskeletal pain (Roffey et al., 2010) with most studies using self-report measures rather than objective measures to assess physical activity and sitting. In one of the few studies that have used an objective measure of physical activity, Ryan et al (2009) used activPAL™ activity monitors to assess walking and the pattern of physical activity in people with low back pain. It was found that individuals with low back pain had reduced physical activity and altered pattern of activity when compared to a group of healthy people. While this study examined some aspects of physical activity, it did not assess sedentary or sitting time. To date, there does not appear to any studies that have specifically assessed the relationship between accelerometer derived sedentary time and physical activity and musculoskeletal pain in office workers.

Furthermore, to date there is very limited research available that examines the relationship between work factors and physical activity (Bernaards et al., 2007). Job satisfaction is an important component of occupational wellness and has been found to be related to mental health, stress and cardiovascular symptoms (Bogg & Cooper, 1995; Heslop et al., 2002; Warr et al., 1979). The relationship between job satisfaction and sedentary behaviour and physical activity has not been fully explored. Similarly, there appears to be very limited research

(Grunseit et al., 2013; Strijk, Proper, van Mechelen, & van der Beek, 2013) that specifically addresses the relationship between self-reported work productivity and sedentary behaviour and physical activity at work and outside of work hours.

Currently, there are no comprehensive studies that examine the total amount and pattern of exposure for sedentary time and physical activity of contemporary office workers during work hours and non-work hours. Further, there are limited studies that have examined other potential correlates of sedentary time and physical activity such as musculoskeletal pain, job satisfaction and work productivity. It is important to understand the overall amount of exposure, pattern of exposure and potential correlates of sedentary behaviour and physical activity in order to target appropriate work based physical activity and sedentary reduction intervention programmes. This study therefore aimed to determine:

1. The proportion of sedentary time, light activity and MVPA during work and non-work periods (work days compared to non-work days, work hours on a work day compared to non-work hours on a work day and work hours on a work day compared to total non-work time).
2. The overall contribution of work sedentary time exposure to overall sedentary time exposure.
3. The pattern of sedentary time, light activity and MVPA during work and non-work periods in terms of bouts of activity (0-<5 minutes, 5-<10 minutes, 10-<30 minutes, bouts >30 minutes and bouts >60 minutes) and the break rate (number of breaks/sedentary hour)
4. Relationships among the total amount and patterns of sedentary time, light activity and MVPA.
5. Relationships between work and non-work sedentary time, light activity and MVPA.
6. The distribution and lifestyle impacts of self-reported musculoskeletal pain.
7. Relationships between self-reported musculoskeletal pain and sedentary time, light activity and MVPA.

8. Relationships between self-reported job satisfaction and sedentary time, light activity and MVPA of office workers.
9. Relationships between self-reported work productivity and sedentary time, light activity and MVPA of office workers.

Selected results from Study 1 have been published in:

Parry, S and Straker, L (2012). "Does work contribute to the sedentary risk of office workers?" *Proceedings of 4th International Congress on Physical Activity and Public Health*, Sydney, October 2012

Parry, S. and Straker L. (2013). "Office work contributes significantly to sedentary behaviour associated risk." BMC Public Health **13**: 296.

4.0 Study 1 - Method

4.1 Study design

Cross-sectional observational study

4.2 Participants

Workers participating in office bound duties for six or more hours per day and working four or more days per week in a large resource company in Perth, Western Australia were invited to participate in the study. Job descriptions include accountants, engineers, draftsmen, managers, health and safety personnel, secretaries and general administration. Participants were only excluded from the study if it was not possible to wear an accelerometer due to disability or being confined to a wheelchair.

4.2.1 Recruitment

Workplaces in Perth, Western Australia were invited directly to participate in the study. Workplaces were sourced in a variety of ways. Some workplaces had existing relationships with Curtin University and were asked directly to participate in the project. E-mail requests for organisations willing to participate in the study were also sent to members of the Human Factors and Ergonomics Society (Western Australia). A number of organisations responded and after initial e-mail correspondence, a workplace meeting followed to discuss the interest in and feasibility of the project.

Six workplaces agreed to participate in the study. However, only the data from the largest organisation is presented in this thesis as the other five organisations had small numbers of volunteers (less than ten). In this large organisation, rather than sending an e-mail to all employees, work groups (work teams such as financial or project based teams) within the organisation were approached. Group leaders within the organisation were sent an introductory e-mail. Groups whose leader expressed an interest were invited to a presentation explaining the purpose of the study and a detailed description of the study protocol. The presentation was scheduled as part of their regular monthly health/safety and "Operational Excellence" meeting that all employees in the organisation were required to attend. Presentations were typically made to groups of 20-40 employees. At the end of the presentation, all those attending the meeting were invited to volunteer to participate in the study. Volunteers were given a 'Participant Information and Consent' form (Appendix A) then asked to complete the surveys (outlined in section 4.4 below). In addition, volunteers were sought to wear the two available "Actical" accelerometers during waking hours for seven consecutive days (see section 4.6 Procedure below). In total, 12 groups attended recruitment meetings (approximately 350 people) and from these meetings 185 volunteers completed surveys and 59 volunteers additionally wore accelerometers for 7 days (see participant flow chart presented in section 5.1).

4.2.2 Ethics Statement

All participants provided informed consent and ethics approval was obtained from the Human Research Ethics Committee, Curtin University (HR20/2007).

4.3 Organisation

The organisation that participated in this study was a large international resource company with exploration projects in north-west Western Australia. More than 750 employees of the organisation worked in two office blocks located in the central business district of Perth, Western Australia. The offices were newly refurbished with excellent amenities. Most employees had flexible work hours and could schedule their own work and meal breaks.

The organisation had an active health and wellness programme and sponsored many community physical activity initiatives. Participation in workplace physical activity challenges were encouraged and supported by the organisation. Office workstation design was contemporary with near-new desks and chairs. Employees could request an electronically controlled sit-stand workstation if they had a medical condition such as low back pain exacerbated by sitting. A group of eight participants that used the sit-stand workstation were analysed separately and the results are presented in Chapter 8 of this thesis.

4.4 Measurement of sedentary time and physical activity

4.4.1 Self-reported sitting time and physical activity

Recall of the last seven days of MVPA and sitting time was assessed using the long form of the International Physical Activity Questionnaire (IPAQ) (Appendix B) (www.ipaq.ki.se). IPAQ has been used with a wide variety of different groups including office workers (Bauman et al., 2011; Colley et al., 2011; Faulkner et al., 2006; Osteras & Hammer, 2006; Tehard et al., 2005). The long form of the IPAQ is divided into 5 parts – Part 1 -Job related physical activity, Part 2 - transportation physical activity, Part 3 -housework, house maintenance and caring for family, Part 4 -recreation, sport and leisure-time physical activity and Part 5 - time spent sitting. There are instructions on the front page of the questionnaire that emphasise that the information should be physical activity from the **last 7 days**. In addition, definitions of vigorous and moderate activities are provided:

> "Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal
>
> Moderate activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal"

At the beginning of each section, there is an explanation describing in detail the nature of the questions that will follow. For example, Part 1 – Job related physical activity:

> "This section is about work related physical activities. This includes paid jobs, farming, volunteer work, manual work carried out at work,

and any other unpaid work that you did outside your home. **Do not** include unpaid work you might do around your home, like housework, yard work, general maintenance and caring for your family. These questions are asked later in Part 3. Do not include sports or leisure activities, which are asked in Part 4"

In each section (except Part 5), questions are asked about the number of days and minutes per day participating in moderate and vigorous activity. In addition occupational, transport and leisure time walking are also estimated. In Part 5, the questions relate to how much time is usually spent sitting on a weekday (including work and leisure time) and on a weekend day, not including time spent sitting in a motor vehicle or on a bike as this information was captured in previous sections. Estimates of energy expenditure, in either MET minutes or kilocalories, could be calculated from the reported data according to data processing instructions available from the IPAQ website (www.ipaq.ki.se). As sedentary time and time in MVPA were primary outcome measures in this study, estimates of sedentary time and MVPA were calculated directly from the IPAQ, rather than energy expenditure calculations.

4.4.2 Accelerometer derived sedentary time and physical activity

The Actical (Phillips-Respironics, Oregon, USA) accelerometer was used to measure sedentary time, light, moderate and vigorous intensity activity. The Actical accelerometer is small (2.8 × 2.7 × 1.0 cm), light (17g) and waterproof and can be worn on the hip, ankle or wrist. It is described as "omnidirectional" as it detects movements in planes other than the vertical axis. The Actical accelerometer has been found to be a valid and reliable accelerometer to measure sedentary time (Eslinger & Tremblay, 2006; Wong et al., 2011). The Actical accelerometer has been used to measure physical activity in a number of different population groups (Colley et al., 2011; Kayes et al., 2009; Rand et al., 2009) and also to evaluate sitting time of office workers (Oliver et al., 2010). Each participant was required to wear two accelerometers. One accelerometer was attached to a strap, similar to a watchstrap, and was worn on the dominant wrist. The second accelerometer was attached to an elastic belt and was worn at the waist about the right hip. The data collected from the wrist accelerometers does not form part of this thesis. Prior to distributing the accelerometers at the workplace, the accelerometers were initialised according to the manufacturer's requirements. The same research computer was used for setting all the accelerometers. Accelerometer batteries were changed when battery life was running low.

4.5 Other Measures

4.5.1 Musculoskeletal Questionnaire

A modified version of the Nordic Musculoskeletal Questionnaire (Kuorinka et al., 1987) (Appendix C) was used to assess overall distribution of any musculoskeletal pain and the impact of musculoskeletal pain on work, leisure activities and the requirement for medical intervention. The Nordic Musculoskeletal Questionnaire was developed to standardise the reporting of work related musculoskeletal symptoms (Dickinson et al., 1992; Kuorinka et al., 1987) and has been used in a variety of settings including office work (Gummesson et al., 2006; Janwantanakul et al., 2008; Macdonald & Waclawski, 2006; Meijsen et al., 2007). The modified version of the Nordic Musculoskeletal Questionnaire asked whether the respondent had experienced any trouble (ache, pain, discomfort) at any time in the past 12 months in eight body regions (neck, shoulders, elbows/wrist/hand, upper back, lower back, one or both knees, one or both ankles/feet). If the response was "yes", then a further response of "yes" or "no" was required for the following questions:

Does work contribute to your pain?	Yes ☐	No ☐
Have you had to reduce your activity at work?	Yes ☐	No ☐
Have you had to reduce your leisure activities?	Yes ☐	No ☐
Have you been seen by a Doctor or other Health Professional	Yes ☐	No ☐
Have you needed to take any medication for this pain?	Yes ☐	No ☐

4.5.2 Job Satisfaction Survey

To assess job satisfaction, a multi-item survey was used. The Warr-Cook-Wall Job Satisfaction Survey was selected from a comprehensive Work and Life Attitudes Survey that was developed by Warr and colleagues (1979)(Appendix D). Job satisfaction was assessed in terms of work environment, relationships with fellow employees and management, work conditions and perceptions of contribution and value to the job. Respondents were asked to rate the 15 aspects of job satisfaction on a seven point scale from "extremely dissatisfied" to "extremely satisfied". Job satisfaction is a complex concept and can be influenced by wide ranging factors such as the characteristics of the job, relationships within the organisation, work stress and health (Kinicki, McKee-Ryan, Schriesheim, & Carson, 2002). The Warr-Cook-Wall Job Satisfaction Survey that was used in this study was able to assess some of these key factors.

4.5.3 Work Performance Questionnaire

A modified version of the Health and Work Performance Questionnaire (HPQ) (Kessler et al., 2003) was used to measure self-reported work productivity. The full version of the HPQ is a comprehensive survey examining health, work productivity and absenteeism. Three questions were chosen to assess global self-reported health impacts on the quality and quantity of work (on a scale 0-5) and self-rated work productivity (on a scale 0-10) (Appendix E).

4.6 Procedure

Participants completed all the questionnaires at the end of the recruitment meeting or completed questionnaires were collected at a later date. Body measurements, height (cm), weight (kg) and waist circumference (cm measured at the navel), for all volunteers were taken by the author at the recruitment meeting using standard procedures. Weight was measured using the same set of scales that were placed on a hard (non-carpeted) floor. Height was measured using a stadiometer with participants standing without shoes. Waist girth was measured using a standard tape measure at the level of the navel.

Participants that volunteered to wear accelerometers were given their accelerometers at the recruitment meeting and were instructed in how to wear the accelerometers and given a written instruction sheet (Appendix F). As there were only limited numbers of accelerometers allocated to the study, not all volunteers could receive accelerometers at the recruitment meeting. Contact details were collected and all volunteers were contacted by e-mail when accelerometers were available. Accelerometers were then delivered to the workplace and participants were shown individually how to wear the accelerometer and complete the activity diary. Participants wore the accelerometer for 7 days (Colley, Gorber, & Tremblay, 2010; Troiano et al., 2008). The accelerometer was set to record data using a 60 second epoch (Welk et al., 2004). The accelerometer was attached to an elastic belt and worn over the right hip (Welk, 2002).

In order to assess discreet activities during work hours and during non-work periods, a simple activity diary was developed (Appendix G). There were separate colour-coded pages for work and non-work days. Participants were required to record waking hours, accelerometer wear time and, most importantly, work hours in the diary. There were also sections to describe transportation to and from work and any activities before and after work and during lunch periods. Participants were instructed that work hours consisted of the time from sitting at their desk in the morning to the time of leaving their desk at the end of the day. Additionally, the participants were asked to rate the intensity of their activity as light, moderate or hard in the diary.

At the completion of the observation period, the accelerometers were collected from the workplace. After all data had been collected, participants that wore an accelerometer were given a copy of their accelerometer output and an accompanying letter explaining the output graph (Appendix H). Further, at the end of the study, all participants were invited to attend a workplace meeting where the results were presented and discussed.

4.7 Data Processing

4.7.1 IPAQ

IPAQ data were processed according to the processing instructions (www.ipaq.ki.se) using Excel (Microsoft) and selected variables were exported to SPSS (PASW Statistics 18) for further analysis. Self-reported sitting time (mean minutes ± SD) on work days and weekend days was calculated directly from the surveys. MVPA minutes/week were calculated by adding walking, moderate and vigorous minutes for each domain.

4.7.2 Accelerometer

Actical count data were downloaded onto a research computer using the manufacturer's software (Actical® Software, Version 2.05). The downloaded data were then viewed as an "Actigram", a graphical representation of the activity output showing activity across each day for the worn period. The Actigram was used as a quick quality assurance check to assess if there were any missing days or if there was a faulty accelerometer data. A printout of the Actigram was given to participants to provide feedback about their activity pattern and exposure (Appendix H).

The activity count data were exported as a .CSV file and then processed using a custom LabVIEW program (LabVIEW 8.6.1 National Instruments, Texas, USA). The LabVIEW program enabled detailed simultaneous analysis of the pattern of activity intensity and duration to be studied using Exposure Variance Analysis (EVA) (Mathiassen, 2006). EVA has successfully been used to capture the pattern of sedentary time and physical activity in office workers (Straker et al., 2014). Activity intensity categories of sedentary, light, moderate and vigorous were determined from counts per minute. As counts are arbitrary and device specific (Paul, Kramer, Moshfegh, Baer, & Rumpler, 2007), intensity category cut-points (sedentary<91 counts, light 91≤1767 counts, moderate 1767≤5182 counts and vigorous >5182) were based on those widely used for Actigraph accelerometers (sedentary<100 counts, light 100≤1951 counts, moderate 1951≤ 5275 counts and vigorous >5275 (Freedson et al., 1998; Matthews et al.,

2008) but translated to Actical using an equation based on a study collecting biological data simultaneously from Actigraph and Actical accelerometers (Straker & Campell, 2012). Duration was characterised as bouts within the same intensity lasting 0≤5mins, 5≤10mins, 10≤30mins, 30≤60 mins and 60+ mins to match other research and recommendations (Hagstromer et al., 2007; Metzger et al., 2008; Straker & Campell, 2012).

Non-wear during waking hours was firstly determined from diary entries and then during the data processing. Periods greater than 120 minutes with counts of zero were considered non-wear time, rather than periods of greater than 60 minutes as pilot testing observations showed some office workers were sustaining sedentary time for greater than 60 minute bouts. A break in sedentary time was defined as accelerometer counts above 91 counts/min (Actical translated break cut-point) for greater than one minute during sedentary periods (Healy, Dunstan, Salmon, Cerin, et al., 2008). While minimum wear time of 600 minutes/day has been used in some studies (Healy, Dunstan, Salmon, Cerin, et al., 2008; Troiano et al., 2008), minimal wear time was set at 500 minutes/day (Jago, Fox, Page, Brockman, & Thompson, 2010; Steele, van Sluijs, Cassidy, Griffin, & Ekelund, 2009), to maximise the data that could be used in analysis. Only 12 of the 359 days included had wear time between 500-600 minutes. Days with less than 500 minutes were automatically discarded and not included in the data processing.

Participants were required to wear the accelerometer for a minimum of three work days and one non-work day to be included in data processing (Trost et al., 2005; Ward et al., 2005). Measures of the pattern of activity extracted from the EVA and of particular interest for this study were sustained (>30mins) and prolonged sustained (> 60 mins) periods of sedentary time, brief (0-5mins and 5-10mins) periods of light activity and bouts (>10mins) of MVPA.

Break rate, the number of breaks/sedentary hour, was calculated to match other research findings examining breaks in sedentary time (Healy, Dunstan, Salmon, Cerin, et al., 2008).

4.7.3 Nordic Musculoskeletal Questionnaire

The raw questionnaire data, in terms of the distribution of musculoskeletal symptoms in eight body regions and lifestyle impacts were tallied and transferred to a SPSS (PAWS Statistics 18) database.

4.7.4 Job Satisfaction Survey and HPQ

Raw data from the Warr-Cook-Wall Job Satisfaction Survey tallied by adding the score (1-7) from each of the 15 questions. A maximum score of 105 could be achieved. The raw data were then transferred to an SPSS (PAWS Statistics 18) database. HPQ scores for each question (from 1-5 for question 1 and from 1-10 for question 2) were transferred to an SPSS (PAWS Statistics 18) database.

4.8 Statistical Analysis

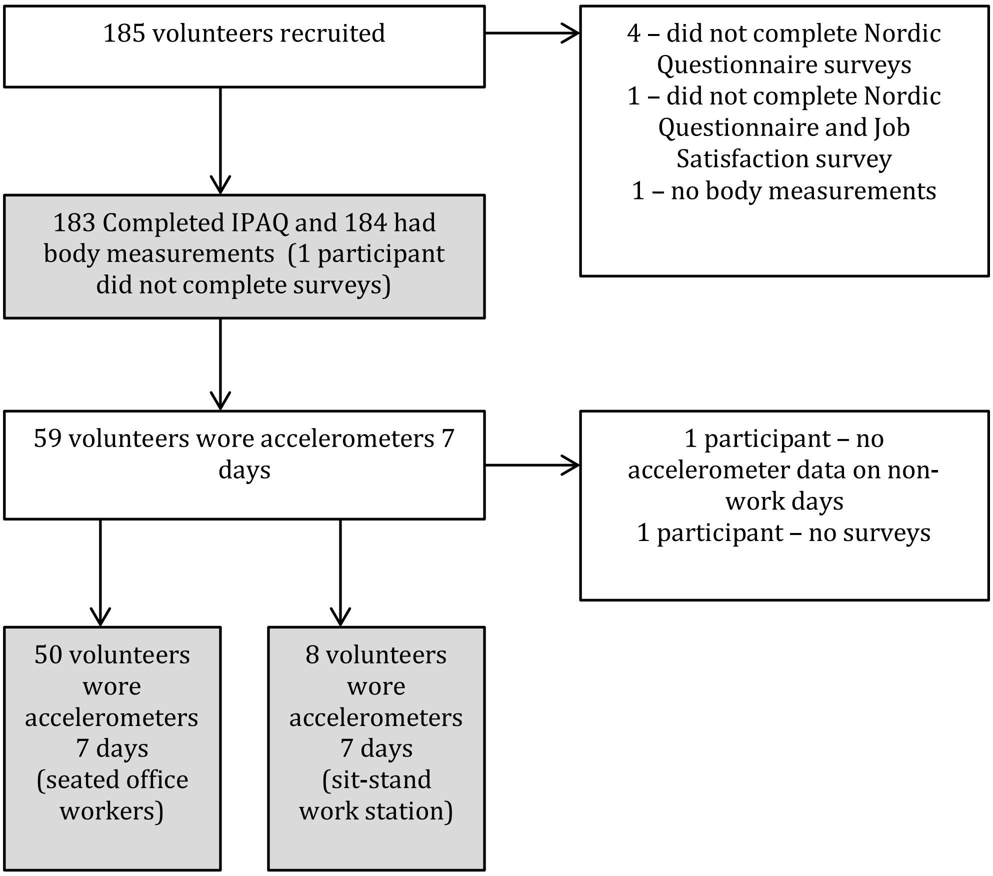
Tests for normality were undertaken to confirm that the data were normally distributed. One-way analysis of variance (ANOVA) or chi-squared tests were used to assess participant characteristics (age, BMI and gender) and compare participants that completed the surveys only, participants that completed the surveys and wore an accelerometer (seated office workers) and participants that completed the surveys and wore an accelerometer (sit-stand workstation). One-way ANOVA was also used to compare self-reported activity levels between participants that completed the surveys only and participants that completed the surveys and wore an accelerometer (seated office workers). Paired t-tests were used to compare time in activity levels between work and non-work days and between work hours on work days and non-work periods. Correlations between activity levels at work and non-work periods were performed using Pearson's correlations. Correlations between activity levels and the level of musculoskeletal pain and job satisfaction score were performed using Pearson's correlations. Correlations between activity levels and work productivity scores were performed using Spearmans' correlations. All calculations were made using the percentage of wear time for each time period. All analysis was done using PASW Statistics 18 with a critical alpha level of 0.05.

5.0 Study 1 - Results

5.1 Participants

185 participants volunteered to take part in Study 1. One participant did not have body measurements taken and was not included in subsequent analysis. 184 participants (62% men) aged between 20 and 72 years (mean ± SD, 37.8 ± 10.7 years) with a BMI of 25.5 ± 3.9 completed the IPAQ survey. 5 participants did not complete one or more of the other surveys. 59 participants, in addition to completing the surveys, volunteered to wear an accelerometer for 7 days. Figure 5.1 illustrates the distribution of the participants. 51 participants from this group worked at a standard desk. One participant did not have accelerometry data from non-work days and was not included in the analysis. Eight participants were using an electronically height adjustable workstation that could be elevated to a standing position. These participants had requested the workstation from their employer due to pre-existing health factors. Data was not collected about the specific nature of the health conditions. Further details on these eight participants are provided in Chapter 8.

Figure 5.1: Flow of participants in Study 1



There were no significant differences in age, BMI or gender composition between the groups that only completed one or more surveys, the accelerometer group (seated office workers) and the accelerometer group (sit-stand workstation) (Table 5.1).

Table 5.1: Comparison of participant characteristics between participants that completed one or more survey, participants that completed surveys and wore and accelerometer (seated office workers) and participants that completed surveys and wore an accelerometer (sit-stand workstation).

Variable	Survey only [n = 126]	Surveys and accelerometer (seated office workers) [n = 50]	Surveys and accelerometer (sit-stand workstation) [n = 8]	P for group comparison
Age (mean years; [SD]	38.3 [11.5]	36.5 [8.6]	37.9 [9.1]	0.611
BMI (mean kg/m^2; [SD])	25.7 [3.9]	24.8 [4.1]	25.3 [3.3]	0.351
Gender (n (%) male)	81 (65)	29 (58)	5 (63)	0.553

5.2 Sedentary time, light and MVPA at work and during non-work

5.2.1 Self-reported sitting time and MVPA

Analysis of self-reported sedentary time and physical activity included all participants that completed the IPAQ survey (n = 175) except for those participants that were using the sit-stand workstation. The small sit-stand group (n = 8) was analysed separately and the results are presented in Chapter 8 of this thesis. Self-reported sedentary time (sitting time) on work days of 8.0 hours per day (479.8 ± 170.3 mins) was significantly greater than the 4.7 hours per day reported on non-work days (285.4 ± 189.8 mins, $t = 13.2$, df_{174}, $p<0.001$). Self-reported MVPA in bouts of 10 or more minutes was least during work hours (74.6 ± 139.0 mins/week) compared to MVPA during non-work time - transport (247.3 ± 238.1 mins/week), domestic activities (349.1 ± 434.4 mins/week) and leisure activities (292 ± 295 mins/week) (see Figure 5.2). There was no significant difference in MVPA at work and MVPA during non-work (transport, domestic and leisure) between the groups that only completed surveys and those that also wore an accelerometer ($F > 1.01$, $p > 0.132$) (Figure 5.3)

Figure 5.2: Mean (standard deviation) self-reported MVPA mins/week during work and non-work (active transport, domestic duties (inside and outside the house) and leisure time activities), all participants (surveys only and accelerometer group (n = 175)).

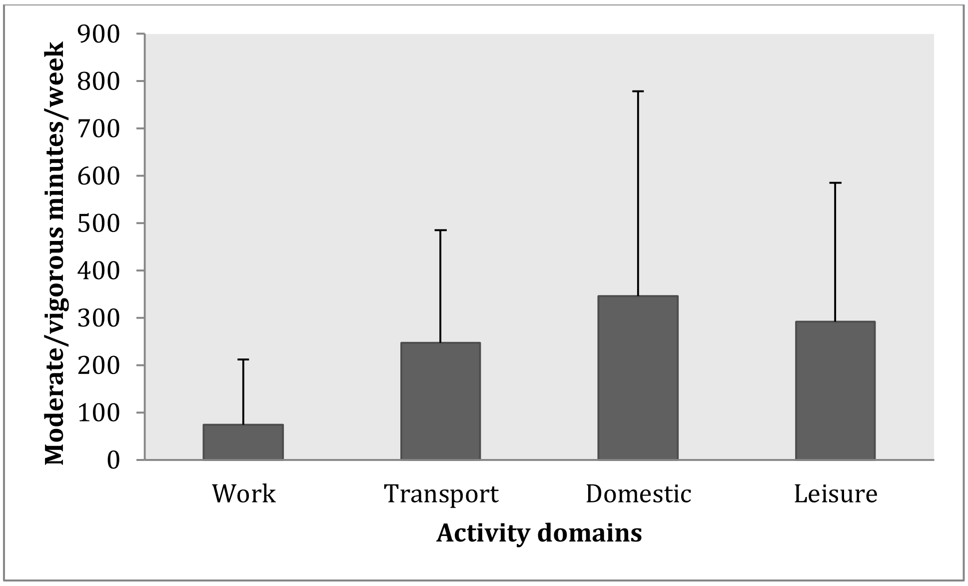
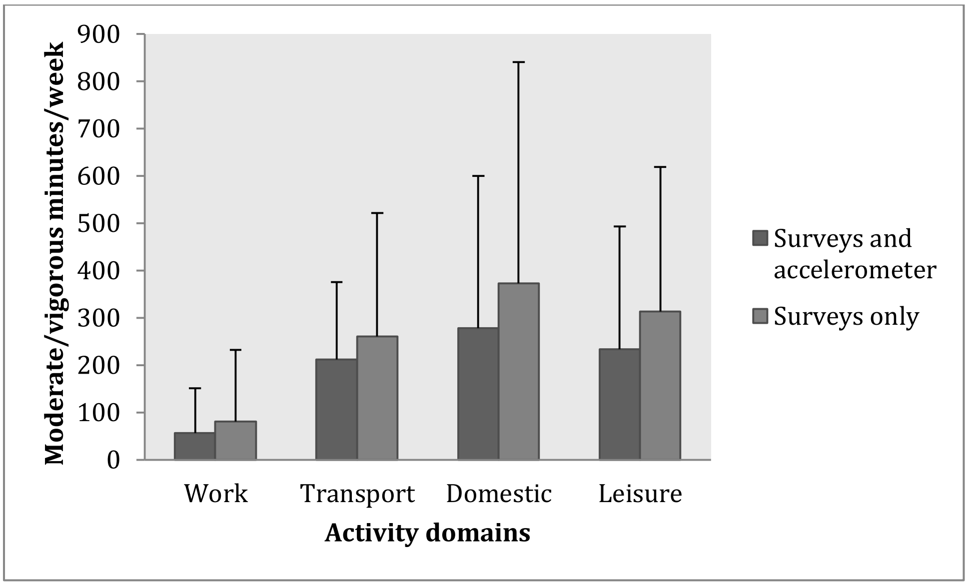


Figure 5.3: Mean (standard deviation) self-reported MVPA mins/week during work and non-work (active transport, domestic duties (inside and outside the house) and leisure time activities), comparison between surveys only group (n = 125) and accelerometer and surveys group (n = 50).



5.2.2 Accelerometry

From the initial group of 185 volunteers, 59 participants also agreed to wear an accelerometer for 7 days. As mentioned above, eight participants were using a sit-stand workstation and the results are presented in Chapter 8. Fifty participants (one participant had incomplete data) (58% men) aged between 22 and 59 years (36.5 ± 8.6 years) with a BMI of 24.8 ± 4.1 kg/m^2 (Table 5.1) wore an accelerometer for an average of 7.0 ± 0.9 days (4.7 ± 0.6 work days and 2.3 ± 0.9 non-work days). A total of 231 valid work days and 121 valid non-work days were included in analysis. The average accelerometer wear time for work days was 14.9 hours (892 ± 66 mins) which was significantly greater than the 13.7 hours wear time for non-work days (821.6 ± 85.5 mins, $t = 6.0$, df_{49}, $p<0.001$). Wear time for work hours was 8.9 hours (535.5 ± 46.6 mins) which was 60.10% of the total work day wear time.

Sedentary time on work days of 11.3 hours per day ([676.0 ± 58.7 mins/day], 75.91% wear time) was proportionally greater than the 9.5 hours per day on non-work days ([570.5 ± 88.0 mins/day], 69.74% wear time, $t = 6.2$, df_{49}, $p<0.001$). Light activity on work days of 3.0 hours ([176.9 ± 52.6 mins/day], 19.68% wear time) was proportionally less than the 3.7 hours on non-work days ([224.4 ± 78.3 mins/day], 27.21% wear time, $t = -7.8$, df_{49}, $p<0.001$). MVPA on work days of 49.5 ± 18.7 mins/day (4.41% wear time) was proportionally greater than the 25.7± 25.7 mins/day on non-work days (3.05% wear time, $t = 3.3$, df_{49}, $p=0.002$) (Table 5.2). Figures 5.4 (a) and (b) illustrate these differences. 78% of all participants had proportionally more sedentary time on work days compared to non-work days and 84% of participants had proportionally less light activity on work days compared to non-work days

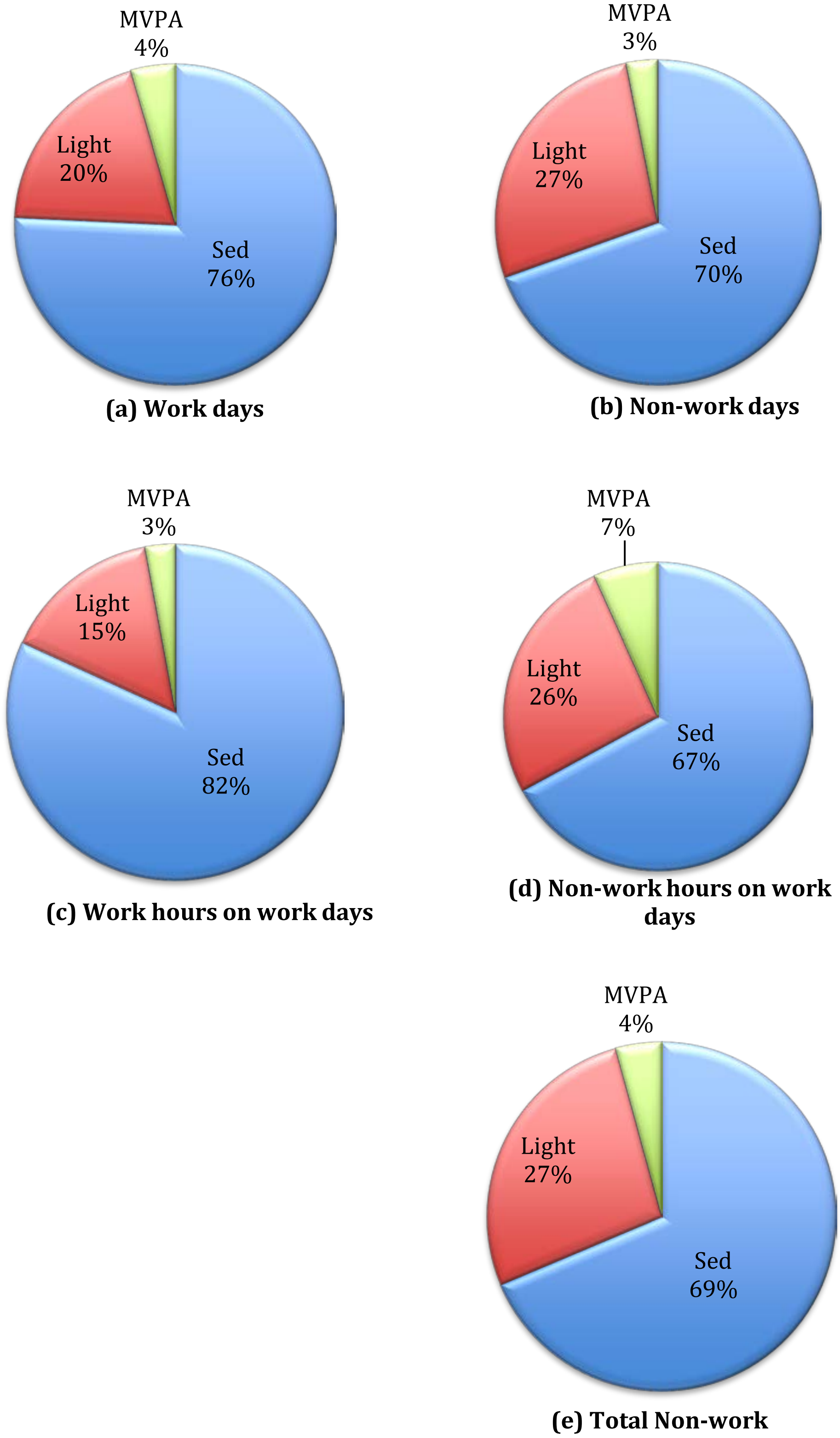
Table 5.2: Accelerometer derived sedentary time, light activity and MVPA on work days, non-work days, work hours on work days, non-work hours on work days and total non-work time over a whole week.

	Type of day		Wear time on work day		Total non-work time
	Work day	**Non-work day**	**Work hours on work days**	**Non-work hours on work days**	
Sedentary time (mean mins ± SD)	676.00 ± 58.72	570.54 ± 88.02	438.33 ± 51.48	237.67 ± 50.74	808.22 ± 115.39
[% wear time ± SD]	[75.91 ± 6.08]#	[69.74 ± 9.32]	[81.80 ± 5.65]^	[67.05 ± 8.80]	[68.95 ± 8.73]
Light activity (mean mins ± SD)	176.94 ± 52.59	224.37 ± 78.28	81.63 ± 25.59	95.31 ± 39.18	319.70 ± 109.01
[% wear time ± SD]	[19.68 ± 5.18]#	[27.21 ± 8.70]	[15.27 ± 4.72]^	[26.18 ± 8.30]	[26.89 ± 8.00]
MVPA (mean mins ± SD)	39.53 ± 18.73	25.70 ± 25.74	15.57 ± 9.43	23.96 ± 14.16	49.66 ± 33.73
[% wear time ± SD]	[4.41 ± 1.99]§	[3.05 ± 2.87]	[2.93 ± 1.72]‡	[6.77 ± 3.74]	[4.16 ± 2.66]

§ Significant difference between work and non-work day ($p<0.05$)
#Significant difference between work and non-work day ($p<0.001$)

^ Significant difference between work hours on work days and non-work hours on work days and between work hours on work days and total non-work time ($p<0.001$)
‡Significant difference between work hours on work days and non-work hours on work days and between work hours on work days and total non-work time ($p<0.05$)

Figure 5.4: Proportion of sedentary, light and MVPA for (a) work days, (b) non-work days, (c) work hours on work days, (d) non-work hours on work days and (e) total non-work time



5.3 Comparison between self-reported and accelerometer derived sedentary time and MVPA at work and during non-work

5.3.1 Comparison between self-reported sitting and accelerometer derived sedentary time

The following comparisons between self-reported and accelerometer derived variables used only the participants that wore an accelerometer and completed the IPAQ (n = 49).

Sedentary time was found to be significantly greater when measured by accelerometer (work day 678.0 ± 57.6 mins/day; non-work day 561.8 ± 114.6 mins/day) compared with self-report (work day 492.9 ± 191.1 min/day; non-work day 296.9 ± 171.3 mins/day) both on work days ($t = -6.5$, df_{48}, $p<0.001$) and non-work days ($t = -9.5$, df_{48}, $p<0.001$) (Figure 5.5). Accelerometer derived sedentary time per day averaged over a whole week (648.6 ± 58.0 mins/week) was significantly greater than self-reported sitting time/day averaged over a whole week (437.1 ± 165.7 mins/week, $t = -8.5$, df_{48}, $p<0.001$).

Figure 5.5: Mean (standard deviation) self-reported and accelerometer derived sedentary time on work days and non-work days

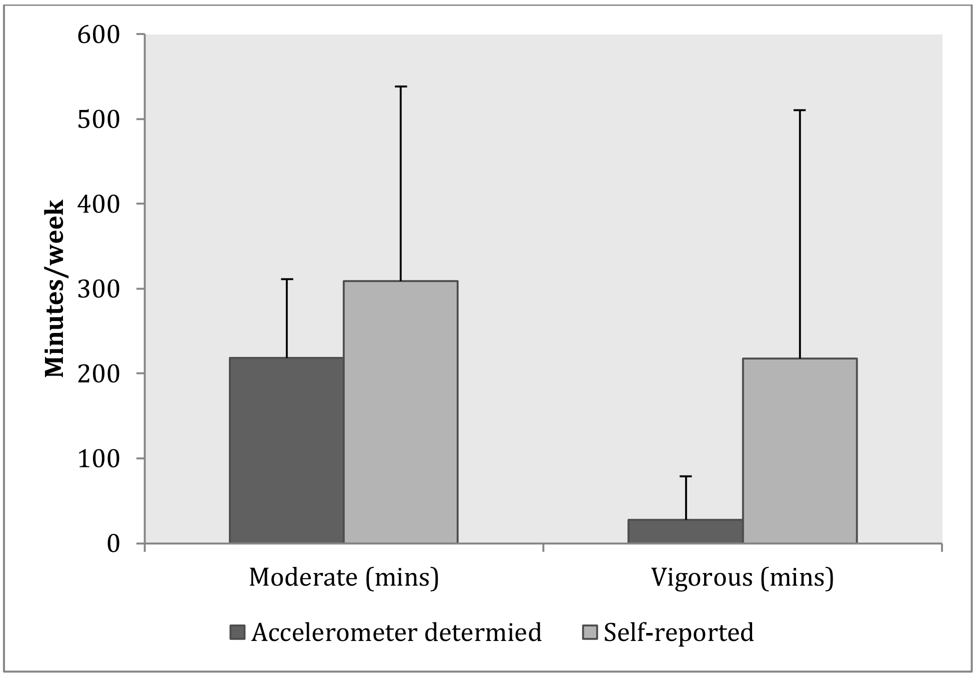
5.3.2 Comparison between self-reported and accelerometer derived MVPA

MVPA during work hours, in bouts of 10 or more minutes was found to be significantly greater when measured by self-report (57.7 ± 94.9 mins) compared to accelerometer derived MVPA (bouts>10 mins) (5.2 ± 0.7 mins, t = 4.1, df_{48}, $p < 0.001$). Similarly, MVPA (bouts>10 mins) during total non-work time over a whole week was significantly greater when measured by self-report (739.7 ± 473.5 mins/week) compared to accelerometer derived MVPA (bouts> 10 mins) (17.3 ± 24.8 mins/week, df_{48}, t = 10.8, $p < 0.001$).

5.3.3 Comparison between self-reported and accelerometer derived MVPA over a whole week

Self-reported moderate mins/week of 319.3 ± 229.4 was significantly greater than the accelerometer derived moderate mins/week of 218.5 ± 92.9 (t = 2.7, df_{48}, $p = 0.009$). Note that self-reported moderate mins/week does not include walking minutes of 270.3 ± 234.9 mins/week. Similarly, self-reported vigorous mins/week of 217.7 ± 292.4 was significantly greater than the accelerometer derived vigorous mins/week of 27.6 ± 51.0 (t = 4.6, df_{48}, $p < 0.001$) (Figure 5.6).

Figure 5.6: Mean (standard deviation) self-reported and accelerometer derived moderate and vigorous time over a whole week



5.4 Physical activity guidelines – comparison between self-reported and accelerometer derived MVPA over a whole week

Using the physical activity guidelines of achieving 150 moderate mins/week, 76% of participants reported greater than 150 moderate mins/week, not including walking (IPAQ). If walking was included in the calculation, then all participants achieved greater than 150 moderate mins/week. 80% of participants had accelerometer derived moderate minutes of greater than 150 mins/week.

5.5 Further accelerometry analysis

5.5.1 Sedentary time, light activity and MVPA at work and during non-work hours on work days

Sedentary time was proportionally greater during work hours on work days compared to non-work hours on work days (work hours [438.3 ± 51.5 mins] 81.80% wear time, non-work hours on work days [237.7 ± 50.7 mins] 67.05% wear time, $t = -12.7$, df_{49}, $p<0.001$) and there was proportionally less light intensity activity during work hours on work days compared to non-work hours on work days (work hours [81.6 ± 25.6 mins] 15.27% wear time, non-work hours on work days [95.3 ± 39.2 mins] 26.18 % wear time, $t = -9.6$, df_{49}, $p<0.001$). MVPA of 15.6 ± 9.4 mins (2.93% wear time) during work hours on work days was proportionally less than the 24.0 ± 14.2 mins (6.77% wear time) during non-work hours on work day ($t = -6.9$, df_{49}, $p<0.001$)(see Table 5.2 and Figures 5.4(c) and 5.4(d)).

5.5.2 Sedentary time, light and MVPA at work and during all non-work hours over a whole week

A similar pattern of results was found when comparing work hours on work days with all non-work hours over a whole week. The total non-work hours include the time before and after work on work days and all non-work days, equating to 56.13% of total wear time. Sedentary time was proportionally greater during work hours (81.80 % wear time) compared to total non-work time ([808.2 ± 115.4 mins], 68.95% wear time, $t = 10.8$, df_{49}, $p< 0.001$). Light intensity activity was proportionally less during work hours ([81.6 ± 25.6 mins], 15.27% wear time) compared to total non-work time ([319.7 ± 109.0 mins] 26.89% wear time, $t = -10.5$, df_{49}, $p<0.001$) and MVPA was proportionally less during work hours ([15.6 ± 9.5 mins], 2.93% wear time) compared to total non-work time ([49.7 ± 33.7 mins], 4.16% wear time, $t = -3.0$, df_{49}, $p<0.004$) (See Table 5.2 and Figures 5.4(c) and 5.4(e)).

5.5.3 Overall contribution of occupational sedentary time to total sedentary time

In terms of total weekly sedentary time, work time contributed 36.5 ± 4.3 hours (48.62% of sedentary time) with all non-work time contributing 38.8 hours (51.38% of sedentary time).

5.6 Pattern of sedentary time, breaks in sedentary time (break rate), light activity and MVPA

Sedentary time, light activity and MVPA was examined in bouts of 0-<5 minutes, 5-<10 minutes, 10-<30 minutes, sustained bouts of 30 or more minutes and prolonged sustained, bouts exceeding 60 mins.

5.6.1 Sedentary bouts (0-<5 mins, 5-<10 mins and 10-<30 mins)

Table 5.3 summarises the results of sedentary time in bouts 0-<5 mins, 5-<10 mins, 10-<30 mins, sustained bouts of 30 or more minutes and prolonged sustained bouts of 60 or more minutes. (Table 5.3 also includes break rate, the number of breaks per sedentary hour). Brief periods of sedentary time (bouts 0-<5 mins) were proportionally less on work days ([65.4 ± 20.5 mins] 7.27% wear time) compared to non-work days ([82.0 ± 28.3 mins] 10.10% wear time, $t = -5.9$, df_{49}, $p < 0.001$), and also during work hours on work days ([33.0 ± 13.5 mins] 6.17% wear time) compared to non-work hours on work days ([32.4 ± 12.1 mins] 8.87% wear time, $t = -6.4$, df_{49}, $p < 0.001$) and total non-work time ([114.3 ± 35.9 mins] 9.64% wear time, $t = -4.9$, df_{49}, $p < 0.001$).

Sedentary bouts of 5-<10 mins were proportionally less on work days ([73.9 ± 22.9mins] 8.26% wear time) compared to non-work days ([78.8 ± 28.9 mins] 9.57% wear time, $t= -2.0$, df_{49}, $p = 0.047$).

Longer bouts of sedentary time (bouts 10-<30 mins) were proportionally greater on work days ([235.1 ± 47.3 mins] 26.33% wear time) compared to non-work days ([190.3 ± 46.2 mins] 23.30% wear time, $t = 3.2$, df_{49}, $p = 0.002$). Sedentary time in bouts of 10-<30 minutes appeared to be proportionally greater during work hours on a work day compared to non-work hours on a work day and during work hours on a work day compared to total non-work time, but these differences were not statistically significant (work hours on a work day [141.2 ± 41.9] 26.27% wear time, non-work hours on a work day [93.9 ± 28.4 mins] 26.40 % wear time, $t = -0.1$, df_{49}, $p = 0.923$; total non-work [284.7 ± 59.6] 24.20% wear time, $t = 1.8$, df_{49}, $p = 0.086$) (Table 5.3).

Table 5.3: Pattern of sedentary time in bouts of 0-<5 mins, 5-<10 mins, 10-<30 mins, >30 mins and >60 mins (% wear time ± SD) and breaks in sedentary time (breaks/sed hour)

	Type of day		Wear time on work day		Total non-work time
	Work day	**Non-work day**	**Work hours on work days**	**Non-work hours on work days**	
Sedentary time bouts (mins)					
0-<5	7.27 ± 2.05#	10.10 ± 3.24	6.17 ± 2.57^	8.87 ± 2.46	9.64 ± 2.68
5-<10	8.26 ± 2.45§	9.57 ± 3.50	8.01 ± 3.57	8.59 ± 2.57	9.29 ± 2.70
10-<30	26. 33 ± 5.00§	23.30± 5.59	26.27 ± 7.27	26.40 ± 6.45	24.20 ±4.69
30+	34.05 ± 11.61§	26.91 ±11.18	41.36 ±16.30^	23.19±10.58	25.81 ±9.65
60+	13.31 ±9.25	11.15 ± 7.06	16.03 ± 13.44‡	9.55 ± 8.33	10.58 ±6.06
Breaks in sedentary time (breaks/sed hour)	5.97 ± 1.45#	7.83 ± 2.33	5.05 ± 1.68^	7.80 ± 1.99	7.80 ± 2.02

§ Significant difference between work and non-work days ($p<0.05$)

#Significant difference between work and non-work days ($p<0.001$)

^ Significant difference between work hours on work days and non-work hours on work days and between work hours on work days and total non-work time ($p<0.001$)

‡Significant difference between work hours on work days and non-work hours on work days and between work hours on work days and total non-work time ($p<0.05$)

5.6.2 Sustained sedentary time (bouts>30 mins)

Sustained sedentary time (bouts >30 mins) was proportionally greater on work days compared to non-work days (work days [301.6 ± 98.8 mins] 34.05% wear time, non-work day [219.5 ± 99.9 mins] 26.91% wear time, $t = 3.6$, df_{49}, $p = 0.001$), and also during work hours on work days compared to non-work hours on work days (work hours [221.3 ± 88.0 mins] 41.36% wear time, non-work hours on work days [80 ± 32 mins] 23.19%, $t = 7.6$, df_{49}, $p<0.001$) and total non-work time over a whole week ([300.0 ± 104.6 mins] 25.81% wear time, $t = 6.2$, df_{49}, $p<0.001$) (Table 5.3). Weekly work time sustained sedentary time (bouts>30 mins) was 18.4 hours/week making work time account for 56.83% of total weekly sustained sedentary time (32.5 hours/week).

5.6.3 Prolonged sustained sedentary time (bouts>60 mins)

Prolonged sustained sedentary time (sedentary bouts>60 mins) was proportionally greater during work hours compared to non-work hours on work days (work hours [85.6 ± 70.6 mins] 16.03% wear time, non-work hours on work days [31.8 ± 25.0 mins] 9.55% wear time, $t = 3.3$, df_{49}, $p = 0.002$), and also during work hours on work days compared to total non-work time over a whole week ([122.9 ± 69.0 mins] 10.58% wear time, $t = 3.0$, df_{49}, $p = 0.005$). Prolonged sustained sedentary time appeared to be greater on work days compared to non-work days, but this was not statistically significant (work day [117.5 ± 80.8] 13.31% wear time, non-work day [91.0 ± 59.4 mins] 11.15 % wear time, $t = 1.6$, df_{49}, $p = 0.118$) (Table 5.3). Prolonged sustained sedentary bouts accounted for 12.8 hours over a whole week, 17.01% of total weekly sedentary time.

5.6.4 Break rate

Break rate (number of breaks/sedentary hour) was proportionally less on work days compared to non-work days (work day 5.97 ± 1.45 breaks/sed hour, non-work day 7.83 ± 2.33 breaks/sed hour, $t = -6.0$, df_{49}, $p<0.001$) and during work hours on work days compared to non-work hours on work days (work hours 5.05 ± 1.68 breaks/sed hour, non-work hours on work day 7.80 ± 1.99, $t = -8.9$, df_{49}, $p < 0.001$). Break rate was also proportionally less during work hours on work days compared to total non-work hours over a whole week (total non-work hours 7.81 ± 2.02 breaks/sed hour, $t = -8.3$, df_{49}, $p < 0.001$) (Table 5.3).

5.6.5 Light activity bouts

Table 5.4 summarises the results of light activity in bouts 0-<5 mins, 5-<10 mins and 10-<30 mins. Brief periods of light intensity activity (bouts 0-<5 mins) were proportionally less on work days ([119.8 ± 23.2 mins] 13.39% wear time) compared to non-work days ([120.2 ± 26.6 mins] 14.62% wear time, $t = -2.6$, df_{49}, $p = 0.013$), and also during work hours on work days ([65.0 ± 16.6 mins] 12.17% wear time) compared to non-work hours on work days ([54.9 ± 14.3 mins] 15.31% wear time, $t = -6.5$, df_{49}, $p < 0.001$) and total non-work time ([175.0 ± 34.6 mins] 14.82% wear time, $t = -4.9$, df_{49}, $p < 0.001$).
Light activity bouts of 5-<10 minutes were proportionally less on work days ([37.3 ±19.7 mins] 4.12% wear time) compared to non-work days ([61.7 ± 31.4mins] 7.50% wear time, $t= -8.4$, df_{49}, $p < 0.001$), and also during work hours on work days ([13.6 ± 8.9 mins] 2.56% wear time) compared to non-work hours on work days ([23.6 ± 14.3 mins] 6.42% wear time, $t = -8.6$, df_{49}, $p < 0.001$) and total non-work time ([85.4 ± 42.8 mins] 7.17% wear time, $t = -10.4$, df_{49}, $p < 0.001$).

Similarly, longer bouts of light intensity activity (bouts 10-<30 mins) were proportionally less on work days ([18.3 ± 16.7 mins] 2.01% wear time) compared to non-work days ([36.3 ± 34.0 mins] 4.36% wear time, $t = -5.0$, df_{49}, $p<0.001$) and also during work hours on work days ([2.6 ± 3.9 mins] 0.48% wear time) compared to non-work hours on work days ([15.7 ± 15.6 mins] 4.21% wear time, $t = -6.2$, df_{49}, $p < 0.001$) and total non-work hours ([52.1 ± 45.1mins] 4.30% wear time, $t = -7.6$, $df = 49$, $p < 0.001$) (Table 5.4).
Sustained bouts of light activity (bouts > 30 mins) were proportionally less on work days ([1.5 ± 4 .5mins] 0.16% wear time) compared to non-work days ([6.2 ± 12.7 mins] 0.72% wear time, $t = -2.9$, df_{49}, $p=0.005$) and also during work hours on work days ([0.42 ± 3.0 mins] 0.42% wear time) compared total non-work hours ([7.2 ± 2.0 mins] 0.60% wear time, $t = -3.3$, $df = 49$, $p =0.002$) (Table 5.4).

Table 5.4: Light activity bouts 0-<5 mins, 5-<10 mins and 10-<30 mins. All activity time expressed as %wear time ± SD

	Type of day		Wear time on work day		Total non-work time
	Work day	**Non-work day**	**Work hours on work days**	**Non-work hours on work days**	
Light activity bouts (mins)					
0-<5	13.39 ± 2.21#	14.62 ± 2.80	12.17 ± 3.11^	15.31 ± 2.15	14.82 ± 2.28
5-<10	4.12 ± 2.06#	7.50 ± 3.67	2.56 ± 1.68^	6.42 ± 3.39	7.17 ± 3.32
10-<30	2.01 ± 1.83#	4.36 ± 1.83	0.48 ± 1.83^	4.21 ± 1.83	4.30 ± 1.83
30 +	0.16 ± 0.47#	0.72 ± 0.21	0.07 ± 0.07‡	1.06 ± 0.49	0.60 ± 0.16

#Significant difference between work and non-work day ($p<0.001$)

^ Significant difference between work hours on work days and non-work hours on work days and between work hours on work days and total non-work time ($p\leq0.001$)

‡Significant difference between work hours on work days and total non-work time ($p<0.05$)

5.6.6 MVPA bouts

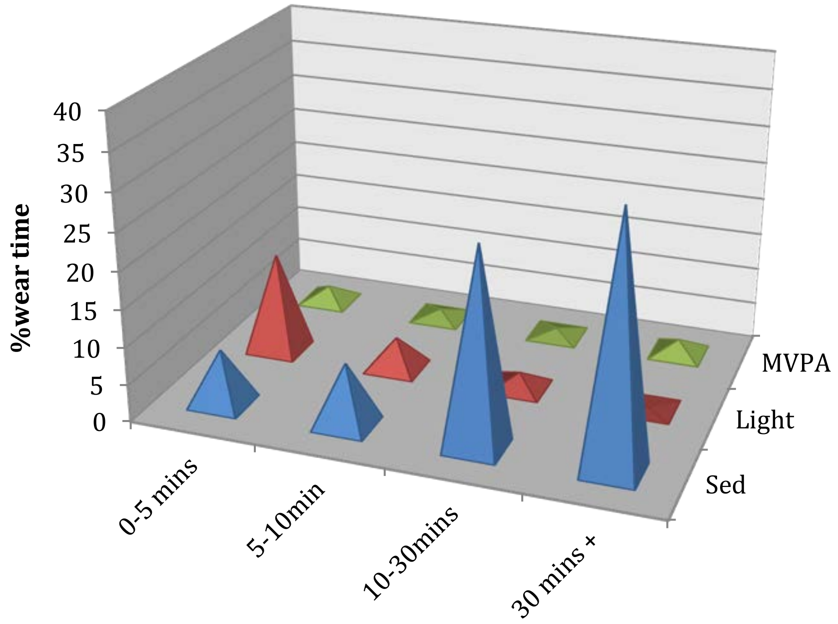
The majority of MVPA occurred in bouts of less than 10 mins, with only 74 minutes per week of MVPA accumulated in bouts of 10 minutes or greater. 14% of participants had greater than 150 minutes per week of moderate intensity activity in bouts of 10 or more minutes, additionally 14% of participants had greater than 60 minutes per week of vigorous intensity activity in bouts of 10 or more minutes. Bouts of MVPA >10mins were proportionally less during work hours on work days ([2.8 ± 5.3 mins] 0.53% wear time) compared to non-work hours on work days ([8.3 ± 12.0 mins] 2.24% wear time, $t = -4.0$, $df = 49$, $p < 0.001$) and total non-work time ([17.5 ± 24.6 mins] 1.43% wear time, $t = -3.4$, $df = 49$, $p = 0.001$) (Table 5.5).

Comparison of both the intensity of physical activity and the duration of sustained activity during work and non-work periods is shown in Figure 5.7. The taller columns for sustained sedentary time and the shorter columns for brief bouts of light activity during work hours on work days (Figure 5.7(c)) highlight the differences in exposure pattern between work and non-work periods. MVPA columns are all very short as MVPA only accounted for 4.08% (249 mins) of total wear time.

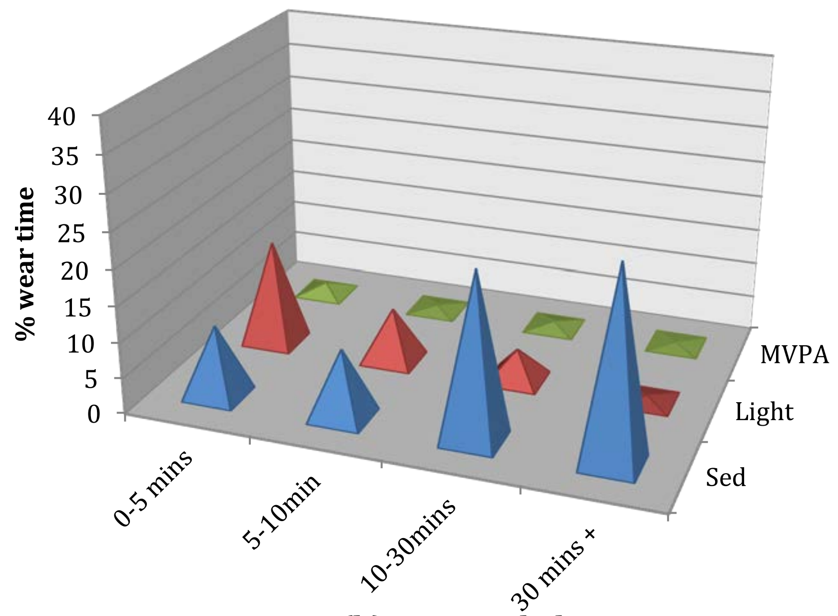
Table 5.5: MVPA bouts 10+ minutes. All activity time expressed as %wear time ± SD

	Type of day		Wear time on work day		Total non-work time
	Work day	Non-work day	Work hours on work days	Non-work hours on work days	
MVPA bouts (mins) 10+	1.22 ± 0.22	1.07 ± 1.91	0.53 ± 0.14^	2.24 ± 3.23	1.43 ± 1.96

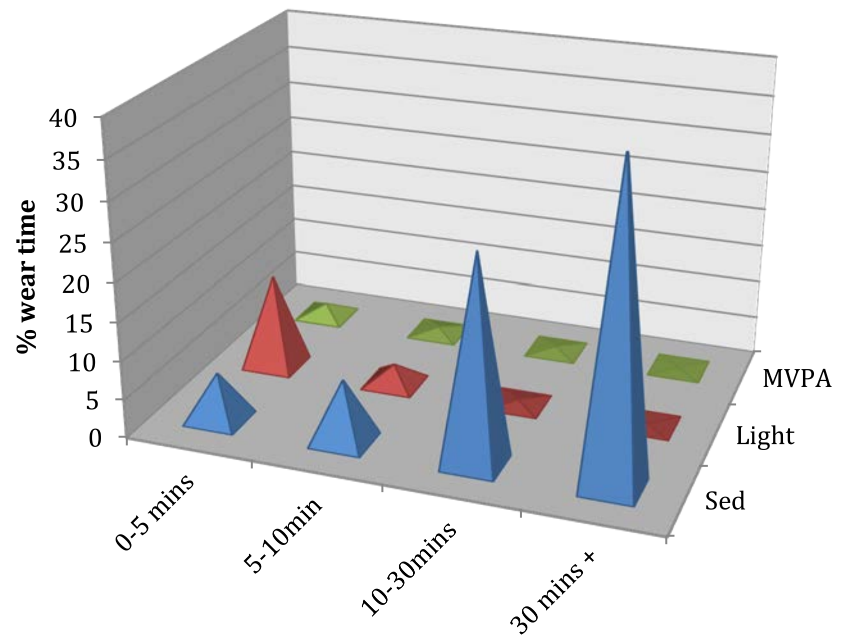
Figure 5.7: Exposure Variance Analysis showing proportion of wear time in sedentary, light and MVPA in bouts of 0-<5, 5-<10, 10-<30 and 30+ minutes on a work days (a), non-work days (b), work hours on work days (c), non-work hours on work days (d) and total non-work time over a whole week (e)



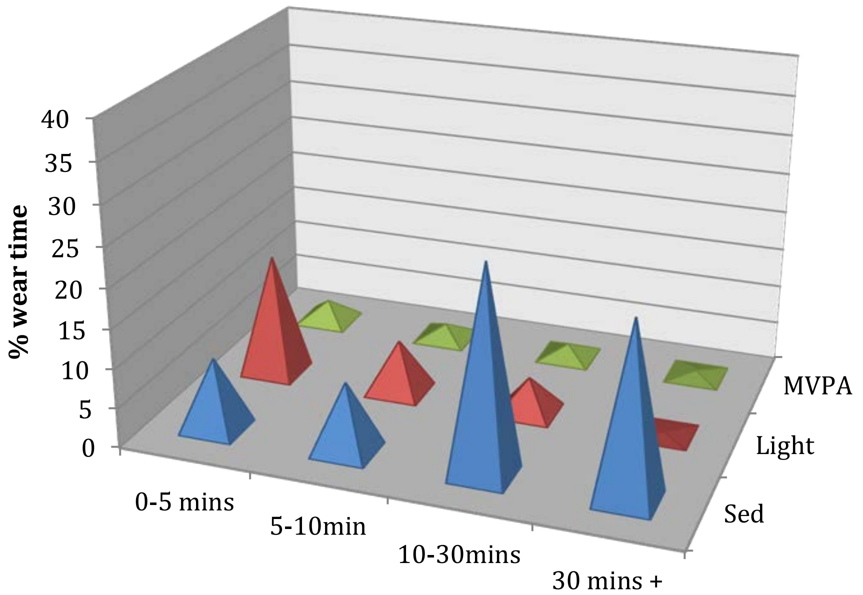
(a) Work days



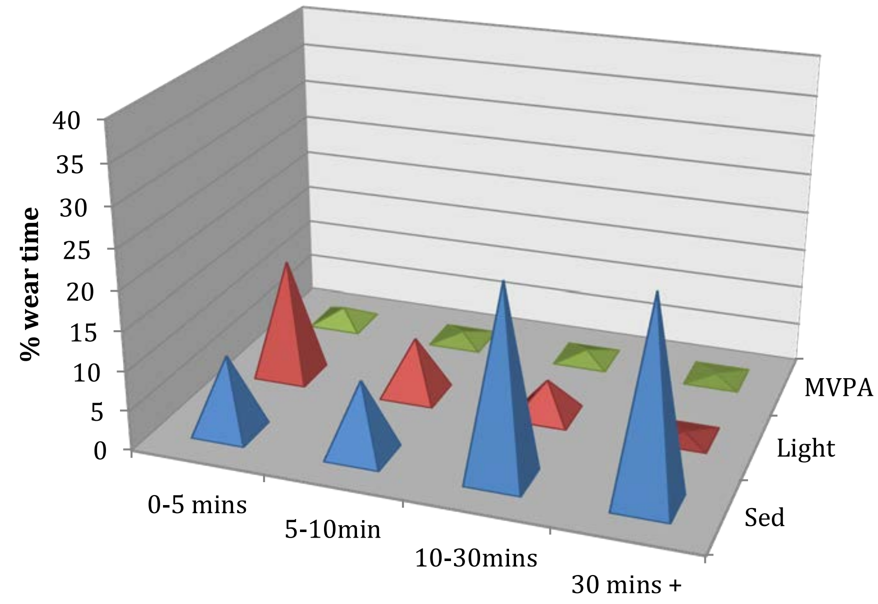
(b) Non-work days



(c) Work hours on work days



(d) Non-work hours on work days

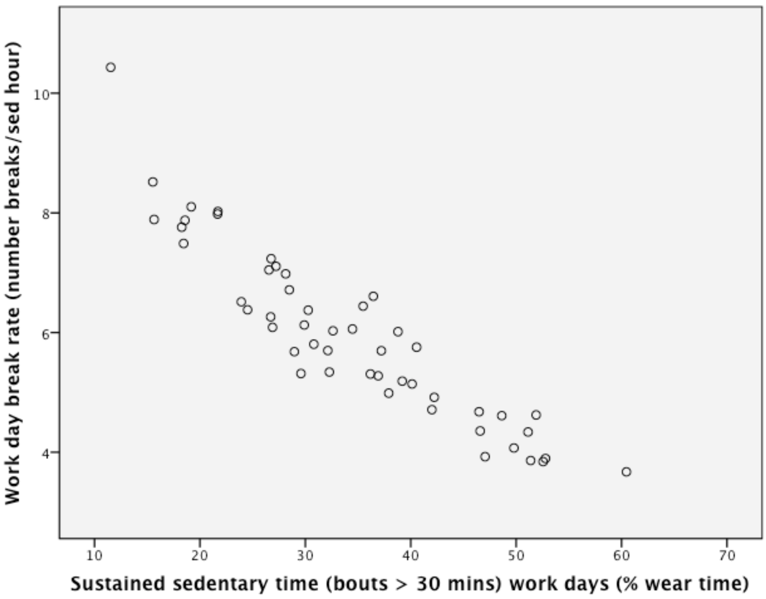


(e) Total non-work time over whole week

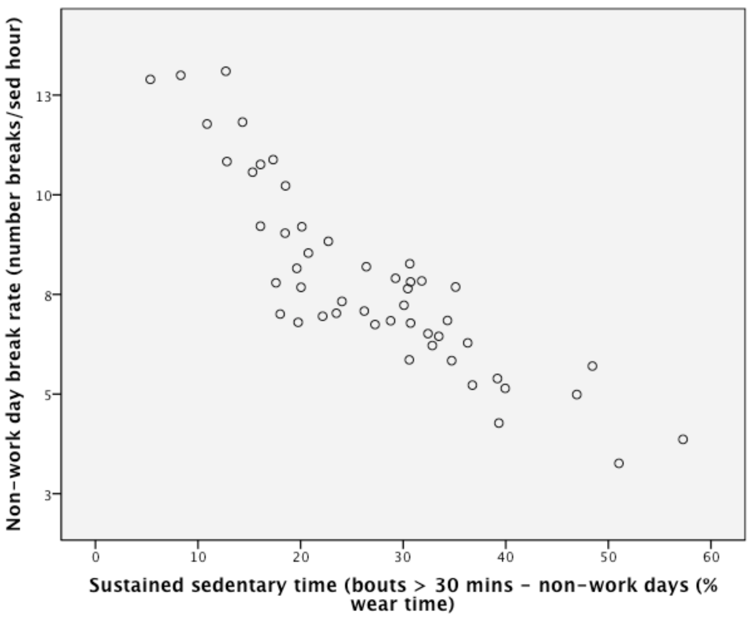
5.7 Relationship between sedentary and physical activity variables

Sustained sedentary time in bouts greater than 30 minutes was strongly negatively associated with the number of breaks in sedentary time on work days ($r = -0.93$, $p<0.001$) (Figure 5.8 (a)), on non-work days ($r = -0.88$, $p<0.001$) (Figure 5.8(b)), during work hours on work days ($r = -0.95$, $p<0.001$) (Figure 5.8(c)), during non-work hours on work days ($r = -0.79$, $p<0.001$) (Figure 5.8(d)) and for total non-work time ($r = -0.89$, $p<0.001$) (Figure 5.8(e)). There was a strong negative relationship between sedentary time at work and light activity at work ($r = -0.96$, $p<0.010$) (Figure 5.9(a)). There was also a significant negative relationship between sedentary time at work and MVPA at work ($r = -0.65$, $p<0.010$)(Figure 5.9(b)).

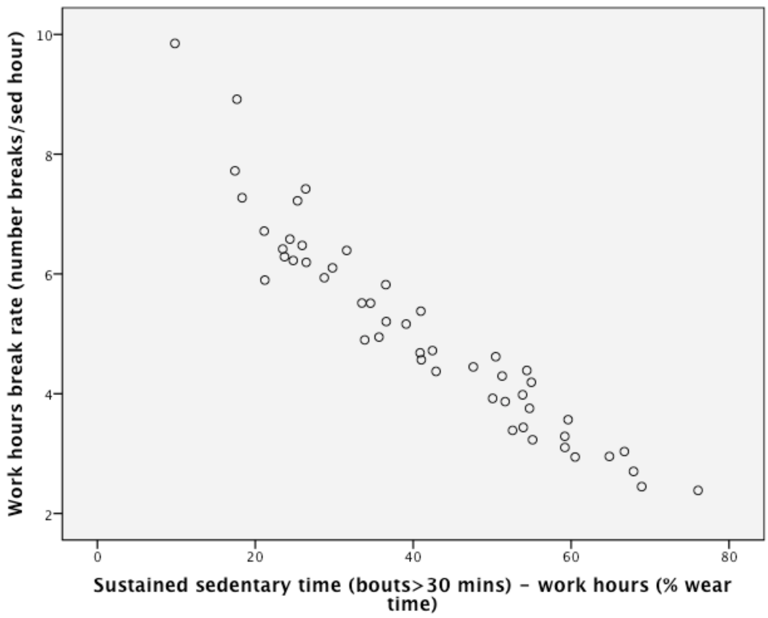
Figure 5.8: Relationship between sustained sedentary time (% wear time)(bouts >30 mins) and break rate (number of breaks/sed hour) on work days (a), non-work days (b), work hours (c) non-work hours on work days (d) and total non-work time (e). Note – proportional measures used (% wear time) for each variable



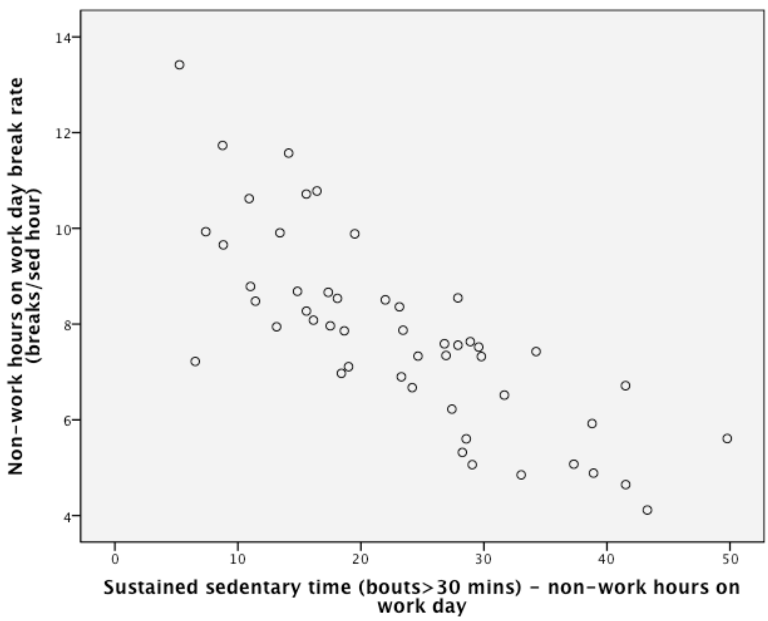
(a) Work days



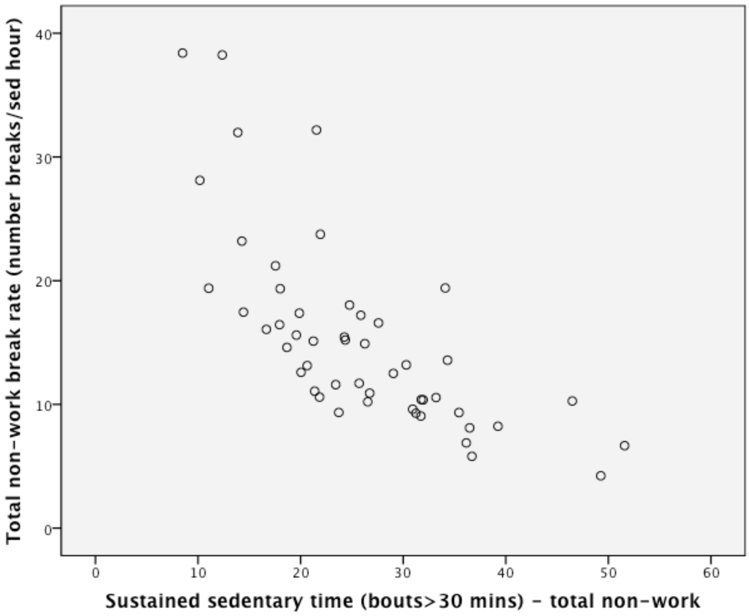
(b) Non-work days



(c) Work hours on work days

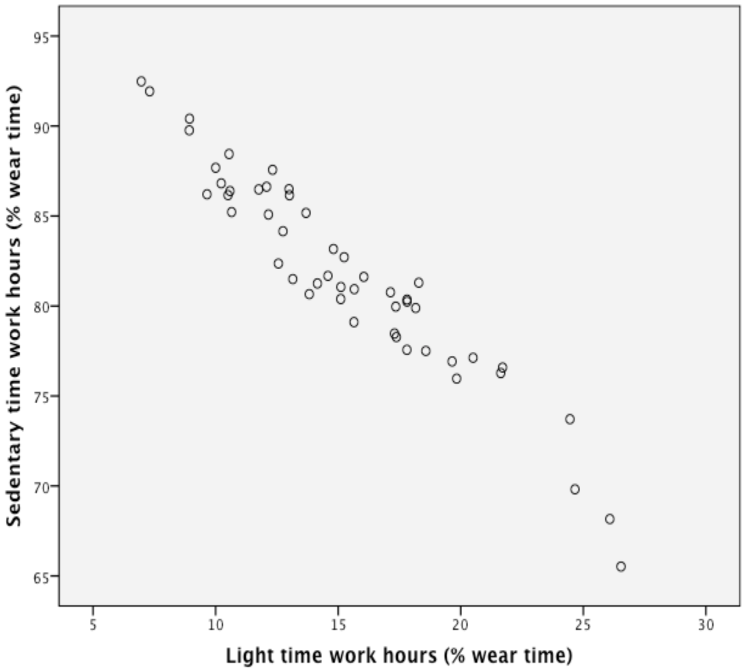


(d) Non-work hours on work day

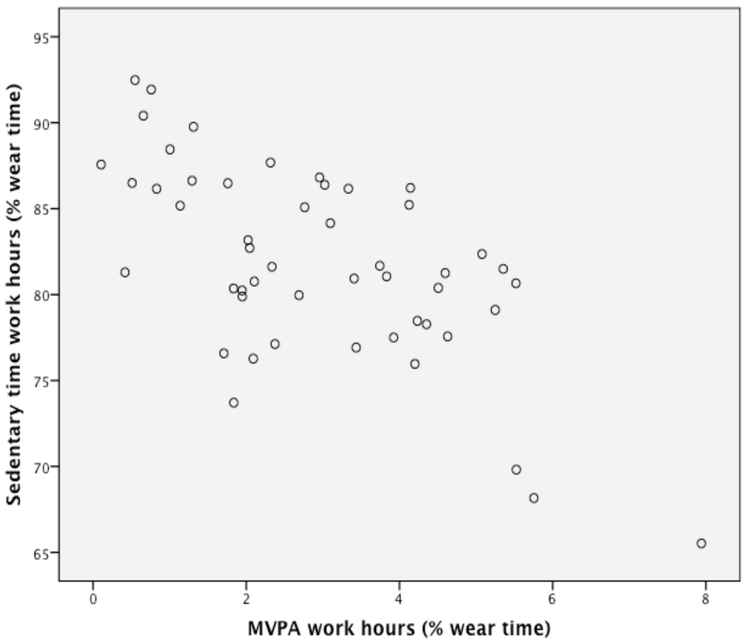


(e) Total non-work

Figure 5.9: Relationship between sedentary time and light activity during work hours (a) and sedentary time and MVPA during work hours (b). Note – proportional measures used (% wear time) for each variable.



(a) Sedentary time/light activity work hours on work days

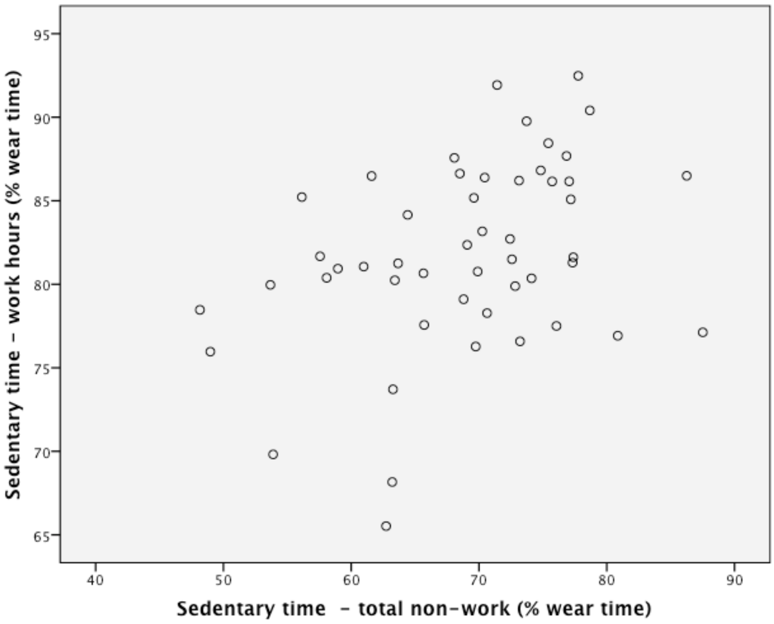


(b) Sedentary time/MVPA work hours on work days

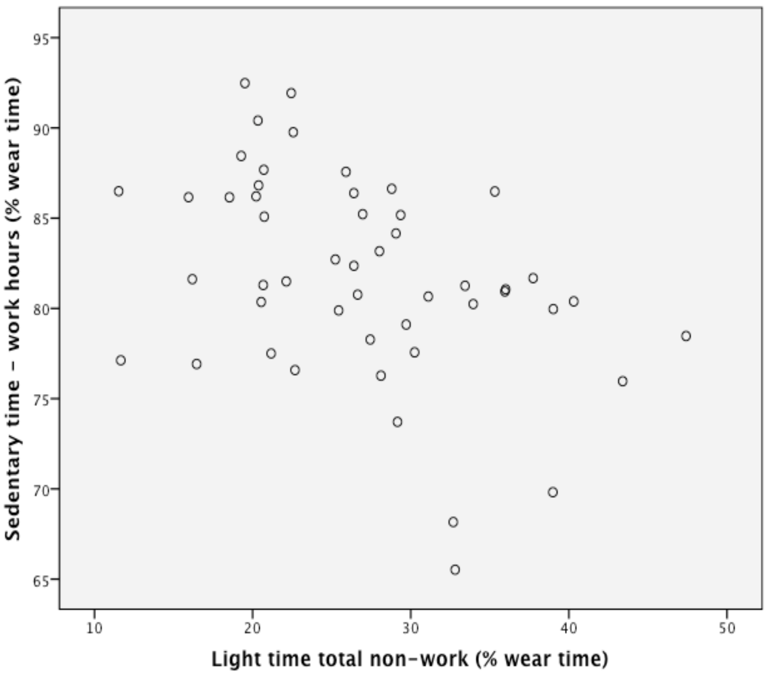
5.8 Relationship between work and non-work time activity

The proportion of sedentary time at work was moderately associated with the proportion of sedentary time during non-work hours ($r = 0.38$, $p = 0.006$) (Figure 5.10(a)) and was moderately negatively associated with the proportion of light intensity activity during non-work hours ($r = -0.42$, $p=0.002$)(Figure 5.10(b)). The proportion of sedentary time at work was not significantly associated with the proportion of non-work MVPA ($r = -0.01$, $p=0.925$)(Figure 5.11(a)). Further, there was no significant association between the proportion of MVPA at work and the proportion of MVPA during non-work periods ($r=0.17$, $p=0.234$) (Figure 5.11(b)).

Figure 5.10: Relationship between sedentary time during work hours and sedentary time during total non-work time (a) and light activity during total non-work time (b). Note – proportional measures used (% wear time) for each variable.

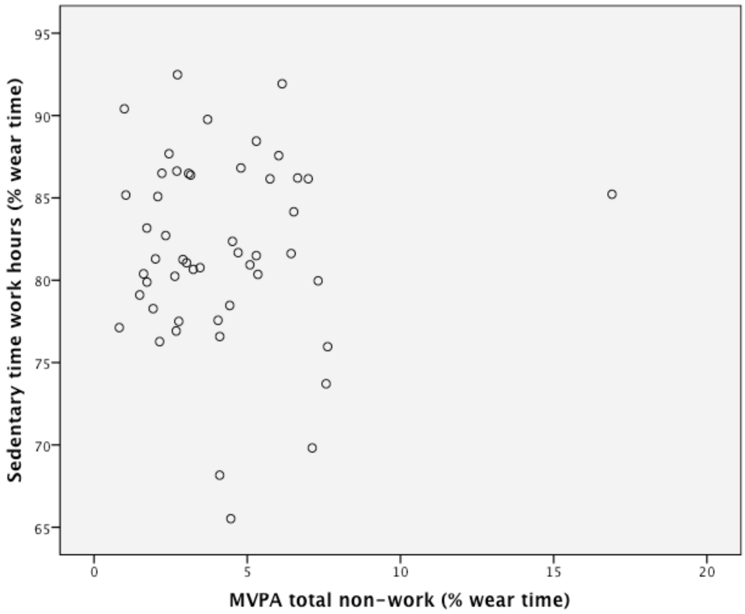


(a) Sedentary time work hours/sedentary time total non-work hours

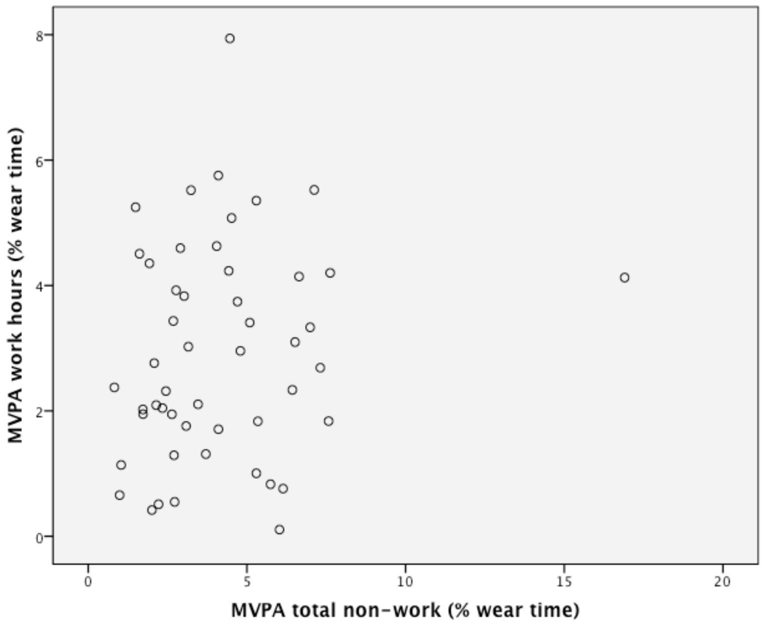


(b) Sedentary time work hours/light activity total non-work hours

Figure 5.11: Relationship between sedentary time during work hours and MVPA during total non-work time (a) and relationship between MVPA at work and MVPA during total non-work time (b). Note – proportional measures used (% wear time) for each variable.



(a) Sedentary time work hours/MVPA total non-work

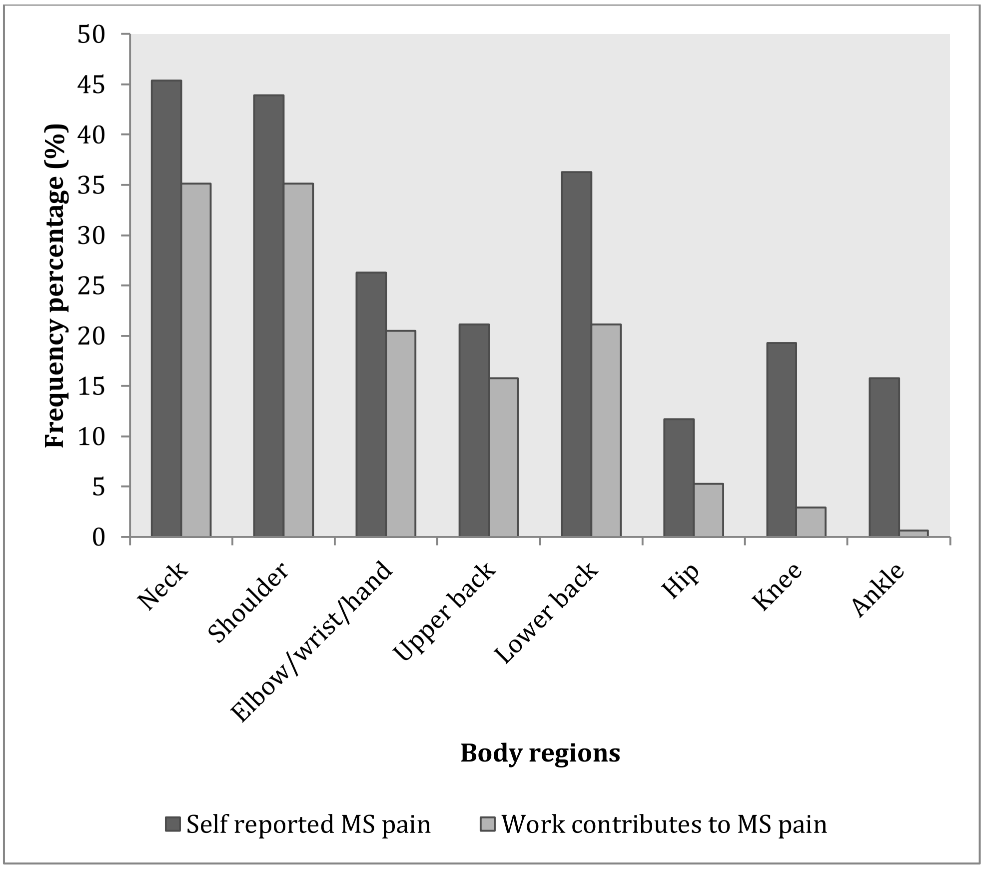


(b) MVPA work hours/MVPA total non-work

5.9 Self-reported musculoskeletal pain

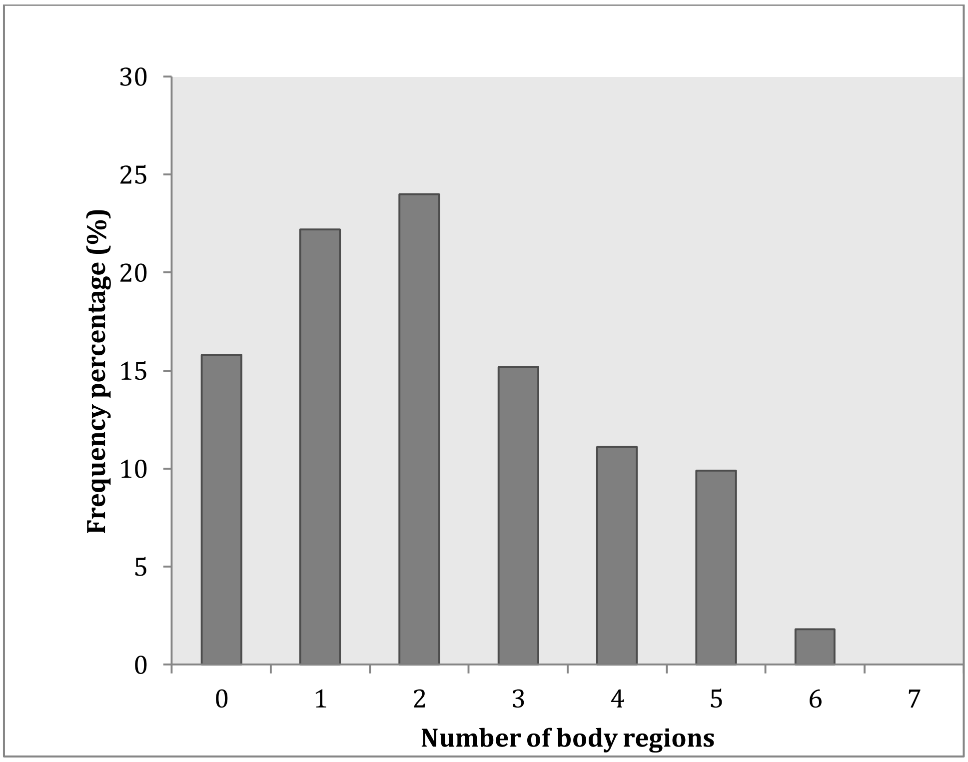
171 participants completed the modified Nordic Musculoskeletal Questionnaire (including 49 participants that also wore an accelerometer for 7 days, 4 participants that completed the IPAQ, did not complete the Nordic Musculoskeletal Questionnaire). Neck pain (46% of participants) was most frequently reported, followed by shoulder pain (44% of participants) and lower back pain (36% of participants). The distribution of reported symptoms in terms of body regions and the percentage of participants that reported work contributed to their pain are illustrated in Figure 5.12.

Figure 5.12: Distribution of self-reported musculoskeletal pain and work contribution to pain by body region



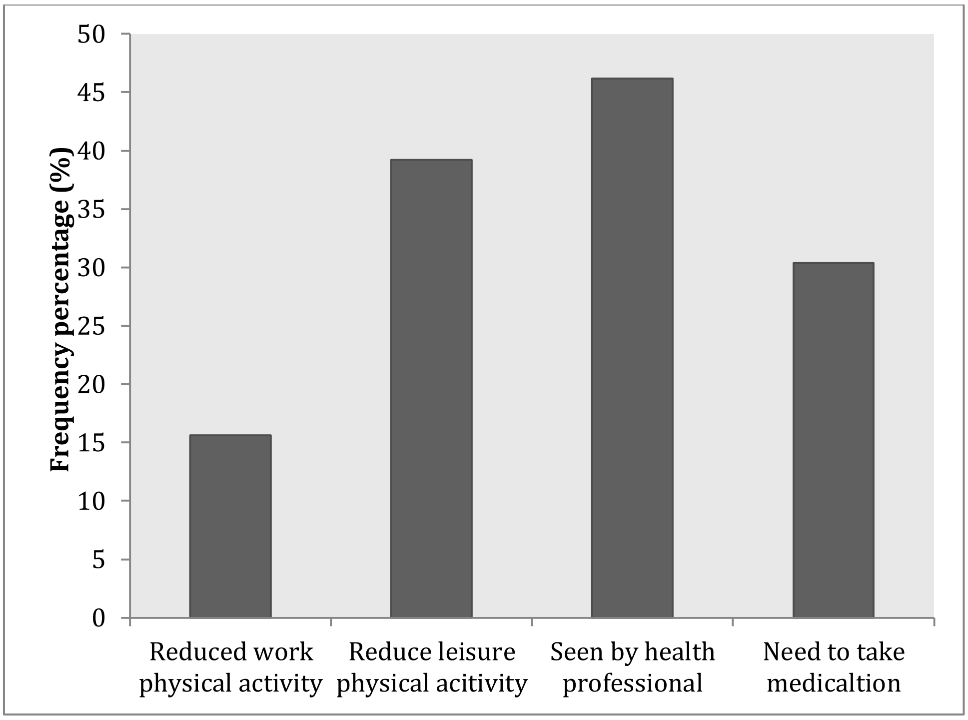
More than half of the participants (61%) reported pain in 1-3 body regions (Figure 5.13).

Figure 5.13: Reported musculoskeletal pain in relation to number of body regions



93 participants (54%) reporting that work contributed to their reported musculoskeletal pain. Not surprisingly, as office work does not require high levels of physical activity, only 16% of participants reported reducing their work related physical activity. 39% reported reducing their leisure time physical activity, 46% of participants reported seeing a health professional for their musculoskeletal pain, and 30% reported needing to take medication for their pain. The impact of musculoskeletal pain on these lifestyle factors is illustrated in Figure 5.14.

Figure 5.14: Self-reported musculoskeletal pains and lifestyle impacts



5.10 Relationship between self-reported musculoskeletal pain and sedentary time and physical activity levels

Only the participants that wore an accelerometer and completed the Nordic Musculoskeletal Questionnaire were included in this analysis (n = 48 as 2 participants did not complete the Nordic Musculoskeletal Questionnaire). In order to examine the relationship between musculoskeletal pain and activity, the body regions from the survey were divided into pain areas that are most associated with seated desk work and those areas not typically associated with desk work (Table 5.6). The body areas associated with desk work were also the body areas most frequently reported as those where work contributed to the pain (See Figure 5.12).

Table 5.6: Body regions associated with desk work and non-desk work

Desk work	**Non-desk work**
Neck	Hip
Shoulder	Knee
Elbow/wrist/hand	Ankle
Lower back	
Upper back	

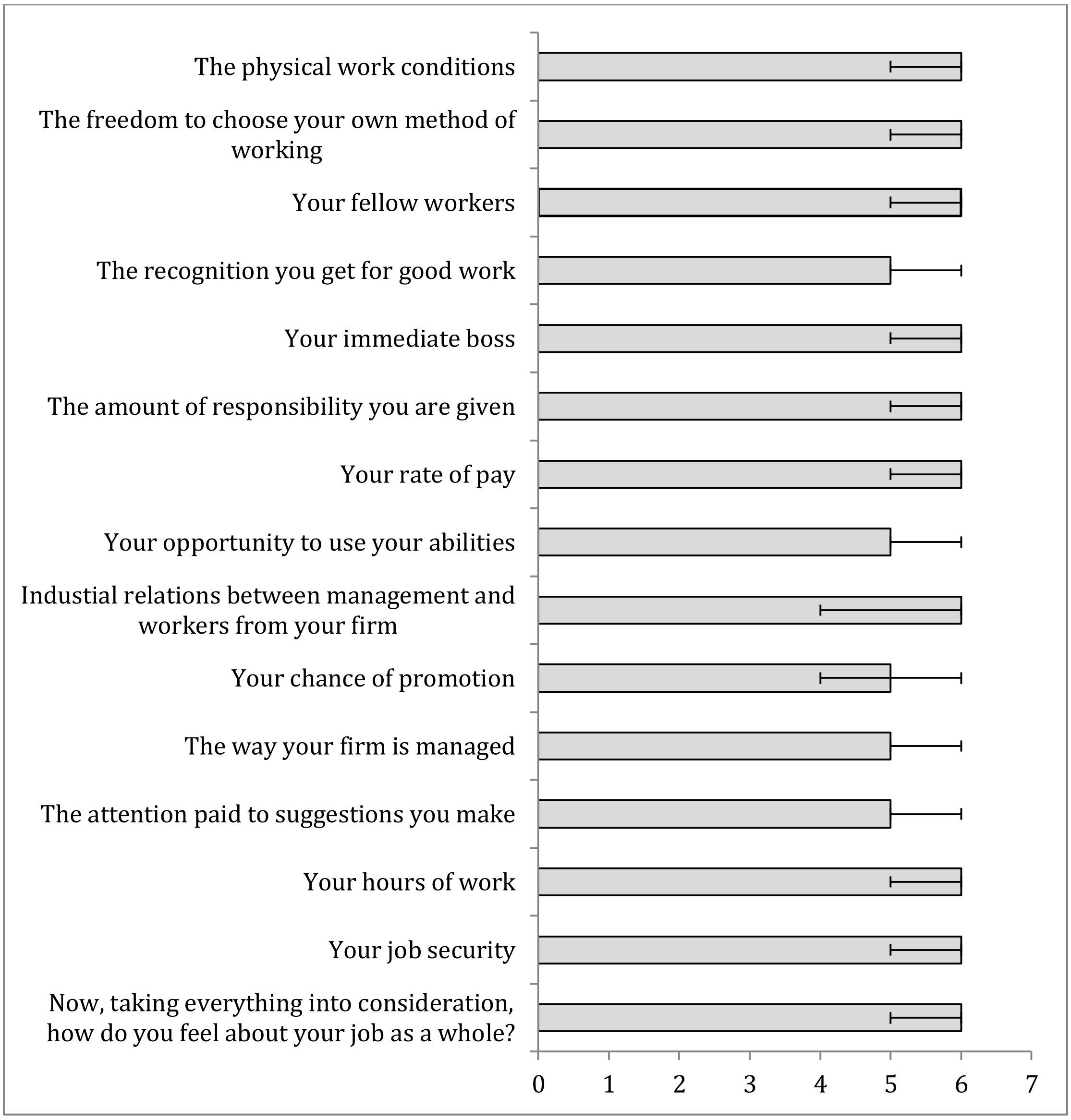
There was no significant relationship between the total number of desk-related body regions and the proportion of sedentary time during work hours ($r = -0.08$, $p = 0.615$), the proportion of light time during work hours ($r = 0.09$, $p = 0.563$) or the proportion of MVPA during work hours ($r = 0.01$, $p = 0.954$). There was no significant relationship between the total number non-desk-related body regions and the proportion of sedentary time and the proportion of light activity during non-work time (sedentary time $r = -0.09$, $p = 0.535$; light time $r = -0.12$, $p = 0.407$). However, there was a modest significant relationship between the total number of non-desk-related body regions and the proportion of MVPA during non-work time ($r = 0.29$, $p = 0.043$). The scatter plots for these relationships can be found in Appendix I.

5.11 Relationship between job satisfaction and sedentary time and physical activity levels

175 participants completed the Warr-Cook-Wall Job Satisfaction Survey (including 49 participants that also wore an accelerometer for 7 days). The median and interquartile range for each question is illustrated in Figure 5.15. Total job satisfaction score (sum of all 15 questions to a maximum of 105) ranged from 33-105 with a mean score of 80 ± 11. There was little variability between aspects of job satisfaction with all questions scoring between 5 or 6 (median) from a maximum satisfaction rating of 7 (Figure 5.15).

For the participants that wore an accelerometer and completed the Warr-Cook-Wall Job Satisfaction Survey ($n = 49$), there was no significant relationship between overall job satisfaction and the proportion of sedentary time and physical activity during work hours (sedentary time $r = 0.10$, $p = 0.509$; light time $r = -0.10$, $p = 0.478$; MVPA $r = -0.03$, $p = 0.839$) and total non-work time (sedentary time $r = 0.03$, $p = 0.862$; light time $r = -0.10$, $p = 0.520$; MVPA $r = 0.20$, $p = 0.174$) The scatter plots for these relationships can be found in Appendix J.

Figure 5.15: Median and interquartile range for each question of the Warr-Cook-Wall Job Satisfaction Survey, 1 = extremely dissatisfied; 4 = not sure and 7 = extremely satisfied

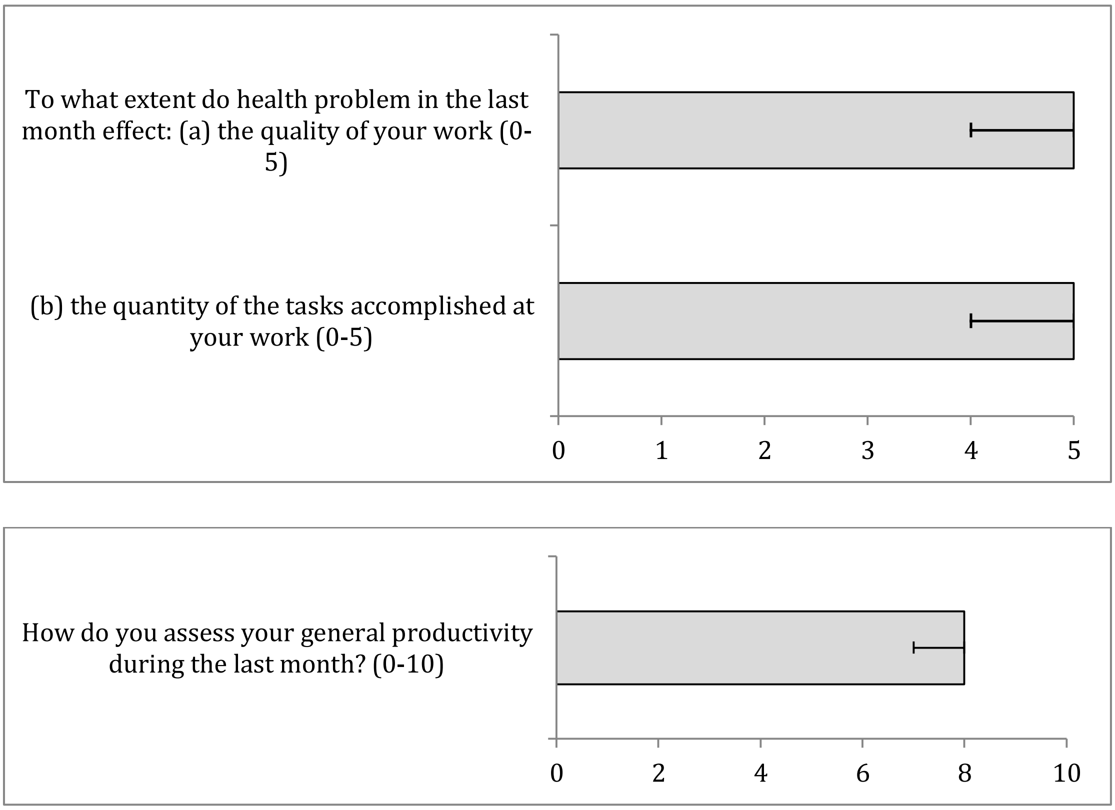


5.12 Relationship between self-reported work productivity and sedentary time and physical activity levels

176 participants completed the Health and Work Performance Questionnaire. In general the participants rated their productivity as high with median score for questions 1 (a) and (b) of 5/5 and for question 2, 8/10. The results are illustrated in Figure 5.16 below.

To assess the relationship between work productivity and physical activity and sedentary behaviour, the data from participants that wore an accelerometer and completed the Health and Work Performance Questionnaire were analysed (n = 49). As the data was skewed, Spearmans' correlations were used. There was no significant relationship between self-reported health related work productivity (Questions 1(a) and (b)) and sedentary time, light activity and MVPA during work hours and during total non-work time. There was no significant relationship between self-reported productivity (Question 2) and sedentary time and MVPA during work hours and total non-work time. However, there was a significant relationship between self-reported productivity and light activity during work hours ($r = 0.32$, $p = 0.023$) but not during total non-work time ($r = 0.024$, $p = 0.868$).

Figure 5.16: Median and interquartile range for each question of the Health and Work Performance Questionnaire



6.0 Study 1 - Discussion

6.1 Main findings

Study 1 specifically examined the overall amount and pattern of exposure to sedentary time, light activity and MVPA of office workers during work hours and all non-work periods. Further it examined the relationship between musculoskeletal pain, job satisfaction, self-reported work productivity and sedentary behaviour and physical activity. The main findings were:

1. Amount of sedentary exposure and physical activity

- Office workers were sedentary for a large proportion (82%) of working hours.
- A very small proportion of the day was MVPA (3%).

2. Pattern of sedentary exposure and physical activity

- Work hours were characterised by long bouts of sedentary time with only a small proportion of the work hours in brief bouts or sustained bouts of light activity.
- Sustained sedentary time (bouts > 30 mins) was negatively associated with break rate in all time periods.

3. Occupational sedentary time

- Occupational sedentary time contributed 49% to overall weekly sedentary time.

4. Relationship between sedentary and physical activity variables

- There was a strong negative relationship between sedentary time at work and light activity at work.

5. Relationship between work and non-work time activity

- There was a moderate positive association between sedentary time at work and sedentary time during non-work periods.

6. Self-reported sedentary time and physical activity

- Self-reported sedentary time significantly underestimated accelerometer derived sedentary time and self-reported MVPA significantly overestimated accelerometer derived MVPA.

7. Self-reported musculoskeletal pain

- 61% of office workers reported musculoskeletal pain in 1-3 body regions with neck, shoulder and low back most frequent regions.
- 54% of office workers that reported musculoskeletal pain reported that work contributed to their musculoskeletal pain.
- There was no association between the number of desk-related body regions with musculoskeletal pain and the proportion of sedentary time, light activity or MVPA.

8. Self-reported job satisfaction and work productivity

- Overall there was a high level of self-reported job satisfaction and work productivity reported.
- There was no significant relationship between work factors and sedentary time or physical activity with the exception of a moderate positive association between work productivity and light activity during work hours.

6.2 Discussion

6.2.1 Accelerometer derived sedentary time and physical activity at work and during non-work periods

The present study found that office workers were sedentary for 88% of working hours, which was similar to the subsequent findings of Thorp et al (2012) (office workers sedentary for 76% work hours; call centre workers for 82% of working hours). Sedentary time was higher than the recent findings of Clemes (2014) where office workers were found to be sedentary for 71% of working hours. Ryan et al (2011), using activPAL™ to assess sitting time, found that sitting time of office workers was 66% of working hours and Toomingas et al (2012), using inclinometers, with a group of call centre workers found sitting time of 75% of working hours. The differences in sedentary time between studies may be due to variation in the nature of the work performed, for example, clerical/administrative, call centre or university academic; work practices within the organisation such as the organisational culture regarding breaks and productivity as well as the different devices used to capture sedentary behaviour. The inclinometer based devices that differentiate between sitting postures and standing (Grant et al., 2006; Toomingas et al., 2012) may be particularly appropriate for assessing sitting time, however, motion sensors such as accelerometers differentiate between intensity of activities and have the advantage of providing simultaneous detail about sedentary time, light intensity activity and MVPA (Matthews et al., 2008; Ward et al., 2005).

Office workers spend the vast majority of their time, both at work (97.1%) and during total non-work time (95.7%) either sedentary or participating in light activity, with MVPA contributed only 2.9% of work hours and 4.1% of total non-work wake time. Further, there was consistency across the participants, with 78% of participants more sedentary, and 84% of participants having more light activity on work days compared to non-work days. Traditional health promotion interventions and guidelines have stressed the importance of achieving sufficient MVPA to maintain good health (e.g. “findthirty” campaign that encourages 30 minutes of MVPA (Australian Government Department of Health and Aging, 2005; Findthirty). Given that most waking hours are spent sedentary or in light activity, and the emerging evidence regarding the health implications of prolonged or uninterrupted sedentary time (Healy, Mathews, et al., 2011; Healy, Wijndaele, et al., 2008) and the potential benefits of light intensity activity (Dunstan, Kingwell, et al., 2012; Healy et al., 2007), health promotion campaigns should now consider encouraging reducing sedentary time and promoting light activity. Office workers may be considered a particularly vulnerable population due to the excessive sedentary time associated with office work and should therefore be specifically targeted (Australian Government Department of Health and Aging, 2005; Ekelund et al., 2005; Hagstromer et al., 2007; Metzger et al., 2008; Ottevaere et al., 2011; Troiano et al., 2008).

6.2.2 Pattern of sedentary exposure at work and during non-work hours

Study 1 comprehensively examined the pattern of sedentary time, light activity and MVPA of office workers at work and during non-work periods. Office work was characterised by bouts of sustained sedentary time (bouts>30 mins) (41%

wear time) with weekly work sustained sedentary time accounting for 57% of total weekly sustained sedentary time. These results are similar to those of Ryan et al (2011) who found that 52% of work hours was spent sitting in bouts of greater than 30 minutes. Thorp et al (2012) found that for office workers only 21% of working hours were in sedentary bouts greater than 30 mins and Toomingas et al (2012) found that call centre workers were seated for greater than 30 minutes for 29% of working hours. Further, in Study 1, prolonged sustained sedentary time (bouts >60 mins) accounted for 16% of wear time during work, which is greater than the findings of Toomingas et al (2012) (9% of working hours) but less than the findings of Ryan et al (2011) (25% of working day). Differences in patterns of sustained sedentary time between the present study and those of Ryan et al (2011), Thorp et al (2012) and Toomingas et al (2012) may again be due to the difference nature of the work observed (call centre and clerical) and the devices used in the different studies.

Sustained and prolonged sustained sedentary time make up a large proportion of time during work hours for office workers. Therefore, in light of the evidence of the potential health risks associated with sustained and uninterrupted sedentary time (Dunstan, Kingwell, et al., 2012; Healy, Dunstan, Salmon, Cerin, et al., 2008) future interventions for office workers need to specifically address breaking up long bouts of sedentary time.

One of the interesting findings from the present study was that office workers were sedentary in bouts in excess of 60 minutes (and less than 120 mins) for more than 12 hours/week. Toomingas et al (2012) found that call centre workers were sedentary in bouts greater than 60 minutes for 2.5 hours during week days and Ryan et al (2011) found that office workers were sedentary in bouts greater than 55 minutes for 9.0 hours during week days. Some studies have used periods of greater than 60 minutes of zero counts as the cut point for accelerometer non-wear time (Clark et al., 2011; Healy, Mathews, et al., 2011; Vallance et al., 2011), whereas Study 1 used 120 minutes of continuous zero counts to indicate non-wear time. Studies that have used the 60 minute cut point may have inadvertently misclassified prolonged sedentary time as non-wear time. Consideration should be given to changing the classification of non-wear time in future large population studies, particularly when assessing known inactive populations such as office workers.

6.2.3 Contribution of work sedentary time exposure to overall sedentary time exposure

Office workers were found to be sedentary for a very high proportion of their working hours, with sedentary time at work accounting for nearly half (49%) of the total weekly sedentary time. Clemes et al (2014) found that sedentary time at work contributed 57% of total daily sedentary time on a work day, while in Study 1, work sedentary time contributed 65% of total daily sedentary time on a work day. Study 1 found that for office workers, work is a significant contributor to overall weekly sedentary exposure and therefore, office workers may be particularly susceptible to the associated health risks of prolonged sedentary time. In order to reduce the risks associated with prolonged sedentary exposure, the nature and design of office work practices may need to change. A number of different intervention approaches designed to reduce sedentary exposure and encourage light intensity activity of office workers were trialed in Study 4, with details presented in Chapters 9-12.

6.2.4 Relationships among measures of pattern of sedentary time, light activity and MVPA

A strong reciprocal relationship was found between sedentary time and light intensity activity for office workers at work. While this relationship has been discussed in the literature (Healy et al., 2007; Healy, Wijndaele, et al., 2008), the implications have not been directly applied to office workers. The nature of office work provides limited potential to modify the way in which office tasks are performed. Therefore, interventions should consider replacing a proportion of occupational sedentary time with light activity such as encouraging incidental office activity (light activity) or the use of sit-stand or active workstations.

As expected there was a strong negative relationship between sustained sedentary time and breaks in sedentary time, however it is difficult to determine whether sustained sedentary time carries the same or different risk as fewer breaks in sedentary time. Prolonged sedentary time may have unique and different physiological consequences compared to participating in active breaks (Hamilton et al., 2008; Owen et al., 2010). When examining muscle physiology studies that break up sustained low level muscle contractions, it was found that there were changes to muscle activation patterns following breaks composed of both total rest as well as greater muscle activation (Aaras, 1994; Falla & Farina, 2007; Hagg & Astrom, 1997). Therefore, sustained sedentary time may result in a detrimental physiological state whereas activity breaks may result in a beneficial physiological state. Further, recent laboratory studies have found that even brief bouts of light intensity activity can have a beneficial effect on glucose metabolism (Dunstan, Kingwell, et al., 2012). Therefore, the findings from the current study suggest that further research is needed to explore the physiology of sustained sedentary time and active breaks.

6.2.5 Relationship between work and non-work sedentary time, light activity and MVPA

There was a moderate association (r = 0.38) between sedentary time at work and sedentary time during non-work periods. It is possible that office workers are self-selected, that it, people choose occupations related to their activity preference. It is important to consider this when conducting health promotion interventions, as some office workers may be resistant to modifying activity levels due to a preference for a sedentary lifestyle.

While early research found that white collar workers were more active in non-work periods than workers with high occupational activity (Burton & Turrell, 2000; Steele & Mummery, 2003), more recent evidence suggests that sedentary workers are no more active in non-work periods than active workers (Clemes, O'Connell, et al., 2014; Schofield et al., 2005; Tigbe et al., 2011). Similar to these latter studies, in the present study, it was found that high sedentary time at work was not 'compensated' by increased MVPA during non-work hours. However such efforts may be in vain, as recent evidence suggests that sedentary time and breaks in sedentary time may be independent risk factors (Healy, Dunstan, Salmon, Cerin, et al., 2008; Healy, Mathews, et al., 2011; Healy, Wijndaele, et al., 2008) and are unlikely to be compensated by increased MVPA. Participation in MVPA during leisure time has many health benefits (Chomistek et al., 2013; Davies et al., 2012; Vallance et al., 2011). However, arguably it is equally important to promote a reduction in sedentary time during leisure time. This may be particularly important for office workers that have high sedentary exposure at work and may be equally sedentary out of work. Therefore, health promotion interventions for office workers should consider targeting non-work sedentary behaviour as well as work related sedentary behaviour.

6.2.6 Validity of the IPAQ to measure sedentary time and MVPA of office workers at work and during non-work periods

Self-reported measures of physical activity and sedentary behaviour have the advantage of being inexpensive and easy to administer to research participants, however, in general it has been found that participants do not accurately estimate the amount of time in various activities (Ainsworth, Richardson, et al., 1999; Sallis & Saelens, 2000; Shepherd, 2003) or accurately describe the intensity of physical activity (Richardson, Ainsworth, Jacobs Jr, & Leon, 2001). The IPAQ was developed to address these limitations by using specific time periods (10 minute blocks) of physical activity in moderate or vigorous intensity and also it also provided an estimate of sitting time (minutes/day). IPAQ also partly examines the pattern of activity over a day and week by assessing activity in the four domains of work, transport, domestic and leisure time. However, IPAQ does not attempt to assess the contribution of light intensity activity and sedentary time is only assessed by reporting the number of hours sitting on week days and weekends and during transport.

In the group of participants that wore an accelerometer and completed the IPAQ in Study 1 it was found that IPAQ over estimated MVPA, similar to other research findings (Ottevaere et al., 2011; Sebastiao et al., 2012). IPAQ estimated that 76% of participants achieved greater than 150 minutes/week of moderate intensity physical activity, which was similar to the 80% of participants that had greater than 150 minutes/week of moderate accelerometer derived minutes. However, if walking minutes were added to the moderate minutes when using the IPAQ, all participants achieved the health recommended guidelines of 150 moderate minutes/week, again demonstrating the potential for IPAQ to over-estimate MVPA.

The results from the present study on self-reported sitting time (437 mins/day) was amongst the highest reported by Australians (Bauman et al., 2011) and is consistent with high sitting rates reported by office workers (404-495 mins/day)(Jans et al., 2007). In Study 1 it was found that IPAQ underestimated sedentary time (by 3 hours on work days; 6 hours on non-work days) when compared to accelerometer derived sedentary time, which are similar to other findings that have compared IPAQ sitting time to accelerometer derived sedentary time (Fitzsimons et al., 2012). The large discrepancy between the IPAQ sitting time and accelerometer derived sedentary time in Study 1 suggests that care should be taken when interpreting the results of IPAQ derived sitting time.

One of the potential reasons for the discrepancies between self-reported and accelerometer derived activity reported in Study 1 may be due to the IPAQ reporting activity levels in the previous week, whereas the accelerometer was worn for the up-coming week so that measurement occurred in two isolated weeks. However, both measurement periods reflected typical working weeks for the participants and would likely only account for a small proportion of the differences.

One of the greatest limitations of using IPAQ with office workers is that it does not assess light intensity activity. The greatest variability in activity recording in Study 1 between work and non-work periods was in light intensity activity (work hours 15% wear time; total non-work time 27% wear time) while MVPA only varied 1%. In the future, a survey instrument that adequately captures light activity may provide an inexpensive alternative to the use of motion sensors.

Given the evidence on the validity of IPAQ from this and prior studies, it appears the IPAQ has limited application in the assessment of physical activity and sedentary behaviour of office workers. While the IPAQ was able to determine the general pattern of accumulation of physical activity between the four domains observed, with occupational MVPA contributing least to overall weekly MVPA, it did not assess light activity and was not able to isolate occupational sitting or sedentary time.

6.2.7 Achieving health recommended guidelines for physical activity

In Study 1, of the participants that wore an accelerometer, 80% accumulated greater than 150 minutes of moderate intensity activity/week. Some physical activity guidelines recommend accumulation of MVPA in bouts of 10 or more minutes (M.S Tremblay, LeBlanc, et al., 2011; U.S. Department of Health and Human Services, 2008; World Health Organization, 2010). In Study 1, 26% of participants achieved physical activity recommendations of 150 minutes/week of MVPA in bouts of greater than 10 minute. Other large population studies have found that the proportion of the population achieving 150 minutes/week in bouts greater than 10 minutes ranging from 1-5% (Hagstromer et al., 2007; Metzger et al., 2008; Troiano et al., 2008). The high compliance to physical activity guidelines in the participants in Study 1 may be a product of environmental factors such as a good climate that facilitates physical activity, a supportive workplace and the use of an Actical accelerometer rather than the ActiGraph accelerometer.

The emphasis on accumulation of MVPA in short bouts (10 or more minutes) provides greater flexibility and a more realistic option for inactive populations (Murphy et al., 2009). In a recent review it was found that integrating short bouts of MVPA into the day may provide health and disease prevention benefits (Barr-Anderson, AuYoung, Whitt-Glover, Glenn, & Yancey, 2011). For some health-related outcomes, MVPA accumulated in short bouts have been found to be equally beneficial as participation in continuous bouts (Murphy et al., 2009). However, there is still insufficient evidence that short bouts of MVPA confer the same health benefits of continuous MVPA.

6.2.8 Self-reported musculoskeletal pain

Office workers in general have reported high rates of musculoskeletal pain, in particular upper limb, neck and low back pain (Harcombe & McBride, 2009; Huysmans, 2012; Widanarko et al., 2011). Nearly half the participants in the present study reported neck pain (45%), similar to 42% head/neck symptoms reported by Janwantanakul et al (2008) but less prevalent than the 51% reported for New Zealand office workers (Harcombe & McBride, 2009). Reported shoulder pain (44% of participants) was more prevalent than other studies of office workers (Harcombe & McBride, 2009; Janwantanakul et al., 2008) whereas the reported low back pain (36% of participants) was less prevalent than the 45% reported by New Zealand office workers (Harcombe & McBride, 2009) but similar to other studies of office workers (Janwantanakul et al., 2008). 84% participants reported pain in at least one body region which is less than the prevalence reported in other general population studies (Kamaleri, Natvig, Ihlebaek, Benth, & Bruusgaard, 2008; Widanarko et al., 2011) but similar to prevalence reported by New Zealand office workers (84%) (Harcombe & McBride, 2009).

More than half (54%) of participants reported that work contributed to their pain. These findings are consistent with the evidence that work factors such as prolonged keyboard and mouse use, workplace posture, ergonomic factors, high workload and stress can all contribute to the development of musculoskeletal pain in office workers (Chiu et al., 2002; Cho et al., 2012; Hannan et al., 2005; Hush et al., 2009; Huysmans, 2012; Jensen, 2003; Kiss et al., 2012).

Only a small proportion of participants (16%) reported that musculoskeletal symptoms resulted in reduced work related physical activity. This finding however, was not surprising as office work has low occupational physical activity. The pattern and distribution of musculoskeletal pain in the present study are consistent with other research findings that a high proportion of office workers report musculoskeletal pain in the neck, shoulder and low back. Therefore, office workers appear to be particularly vulnerable to development of musculoskeletal pain. It is possible that in addition to workplace factors, occupational sedentary behaviour may contribute to the development of musculoskeletal pain in office workers.

6.2.9 Relationships between self-reported musculoskeletal pain and sedentary time, light activity and MVPA

This study appears to be the first study to specifically examine the relationship between accelerometer derived sedentary time, light activity and MVPA and self-reported musculoskeletal symptoms. As the relationship between physical activity and musculoskeletal pain has been described as ‘U-Shaped’, where both excessive physical activity and very low physical activity or sedentary behaviour may contribute to the development of musculoskeletal pain (Heneweer et al., 2009), it was not expected that there would be a direct linear relationship between pain and activity. Further, the Modified Nordic Questionnaire used in the present study identified only the location(s) of the pain and some lifestyle modifications in response to reported pain but did not report the intensity of the pain, previous trauma or how the reported pain was impacted by work tasks. Therefore, an assessment of the relationship between activity and intensity of symptoms could not be drawn from the data.

As office workers predominately report musculoskeletal pain in the upper limb, neck and low back (Harcombe & McBride, 2009; Huysmans, 2012; Widanarko et al., 2011), in order to examine relationships between activity and musculoskeletal pain, the body regions were divided into body regions generally associated with desk-related tasks (neck, shoulder, elbow/wrist/hand, lower back and upper back) and body regions not generally effected by desk-related work (hip, ankle, knee). Study 1 did not demonstrate a relationship between either sedentary time or physical activity (light and MVPA) and musculoskeletal pain in ‘desk-related’ body regions. These findings are consistent with the poor evidence of a causal relationship between sitting and musculoskeletal complaints in adults (Cho et al., 2012; Roffey et al., 2010). In contrast to the present findings, in a recent review, Brink and Louw (2013) found strong evidence of a causal relationship between sitting and upper quadrant musculoskeletal pain in children and adolescents. The key determinants of upper quadrant pain were reported to be sitting duration, activities while sitting, amount of movement while sitting, and postural angles while sitting (Brink & Louw, 2013).

As the present study was cross-sectional, it is not possible to demonstrate causal relationships as the data presents only one point in time. Longitudinal and prospective studies can monitor activity and musculoskeletal pain over time. For example, Hush et al (2009) examined the causal relationship between physical and psychological risk factors for neck pain in Australian office workers over one year. It was found that cervical spine mobility and frequent exercise were preventive factors to the development of neck pain in office workers. Future longitudinal population research that incorporates a comprehensive assessment of musculoskeletal pain in different population groups and uses an objective measure of sedentary time and physical activity would be useful in establishing an activity-pain relationship. Study 4 of this thesis investigated whether interventions aimed at reducing occupational sedentary behaviour can also modify musculoskeletal symptoms of office workers.

6.2.10 Other potential correlates of occupational sedentary behaviour and physical activity

It was anticipated that work factors such as job satisfaction may be related participation in occupational physical activity and sedentary behaviour. No correlation between sedentary time or physical activity and self-reported job satisfaction was demonstrated. One of the potential reasons for this finding was the overall high rating of job satisfaction that may reflect a cooperative organisation and workplace. This particular organisation was supportive of health initiatives, wellness programmes and provided sponsorship to community-wide physical activity events. It may also be that job satisfaction does not influence physical activity or sedentary behaviour but rather other work factors such as psychosocial features of an organisation that may influence these behaviours (O'Driscoll & Cooper, 2002; Shaw et al., 2011).

Similarly, it was anticipated that self-reported work productivity may be related to participation in occupational physical activity and sedentary behaviour. Participants in the present study reported high levels of work productivity and there was a moderate association (r = 0.32) between light activity and self-reported work productivity during work hours only. These results may suggest that promotion of light intensity workplace activity could potentially improve work productivity. However, the findings were only demonstrated with a small group of participants and the modified version of the Health and Work Performance Questionnaire only assessed general work productivity on an 11 point scale.

The reported high levels of work productivity could be indicative again of a supportive work environment provided by the organisation but could also be due to a lack of sensitivity in the modified questionnaire that was used to assess work productivity. In the future, a more comprehensive assessment of work productivity may reveal a relationship between work productivity and activity.

6.3 Strengths and limitations

This study was the first to comprehensively examine the overall amount and pattern of exposure of sedentary time, light activity and MVPA of office workers during work hours and during non-work periods. The study used accelerometer and self-report assessment to measure sedentary time, light activity and MVPA rather than self-report alone. This study, for the first time examined the accelerometer derived relationship between sedentary time, light activity and MVPA and self-reported musculoskeletal pain, job satisfaction, self-reported work productivity.

Limitations of the present study include a moderate sample size from only one organisation and the use of an accelerometer that only measures activity intensities rather than a device that also records posture. Further, there may have been a selection bias to more active participants as those participants that volunteered to wear an accelerometer for 7 days may be more likely to be active which could have resulted in an underestimate of overall sedentary time of the cohort. Another limitation was that accelerometer wear time was less on non-work days and that starting times on these days were later, suggesting longer sedentary time on weekends which may have resulted in an underestimation of sedentary time on non-work days.

6.4 Conclusion

This study found that office work contributes significantly to overall sedentary exposure and therefore the associated health risks of sedentary behaviour. Occupational sedentary time of office workers was significantly more prolonged with fewer breaks compared to non-work periods. Office work has traditionally been considered to be a 'low risk' occupation in terms of risks to chronic health outcomes, however, office work may potentially increase the risk of mortality and cardiometabolic disorders as a result of uninterrupted and excessive sedentary time during work hours. Given the evidence for the health impact of sedentary behaviour and light intensity activity, future work-based activity interventions should therefore target reducing total occupational sedentary time and emphasise the importance of interrupting sedentary time and provide opportunity to participate in light intensity activity. Further, while there is no conclusive evidence of a causal relationship between occupational sedentary time or physical activity and musculoskeletal pain, workplace activity interventions should consider the impact of activity modification on musculoskeletal pain.

7.0 Study 2 - Does work need to be sedentary? A comparison of sedentary behaviour and physical activity of teachers and office workers at work and during non-work hours.

7.1 Introduction

In the last 50 years, there has been a move away from industrial and agricultural work to a more technological based society (Brownson et al., 2005) and with this development there has been a concurrent reduction in overall occupational physical activity (Church et al., 2011) and subsequent increase in occupational sedentary behaviour. In Study 1 it was found that office workers were exposed to high levels of occupational sedentary behaviour and the potential risks associated with prolonged and uninterrupted sedentary time. Currently, the structure and work tasks associated with office work offer very few opportunities to participate in light or moderate activity during work hours, making office workers particularly vulnerable to the risks associated with prolonged sedentary exposure.

Other occupations, such as school teachers, complete many of the same work tasks as office workers, for example, computer and administrative tasks. Study 2 aimed to explore whether teachers were less sedentary than office workers when completing their usual work tasks. If teachers were less sedentary during work hours it may be possible for office workers to incorporate similar activity into the work their hours. Further, participants from Study 1 were keen to know how activity levels of office workers compared to other occupational groups.

A number of studies have examined occupational activity in relationship to employment status (employed or unemployed) (Van Domelen et al., 2011) and the relationship between occupation and leisure time physical activity amongst different occupations (Burton & Turrell, 2000; Kirk & Rhodes, 2011; Takao, Kawakami, & Ohtsu, 2003). However, there is limited research that has compared occupational physical activity and sedentary behaviour of different occupational groups, with most of the available literature using self-report measures of physical activity and sitting (Jans et al., 2007; Steele & Mummery, 2003) or pedometers to assess physical activity (Schofield et al., 2005). It appears that only one study has specifically examined the physical activity of school teachers and found that for teachers, based on self-report measures of physical activity, work contributed 41% of daily energy expenditure (Vaz & Bharathi, 2004). At the time that Study 2 was initiated there were no reported studies that measured accelerometer derived occupational physical activity and sedentary behaviour at work and during non-work. Since then Thorp et al (2012) appears to be the only study that has compared occupational physical activity and sedentary time of different occupations using accelerometers however, the occupational groups examined were very similar (office workers, call centre employees and customer service staff) (Thorp et al., 2012).

In order to gauge how sedentary behaviour and physical activity levels of office workers compared to another occupation with similar skills, a small study was conducted comparing sedentary time and activity levels of office workers with school teachers. Teachers were chosen as a comparison as school teachers share many of the same work tasks. It was anticipated that school teachers would have greater activity and a different pattern of accumulation of sedentary time and physical activity than office workers during work hours due to the different work demands of teaching.

As discussed in Chapter 2 of this thesis, the relationship between leisure time physical activity and occupational physical activity is unclear (Kirk & Rhodes, 2011). Recent literature suggests that sedentary workers are not more active in non-work periods than active workers (Schofield et al., 2005; Tigbe et al., 2011). These findings were confirmed in Study 1, where it was found that office workers did not participate in high levels of MVPA during non-work periods. It may be that teachers participate in similar amounts of leisure time physical activity as office workers or it is possible that teachers are more physically active than office workers in non-work periods.

Therefore, the aim of Study 2 was to compare the overall amount and pattern of exposure to sedentary time and physical activity between office workers and teachers at work and outside of work hours. A secondary aim was to compare the distribution of self-reported musculoskeletal symptoms between teachers and office workers.

Selected results from Study 2 were presented in:

"Comparison of the pattern of sedentary exposure of school teachers and office workers" [Poster] at the International Congress on Physical Activity and Public Health in Rio De Janeiro, Brazil March 2014

7.2 Method

7.2.1 Participants and recruitment

Teachers from a co-educational primary and high school were recruited to take part in this study. Teachers attended a recruitment meeting as part of a regular staff development day. At the meeting, the teachers were shown a short presentation outlining the aims and procedure of the study and were then invited to participate in the study. Volunteers were given a 'Participant Information and Consent' form (Appendix K) and were then asked to complete the surveys as described in Study 1. In addition, volunteers were asked to wear an "Actical" accelerometer during waking hours for 7 consecutive days (see 7.2.2 Procedure section below).

7.2.2 Procedure and statistical analysis

Design, ethics and procedure were the same as described in Study 1. Only accelerometer and musculoskeletal data for office workers and teachers are presented in this chapter. Comparison between self-reported sitting and accelerometer derived sedentary time is presented in Appendix L. Paired t-tests were used to compare time in activity levels between work and non-work days and between work hours on work days and non-work periods. In addition, independent t-tests or chi-squared tests assessed participant characteristics (age, BMI and gender) between teachers and office workers. Activity analyses were calculated using percentage of wear time for each time period. Kruskal-Wallis Test was used to assess differences in musculoskeletal pain between office workers and teachers. All analyses were performed using PASW Statistics 18, critical alpha level of 0.05.

7.3 Results

7.3.1 Participants characteristics

Approximately 50 teachers attended the recruitment meeting and 34 teachers volunteered to participate in the study. 20 teachers volunteered to wear an accelerometer for 7 days. 17 participants (24% males) with a mean age of 44.5 ± 9.9 (mean ± SD) and BMI of 26.0 ± 4.9 kg/m^2 had sufficient accelerometer data (wear time of at least 500 minutes/day on 4 work days with at least one non-work day) to be included in the analysis. The data from the 50 office workers that participated in accelerometry measures in Study 1 were used in the present study.

There were no significant differences in BMI (t = -0.10, p = 0.325) between the 2 groups (teachers and office workers), however, the teachers were significantly older than the office workers (F = 1.19, $df_{1,66}$, p = 0.002) and there were significantly more male office workers than male teachers (χ^2 = 6.83, p = 0.033) (Table 7.1).

Table 7.1: Comparison of participant characteristics between office workers and teachers

Variable	Teachers [n=17]	Office workers [n = 50]	P for group comparison
Age (mean years; [SD])	44.5 [9.9]	36.5 [8.6]	0.002
BMI (mean kg/m^2; [SD])	26.0 [4.90]	24.8 [4.10]	0.325
Gender (n; (%) male)	4 (24)	29 (58)	0.033

7.3.2 Sedentary time, light activity, MVPA, sustained sedentary time and break rate for teachers

Table 7.2 summerises overall sedentary time, light activity, MVPA, sustained sedentary time and break rate for teachers on work days, non-work days, during work hours on work days, during non-work hours on work days and during total non-work time. For teachers, there was no significant difference in sedentary time, light activity, MVPA, sustained sedentary time and break rate between work and non-work days.

Teachers were significantly less sedentary and participated in significantly more light activity during work hours compared to non-work hours (Table 7.2). The sedentary exposure and pattern of sedentary behaviour for teachers is described in detail Section 7.3.5.

Table 7.2: Sedentary, light, MVPA, sustained sedentary time (bouts>30 mins) and break rate for teachers on work days, non-work days, work hours on work days, non-work hours on work days and total non-work time. All activity time expressed as %wear time ± SD; Break rate = breaks/sedentary hour

	Type of day		Wear time on work day		Total non-work time
	Work day	Non-work day	Work hours on work days	Non-work hours on work days	
Teachers					
Sedentary time	67.03 ± 5.13	69.96 ± 9.34	62.30 ± 6.49∞	72.53 ± 7.34	69.50 ± 7.47 ß
Light activity	29.35 ± 4.73	27.28 ± 7.29	33.76 ± 6.07∞	24.24 ± 6.36	26.35 ± 5.94 ß
MVPA	3.61 ± 1.75	4.65 ± 3.73	3.94 ± 2.41	3.23 ± 2.39	4.15 ± 2.81
Sustained sed time >30 mins	17.00 ± 6.65	21.43 ± 12.24	8.83 ± 5.45^	26.90 ± 11.78	23.09 ± 10.88
Breaks in sedentary time	9.80 ± 1.43	9.01 ± 3.10	12.05 ± 2.27^	7.75 ± 1.90	8.50 ± 2.39

∞Significant difference between work hours on work days and non-work hours on work days ($p<0.001$)

ß Significant difference between work hours on work days and total non-work time ($p<0.05$)

^ Significant difference between work hours on work days and non-work hours on work days and between work hours on work days and total non-work time ($p<0.001$)

7.3.3 Comparison of sedentary time, light activity, MVPA, sustained sedentary time and break rate between teachers and office workers

Tables 7.3 (i) and (ii) present the comparisons between teachers and office workers for sedentary time, light activity, MVPA, sustained sedentary time and break rate on work days, non-work days, work hours on work days, non-work hours on work days and total non-work time.

Teachers were significantly less sedentary than office workers on work days (mean difference 8.87(% wear time) 95% CI: 5.58, 12.16, $p < 0.001$) and during work hours on work days (mean difference19.50 (% wear time), 95% CI: 16.21, 22.79, $p < 0.001$). The 19.50% difference in sedentary time during work hours is equal to 104 less sedentary minutes per day for teachers during work hours compared to office workers. However, teachers were significantly more sedentary than office workers during non-work hours on work days (mean difference -5.48 (% wear time) 95% CI: -10.23, -0.74, $p = 0.024$). There was no significant difference in sedentary time on non-work days ($p = 0.500$) and during total non-work time ($p = 0.817$) between teachers and office workers (Table 7.3 (i)).

The decreased sedentary time of teachers compared to office workers on work days and during work hours is reflected by the concurrent increase in light activity of teachers compared to office workers. Teachers participated in significantly more light intensity activity compared to office workers on work days (mean difference -9.67 (% wear time), 95% CI: -12.51, -6.82), $p < 0.001$) and during work hours (mean difference -18.49 (% wear time), 95% CI: -21.34, -15.64, $p < 0.001$). The 18.49% difference in light activity during work hours is equal to 99 more light activity minutes per day for teachers during work hours compared to office workers. There was no significant difference in light activity on non-work days ($p = 0.940$), during non-work hours on work days ($p = 0.382$) and for total non-work time ($p = 0.800$) between teachers and office workers (Table 7.3 (i)).

There was no significant difference in MVPA on work days ($p = 0.147$), non-work days ($p = 0.071$), during work hours on work days ($p = 0.064$) and for total non-work time ($p = 0.989$) between teachers and office workers. However, teachers participated in significantly less MVPA during non-work hours on work days compared to office workers (mean difference 3.54 (% wear time), 95% CI: 1.60, 5.48, $p = 0.001$) (Table 7.3 (i)).

Teachers had significantly less sustained sedentary time (bouts > 30 mins) compared to office workers on work days (mean difference 17.05 (% wear time), 95% CI: 11.10, 23.00, $p = 0.001$) and during work hours on work days (32.53% wear time, $t = 8.04$, df_{65}, $p < 0.001$). There was no significant difference in sustained sedentary time on non-work days ($p = 0.093$), during non-work hours on work days ($p = 0.229$) and for total non-work time ($p = 0.334$) between teachers and office workers (Table 7.3(ii)).

The difference in sustained sedentary time between teachers and office workers is also reflected in the changes in break rate. Teachers had a significantly higher break rate compared to office workers on work days (mean difference -3.81 breaks/sed hour, 95% CI: -4.63, -3.00), $p < 0.001$) and during work hours (mean difference -7.00 breaks/sed hour, 95% CI: -8.04, -5.97, $p < 0.001$). There was no significant difference in break rate on non-work days ($p = 0.103$), during non-work hours on work days ($p = 0.938$) and for total non-work time ($p = 0.242$) between teachers and office workers (Table 7.3 (ii)).

In summary, teachers were significantly less sedentary and participated in more light activity than office workers on work days and specifically during work hours. Similarly, teachers had significantly less sustained sedentary time and more breaks in sedentary time than office workers on work days and during work hours. Teachers participated in less MVPA during non-work hours on work days than office workers. Importantly, there was no difference in sedentary time, light activity, MVPA, sustained sedentary time and break rate between teachers and office workers on non-work days or for total non-work time.

Table 7.3(i): Sedentary time, light activity and MVPA for teachers and office workers on work days, non-work days, work hours on work days, non-work hours on work days and total non-work time

Outcome measures	Teachers	Office workers	Mean Difference	95% CI	P
Sedentary time (% wear time ± SD)					
Work days	67.03 ± 5.13	75.91 ± 6.08	8.87	5.58, 12.16	<0.001
Non-work days	69.96 ± 9.34	69.74 ± 9.32	1.78	-3.45, 7.01	0.500
Work hours on work days	62.30 ± 6.49	81.80 ± 5.65	19.50	16.21, 22.79	<0.001
Non-work hours on work days	72.53 ± 7.34	67.05 ± 8.80	-5.48	-10.23, -0.74	0.024
Total non-work	69.50 ± 7.47	68.95 ± 8.73	-0.55	-2.58, 4.18	0.817
Light time (% wear time ± SD)					
Work days	29.35 ± 4.73	19.68 ± 5.13	-9.67	-12.51, -6.82	<0.001
Non-work days	27.28 ± 7.29	27.21 ± 8.69	-0.18	-4.87, 4.52	0.940
Work hours on work days	33.76 ± 6.07	15.27 ± 4.72	-18.49	-21.34, -15.64	<0.001
Non-work hours on work days	24.24 ± 6.36	26.18 ± 8.30	1.94	-2.47, 6.35	0.382
Total non-work	26.35 ± 5.94	26.89 ± 8.00	0.54	-3.69, 4.77	0.800
MVPA (% wear time ± SD)					
Work days	3.61 ± 1.75	4.41 ± 1.99	0.80	-0.29, 1.88	0.147
Non-work days	4.65 ± 3.73	3.05 ± 2.87	-1.60	-3.34, 0.14	0.071
Work hours on work days	3.94 ± 2.41	2.93 ± 1.72	-1.01	-2.09, 0.06	0.064
Non-work hours on work days	3.23 ± 2.39	6.77 ± 3.74	3.54	1.60, 5.48	0.001
Total non-work	4.15 ± 2.81	4.16 ± 2.66	0.01	-1.50, 1.52	0.989

Table 7.3(ii): Sustained sedentary time (bouts>30 mins) and break rate (breaks/sedentary hour), for teachers and office workers on work days, non-work days, work hours on work days, non-work hours on work days and total non-work time

Outcome measures	Teachers	Office workers	Mean Difference	95% CI	P
Sustained Sedentary time (% wear time ± SD)					
Work days	17.00 ± 6.65	34.05 ± 11.61	17.05	11.10, 23.00	<0.001
Non-work days	21.43 ± 12.24	26.91 ± 11.18	5.47	-0.94, 11.89	0.093
Work hours on work days	8.83 ± 5.45	41.36 ± 16.30	32.53	24.45, 40.61	<0.001
Non-work hours on work days	26.90 ± 11.78	23.19 ± 10.58	-3.71	-9.82, 2.40	0.229
Total non-work	23.09± 10.88	25.81 ± 9.65	2.72	-2.86, 8.31	0.334
Break rate (breaks/sed hour)					
Work days	9.80 ± 1.43	5.97 ± 1.45	-3.81	-4.63, -3.00	<0.001
Non-work days	9.01 ± 3.10	7.83 ± 2.33	-1.18	-2.60, 0.25	0.103
Work hours on work days	12.05 ± 2.27	5.05 ± 1.68	-7.00	-8.04, -5.97	<0.001
Non-work hours on work days	7.75 ± 1.90	7.79 ± 1.99	0.04	-1.06, 1.15	0.938
Total non-work	8.50 ± 2.39	7.78 ± 2.03	-0.70	-1.89, 0.49	0.242

7.3.4 Comparison of overall contribution of occupational sedentary time to total sedentary time between teachers and office workers

The contribution of work time sedentary time to total weekly sedentary time is reported in Table 7.4. For teachers, work time contributed 24.03 hours of sedentary time each week (35.94% of total weekly sedentary time) with all non-work time contributing 43.29 hours (64.06%). Whereas for office workers, work time contributed 36.53 hours of sedentary time each week (48.62% of total weekly sedentary time) with all non-work time contributing 38.82 hours (51.38%). For teachers, work sedentary time contributed a significantly lower proportion of overall weekly sedentary time compared to office workers (mean difference 12.68% weekly sed time, 95% CI: 9.74, 15.62, $p < 0.001$) (Table 7.4).

Table 7.4: Contribution of work to weekly sedentary time for teachers and office workers

Outcome measures	Teachers	Office workers	Mean Difference	95% CI	P
Total weekly sedentary hours (mean hours/week [SD])	67.32 [6.92]	75.35 [6.87]	8.03	4.19, 11.89	<0.001
Weekly work sedentary hours (hours/week [SD])	24.03 [3.24]	36.53 [4.29]	12.49	10.22, 14.77	<0.001
Weekly non-work sedentary hours (hours/week [SD)	43.29 [6.73]	38.82 [5.90]	-4.67	-7.89, -1.04	0.011
Weekly work sedentary hours as % of weekly sedentary time (mean % [SD])	35.94 [5.38]	48.62 [5.20]	12.68	9.74, 15.62	<0.001

7.3.5 Comparison of the pattern of sedentary time, light activity and MVPA between teachers and office workers

As the differences in activity levels between teachers and office workers occurred predominately on work days and during work hours, the pattern of activity within these time periods is described in Tables 7.5 and 7.6 below. The results of the Exposure Variance Analysis which illustrates the comparison of the intensity (sedentary, light and MVPA) of activity and the duration of activity in bouts of 0-<5mins, 5-<10, 10-<30 mins and 30+ mins are shown in Figure 7.1.

7.3.5.1 Sedentary bouts

Teachers spent proportionally more time in short bouts of sedentary time (0-<5 mins) compared to office workers on work days and during work hours (work days: mean difference -5.70 (% wear time) 95% CI: -6.79, -4.61, $p < 0.001$; work hours: mean difference -9.58 (% wear time) 95% CI: -11.01, -8.15, $p < 0.001$). A similar pattern was seen for sedentary bouts of 5-<10 mins (work days: mean difference -4.35 (% wear time), 95% CI: -5.66, -3.05, $p < 0.001$; work hours: mean difference -5.96 (% wear time), 95% CI: -7.78, -4.14), $p < 0.001$). There was no significant difference in sedentary bouts of 10-<30 mins on work days ($p = 0.151$) or during work hours ($p = 0.213$) between teachers and office workers. The most striking difference in sedentary bouts between teachers and office workers occurred in sustained sedentary bouts greater than 30 minutes. Teachers spent proportionally less time in bouts of 30 or more minutes compared to office workers on work days and during work hours (work days: mean difference 17.05 (% wear time), 95% CI: 11.10, 23.00, $p < 0.001$; work hours: mean difference 32.52 (% wear time), 95% CI: 24.49, 40.61, $p < 0.001$). A similar pattern was seen for prolonged sustained sedentary bouts on work days and during work hours (work days: mean difference 8.39 (% wear time), 95% CI: 3.77, 13.01, $p = 0.001$; work hours: mean difference 13.57 (% wear time), 95% CI 6.97, 20.18, $p < 0.001$) (Tables 7.5 and 7.6, Figure 7.1).

Table 7.5: Pattern of sedentary time, light activity and MVPA in bouts of 0-<5 mins, 5-<10 mins, 10-<30 mins and 30 mins+ on work days for teachers and office workers

Outcome measures	Teachers (%wear time [SD])	Office workers (%wear time [SD])	Mean Difference	95% CI	P
Work days bouts (mins)					
Sed time (0-<5)	12.97 [1.55]	7.27 [2.05]	-5.70	-6.79, -4.61	<0.001
Sed time (5-<10)	12.61 [1.92]	8.26 [2.45]	-4.35	-5.66, -3.05	<0.001
Sed time (10-<30)	24.45 [3.18]	26.33 [4.99]	1.88	-0.70, 4.46	0.151
Sed time 30+	17.00 [6.65]	34.05 [11.61]	17.05	11.10, 23.00	<0.001
Sed time 60+	4.92 [3.64]	13.31 [9.25]	8.39	3.77, 13.01	0.001
Light time (0-<5)	19.15 [1.60]	13.39 [2.21]	-5.76	-6.92, -4.60	<0.001
Light time (5-<10)	7.19 [1.84]	4.12 [2.06]	-3.07	-4.20, -1.95	<0.001
Light time (10-<30)	2.79 [2.21]	2.01 [1.84]	-0.78	-1.87, 0.31	0.157
Light time 30+	0.21 [0.40]	0.16 [0.47]	-0.06	-0.31, 0.20	0.658
MVPA time (0-<5)	2.58 [1.06]	2.04 [0.82]	-0.54	-1.04, -0.05	0.033
MVPA (5-<10)	0.25 [0.32]	1.15 [0.56]	0.90	0.61, 1.18	<0.001
MVPA (10-<30)	0.42 [0.50]	0.92 [1.20]	0.50	-0.10, 1.10	0.100
MVPA 30+	0.36 [0.62]	0.30 [0.80]	-0.06	-0.49, 0.37	0.779

Table 7.6: Pattern of sedentary time, light activity and MVPA in bouts of 0-<5 mins, 5-<10 mins, 10-<30 mins and 30 mins+ during work hours for teachers and office workers

Outcome measures	Teachers (%wear time [SD])	Office workers (%wear time [SD])	Mean Difference	95% CI	P
Work hours on work day					
Sed time (0-<5)	15.75 [2.52]	6.17 [2.57]	-9.58	-11.01, -8.15	<0.001
Sed time (5-<10)	13.97 [1.87]	8.01 [3.57]	-5.96	-7.78, -4.14	<0.001
Sed time (10-<30)	23.75 [6.62]	26.27 [7.27]	2.51	-1.48, 6.50	0.213
Sed time 30+	8.83 [5.45]	41.36 [16.30]	32.53	24.49, 40.61	<0.001
Sed time 60+	2.45 [3.25]	16.03 [13.44]	13.57	6.97, 20.18	<0.001
Light time (0-<5)	22.29 [2.50]	7.30 [1.87]	-14.99	-16.14, -13.84	<0.001
Light time (5-<10)	8.19 [2.21]	1.51 [0.95]	-6.68	-7.45, -5.91	<0.001
Light time (10-<30)	3.19 [2.82]	0.29 [0.43]	-2.90	-3.71, -2.09	<0.001
Light time 30+	0.09 [0.37]	0.04 [0.30]	-0.05	-0.23, 0.13	0.605
MVPA time (0-<5)	3.64 [1.99]	0.99 [0.56]	-2.64	-3.26, -2.03	<0.001
MVPA (5-<10)	0.21 [0.38]	0.43 [0.40]	0.21	-0.01, 0.43	0.059
MVPA (10-<30)	0.09 [0.28]	0.26 [0.45]	0.17	-0.06, 0.40	0.153
MVPA 30+	0	0.06 [0.30]	0.06	-0.09, 0.20	0.453

7.3.5.2 Light activity bouts

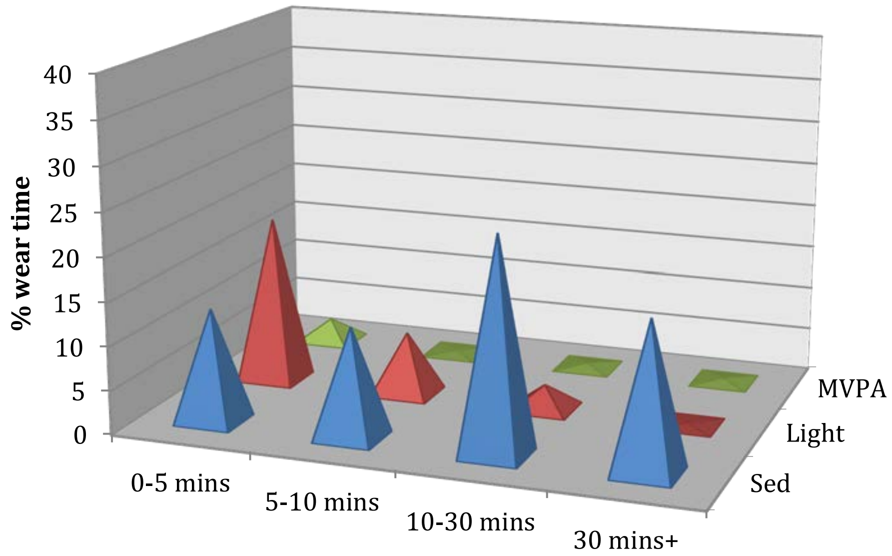
Teachers spent proportionally more time in short bouts of light activity (0-<5 mins) compared to office workers on work days and during work hours (work days: mean difference -5.76 (% wear time), 95% CI: -6.92, -4.60, $p < 0.001$; work hours: mean difference -14.99 (% wear time), 95% CI: -16.14, -13.84, $p < 0.001$). A similar pattern was seen for light activity bouts of 5-<10 mins (work days: mean difference -3.07 (% wear time), 95% CI:-4.20, -1.95, $p < 0.001$; work hours: mean difference -6.68 (% wear time), 95% CI: -7.45, -5.91, $p < 0.001$). Teachers spent proportionally more time in light activity bouts of 10-<30 mins compared to office workers during work hours (mean difference -2.90 (% wear time), 95% CI: -3.71, -2.09, $p < 0.001$) but there was no significant difference on work days ($p = 0.157$). There was no significant difference in light activity of 30 or more minutes on work days ($p = 0.658$) or during work hours ($p = 0.605$) between teachers and office workers (Tables 7.5 and 7.6, Figure 7.1).

7.3.5.3 MVPA bouts

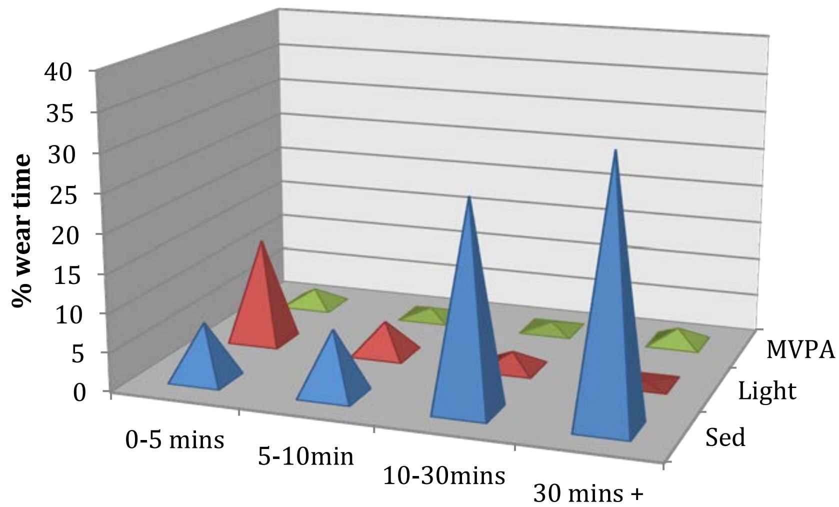
Teachers spent proportionally more time in short bouts of MVPA (0-<5 mins) compared to office workers on work days and during work hours (work days: mean difference -0.54 (% wear time), 95% CI: -1.04, -0.05, $p = 0.033$; work hours: mean difference -2.64 (% wear time) 95% CI -3.26, -2.03, $p < 0.001$). Teachers spent proportionally more time in bouts of MVPA (5-<10 mins) compared to office workers on work days (mean difference 0.90 (% wear time) 95%CI: 0.61, 1.18, $p = 0<0.001$) but not during work hours ($p = 0.059$). There was no significant difference in MVPA bouts of 10-<30 mins on work days ($p = 0.100$) or during work hours ($p = 0.153$) or for MVPA bouts greater than 30 minutes on work days ($p = 0.779$) or during work hours ($p = 0.453$) between office workers and teachers (Tables 7.5 and 7.6, Figure 7.1).

In summary, teachers spent a significantly greater proportion of the work day and work hours in short bouts (0-<5 and 5-<10 mins) of sedentary time and light activity and a significantly smaller proportion of the work day and work hours in sustained sedentary time compared to office workers. Teachers also spent a significantly greater proportion of the work day and work hours in short bouts (0-<5 mins) of MVPA compared to office workers.

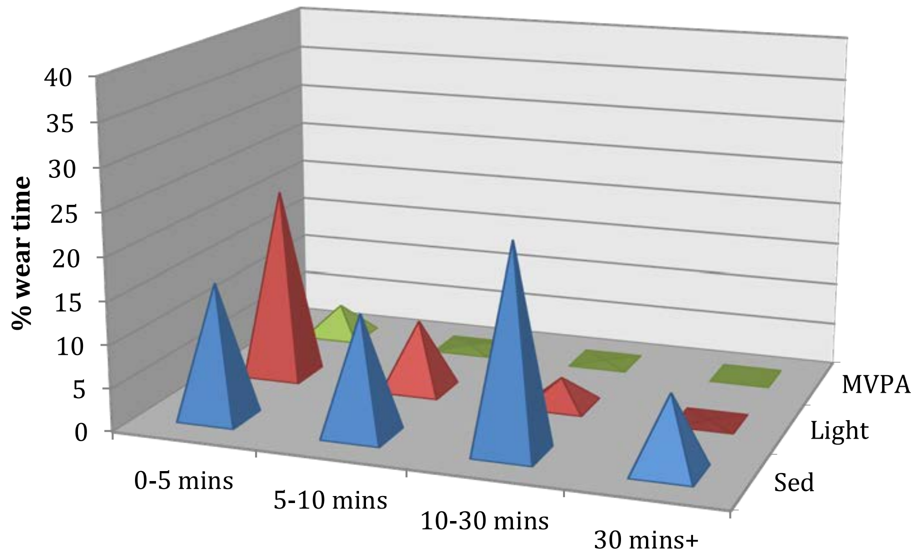
Figure 7.1: Exposure Variance Analysis showing proportion of wear time in sedentary, light and MVPA in bouts of 0-<5, 5-<10, 10-<30 and 30+ minutes for teachers on a work day (a), office workers on a work day (b), teachers during work hours (c) and office workers during work hours (d)



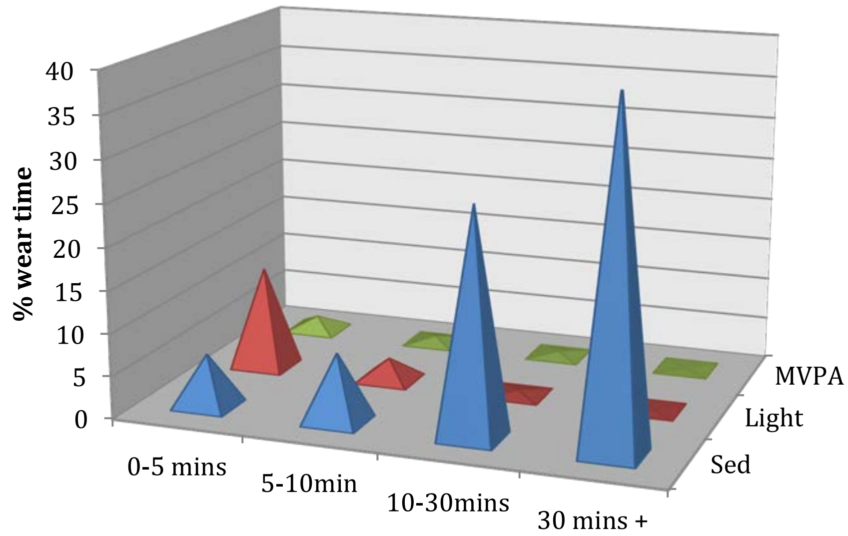
(a) Work day - teachers



(b) Work day - office workers



(c) Work hours on work days - Teachers



(d) Work hours on work days - Office workers

7.3.6 Comparison of sedentary time, light activity and MVPA during work and non-work periods between teachers and office workers

7.3.6.1 Sedentary time

Sedentary time, light activity, MVPA, sustained sedentary time (bouts>30 mins) and break rate (breaks/sedentary hour) for teachers and office workers is presented in Table 7.7. Figures 7.2-7.6 illustrate the comparisons between work days and non-work days, work hours on work days and non-work hours on work days and work hours on work days and total non-work hours for sedentary time, light activity, MVPA, sustained sedentary time and break rate for teachers and office workers.

For teachers, sedentary time was not significantly different on work days compared to non-work days ($t = -0.41$, $df_{16,}$ $p = 0.688$), however, for office workers sedentary time was proportionally greater on work days compared to non-work days ($t = 6.2$, df_{49}, $p < 0.001$) (Table 7.7, Figure 7.2 (i)). Sedentary time was proportionally less during work hours on work days compared to non-work hours on work days for teachers ($t = -4.61$, df_{16}, $p < 0.001$) (Table 7.7, Figure 7.2(ii)). However, sedentary time was proportionally greater during work hours on work days compared to non-work hours on work days for office workers ($t = 12.7$, df_{49}, $p < 0.001$). Similarly, sedentary time was proportionally less during work hours on work days compared to total non-work time for teachers ($t = -3.10$, df_{16}, $p = 0.007$). However, sedentary time was proportionally greater during work hours on work days compared to total non-work time for office workers ($t = 10.8$, df_{49}, $p < 0.001$). (Table 7.7, Figure 7.2(iii))

Table 7.7: Sedentary, light, MVPA, sustained sedentary time (bouts>30 mins) and break rate for teachers and office workers. All activity time expressed as %wear time ± SD; Break rate = breaks/sedentary hour

	Type of day		Wear time on work day		Total non-work time
	Work day	**Non-work day**	**Work hours on work days**	**Non-work hours on work days**	
Teachers					
Sedentary time	67.03 ± 5.13	69.96 ± 9.34	62.30 ± 6.49∞	72.53 ± 7.34	69.50 ± 7.47ß
Light activity	29.35 ± 4.73	27.28 ± 7.29	33.76 ± 6.07∞	24.24 ± 6.36	26.35 ± 5.94ß
MVPA	3.61 ± 1.75	4.65 ± 3.73	3.94 ± 2.41	3.23 ± 2.39	4.15 ± 2.81
Sustained sed time >30 mins	17.00 ± 6.65	21.43 ± 12.24	8.83 ± 5.45^	26.90 ± 11.78	23.09 ± 10.88
Breaks in sedentary time	9.80 ± 1.43	9.01 ± 3.10	12.05 ± 2.27^	7.75 ± 1.90	8.50 ± 2.39
Office workers					
Sedentary time	75.91 ± 6.08#	69.74 ± 9.32	81.80 ± 5.65^	67.05 ± 8.80	68.95 ± 8.73
Light activity	19.68 ± 5.18#	27.2 1± 8.70	15.27 ± 4.72^	26.18 ± 8.30	26.89 ± 8.00
MVPA	4.41 ± 1.99§	3.05 ± 2.87	2.93 ± 1.72‡	6.77 ± 3.74	4.16 ± 2.66
Sustained sed time >30 mins	34.1 ± 11.6#	26.9 ± 11.1	41.4 ± 16.3^	25.8 ± 9.6	25.8 ± 9.6
Breaks in sedentary time	5.97 ± 1.45#	7.83 ± 2.33	5.05 ± 1.68^	7.80 ± 2.02	7.80 ± 2.02

§ Significant difference between work and non-work days ($p<0.05$)

\# Significant difference between work and non-work days ($p<0.001$)

∞ Significant difference between work hours on work days and non-work hours on work days ($p<0.001$)

ß Significant difference between work hours on work days and total non-work time ($p<0.05$)

^ Significant difference between work hours on work days and non-work hours on work days and between work hours on work days and total non-work time ($p<0.001$)

‡ Significant difference between work hours on work days and non-work hours on work days and between work hours on work days and total non-work time ($p<0.05$)

7.3.6.2 Light activity

For teachers, there was no significant difference in light activity on work days compared to non-work days ($t = 0.97$, df_{16}, $p = 0.347$) whereas for office workers, light activity was proportionally less on work days compared to non-work days ($t = -7.88$, df_{49}, $p < 0.001$) (Table 7.7, Figure 7.3 (i)). For teachers, light activity was proportionally greater during work hours on work days compared to non-work hours on work days ($t = 5.09$, df_{16}, $p < 0.001$), whereas for office workers, light activity was proportionally less during work hours on work days compared to non-work hours on work days ($t = -9.59$, df_{49}, $p < 0.001$) (Table 7.7, Figure 7.3(ii)). Similarly, light activity was proportionally greater during work hours on work days compared to total non-work time for teachers ($t = 3.41$, df_{16}, $p = 0.004$) but proportionally less during work hours on a work day compared to total non-work time for office workers ($t = -10.46$, df_{49}, $p < 0.001$) (Table 7.7, Figure 7.3 (iii)).

7.3.6.3 MVPA

For teachers, there was no significant difference in MVPA on work days compared to non-work days ($t = -1.19$, df_{16}, $p = 0.109$) whereas for office workers, MVPA was proportionally greater on work days compared to non-work days ($t = 3.33$, df_{49}, $p = 0.002$) (Table 7.7, Figures 7.4 (i)). Similarly, for teachers there was no significant difference in MVPA during work hours on work days compared to non-work hours on work days ($t = 0.93$, df_{16}, $p = 0.366$) or during work hours on work days compared to total non-work time ($t = -0.25$, df_{16}, $p = 0.803$) whereas for office workers, MVPA was proportionally less during work hours on work days compared to non-work hours on work days ($t = -6.94$, df_{49}, $p < 0.001$) and during work hours on work days compared to total non-work time ($t = -2.99$, df_{49}, $p = 0.004$) (Table 7.7, Figure 7.4 (ii) and (iii)).

7.3.6.4 Sustained sedentary time (bouts > 30 mins)

For teachers, there was no significant difference in sustained sedentary time on work days compared to non-work days ($t = -1.56$, $df_{16,}$ $p = 0.139$) whereas for office workers, sustained sedentary time was proportionally greater on work days compared to non-work days ($t = 3.60$, df_{49}, $p = 0.001$) (Table 7.7, Figure 7.5 (i)). Sustained sedentary time was proportionally less during work hours on work days compared to non-work hours on work days for teachers ($t = -5.37$, df_{16}, $p < 0.001$), however, sustained sedentary time was proportionally greater during work hours on work days compared to non-work hours on work days for office workers ($t = 7.56$, df_{49}, $p < 0.001$). (Table 7.7, Figure 7.5 (ii)). Similarly, sustained sedentary time was proportionally less during work hours on work days compared to total non-work time for teachers ($t = -4.57$, df_{16}, $p < 0.001$) whereas sustained sedentary time was proportionally greater during work hours on work days compared to total non-work time for office workers ($t = 6.24$, df_{49}, $p < 0.001$) (Table 7.7, Figure 7.5(iii)).

7.3.6.5 Break rate

For teachers, there was no significant difference in break rate was on work days compared to non-work days ($t = 1.00$, $df_{16,}$ $p = 0.139$), whereas for office workers, break rate was proportionally less on work days compared to non-work days ($t = -6.02$, df_{49}, $p < 0.001$) (Table 7.7, Figure 7.6(i)). Break rate was proportionally greater during work hours on work days compared to non-work hours on work days for teachers ($t = 5.86$, df_{16}, $p < 0.001$), however, break rate was proportionally less during work hours on work days compared to non-work hours on work days for office workers ($t = -8.92$, df_{49}, $p < 0.001$) (Table 7.7, Figure 7.6(ii)). Similarly, break rate was proportionally greater during work hours on work days compared to total non-work time for teachers ($t = 3.89$, df_{16}, $p = 0.001$), whereas break rate was proportionally less during work hours on work days compared to total non-work time for office workers ($t = -8.30$, df_{49}, $p < 0.001$) (Table 7.7, Figures 7.6(iii)).

In summary, there was no significant difference in total sedentary time, light activity, MVPA, sustained sedentary time and break rate for teachers on work days compared to non-work days. For teachers, sedentary time and sustained sedentary time were significantly less during work hours on work days compared to non-work hours on work days and during work hours on work days compared to total non-work time. For teachers light activity and break rate were significantly greater during work hours on work days compared to non-work hours on work days and during work hours on work days compared to total non-work time.

Figure 7.2: Comparison [mean ± SD] of sedentary time on (i) Work days and non-work days, (ii) Work hours on work days and non-work hours on work days and (iii) Work hours on work days and total non-work time for teachers and office workers

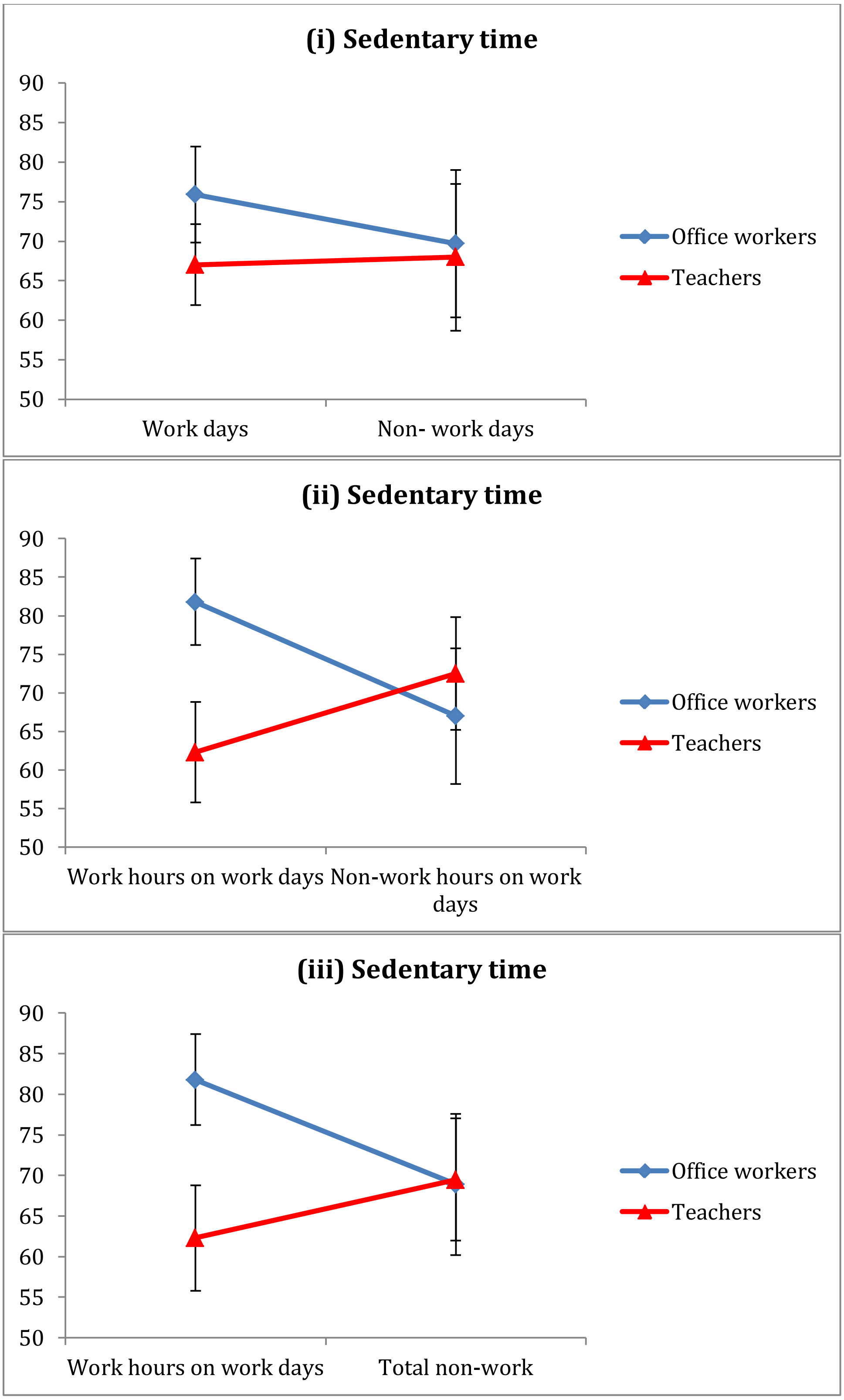


Figure 7.3: Comparison [mean ± SD] of light activity on (i) Work days and non-work days, (ii) Work hours on work days and non-work hours on work days and (iii) Work hours on work days and total non-work time for teachers and office workers

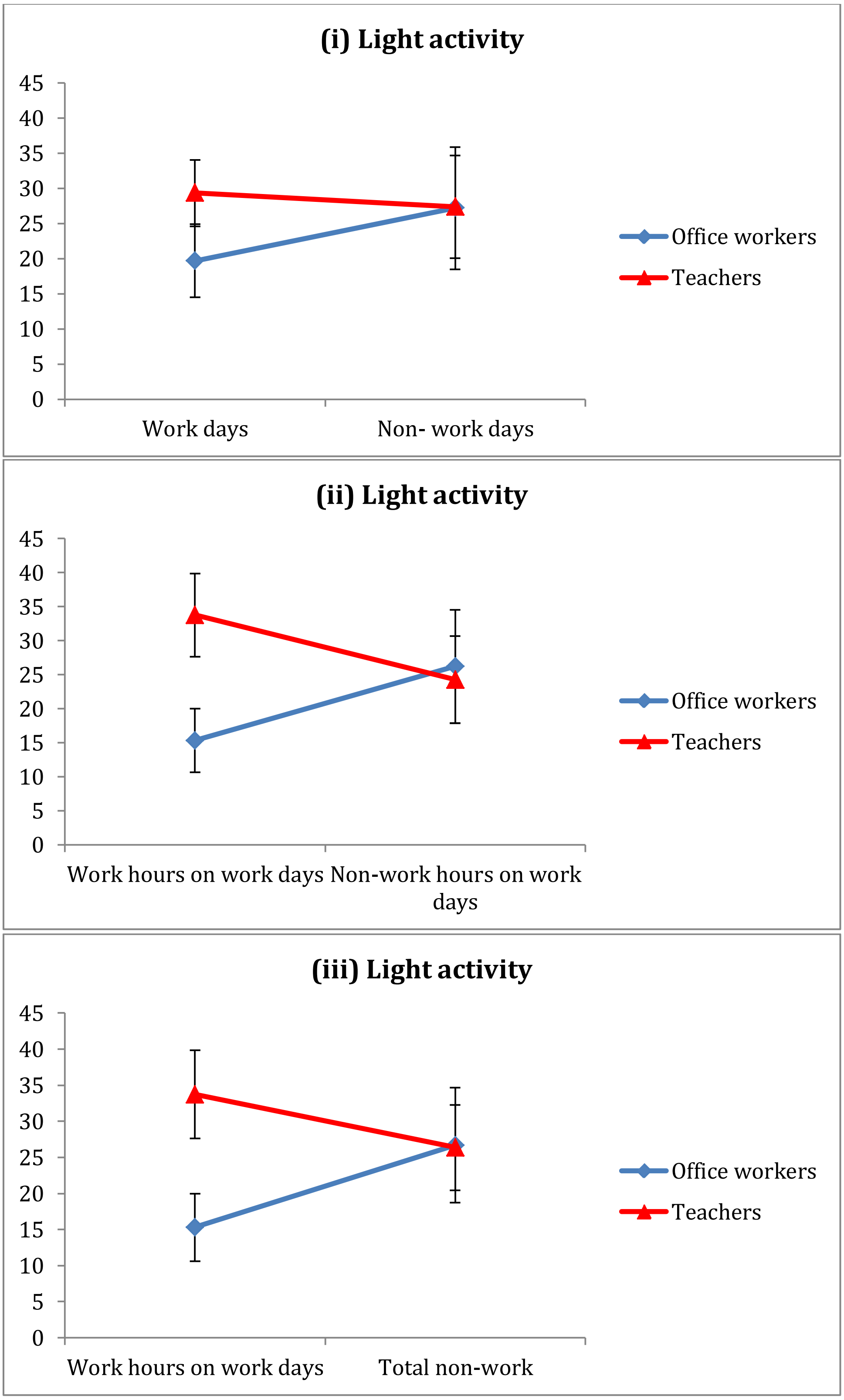


Figure 7.4: Comparison of MVPA [mean ± SD] on (i) Work days and non-work days, (ii) Work hours on work days and non-work hours on work days and (iii) Work hours on work days and total non-work time for teachers and office workers

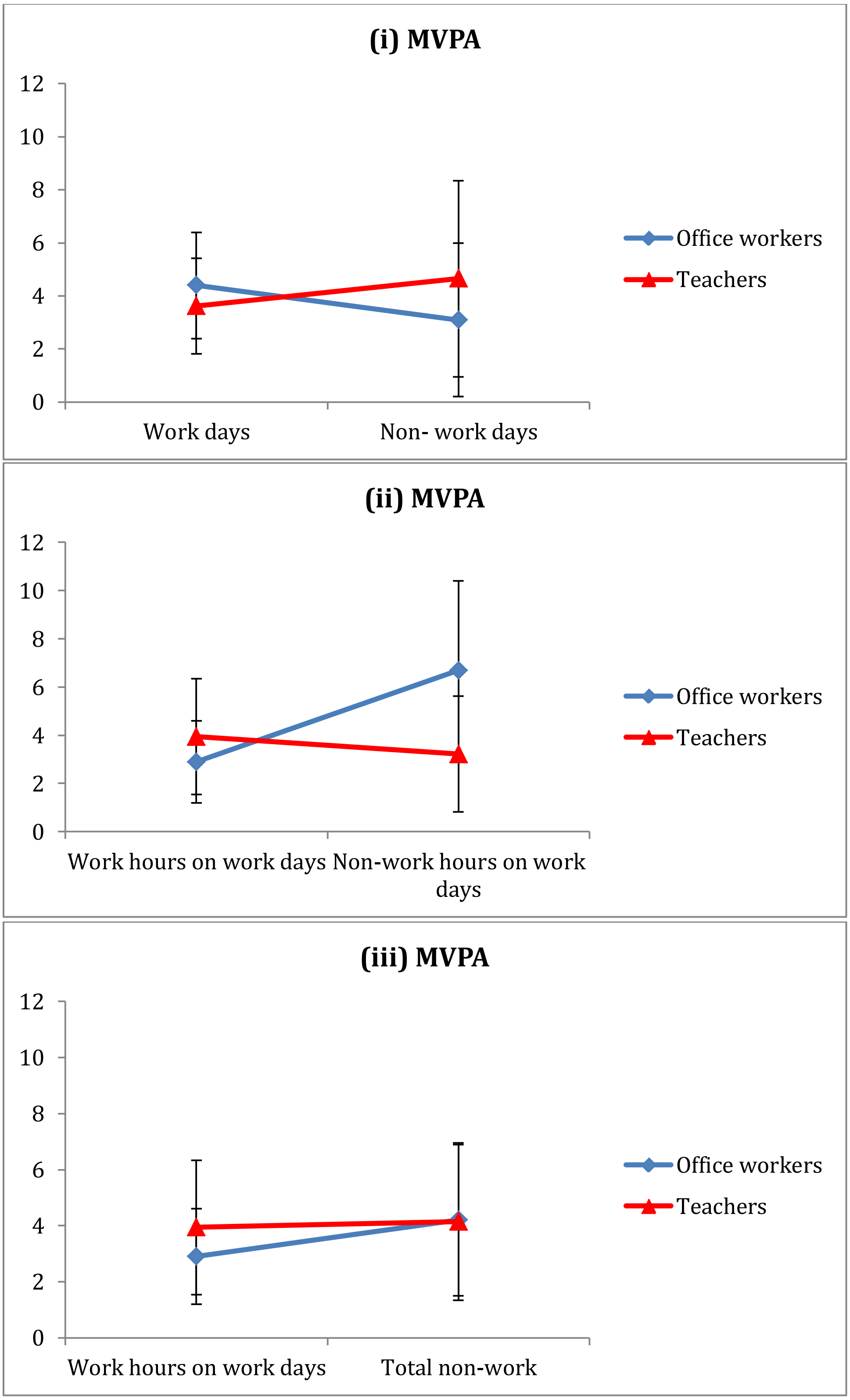


Figure 7.5: Comparison of sustained sedentary (bouts>30 mins) [mean ± SD] on (i) Work days and non-work days, (ii) Work hours on work days and non-work hours on work days and (iii) Work hours on work days and total non-work time for teachers and office workers

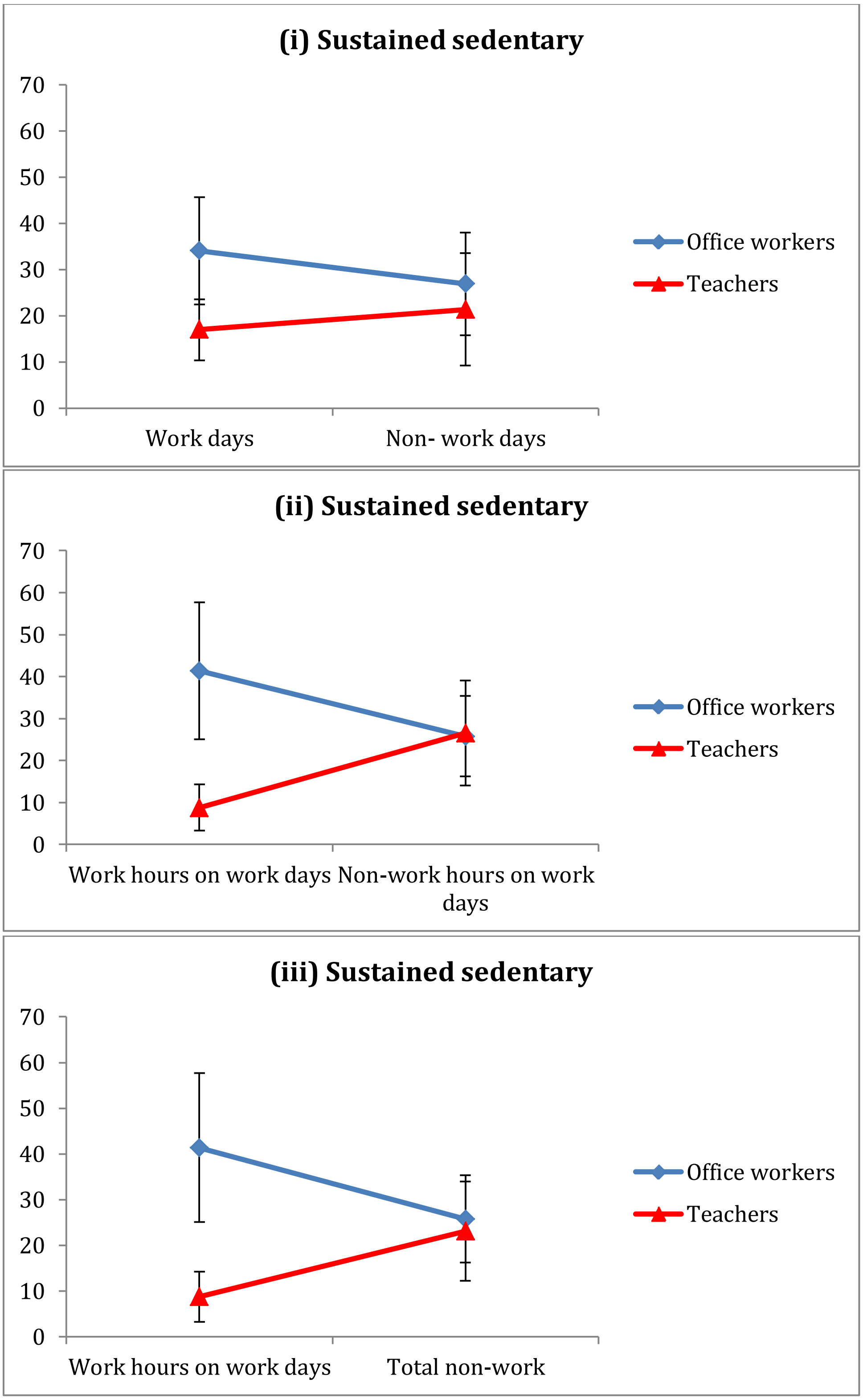
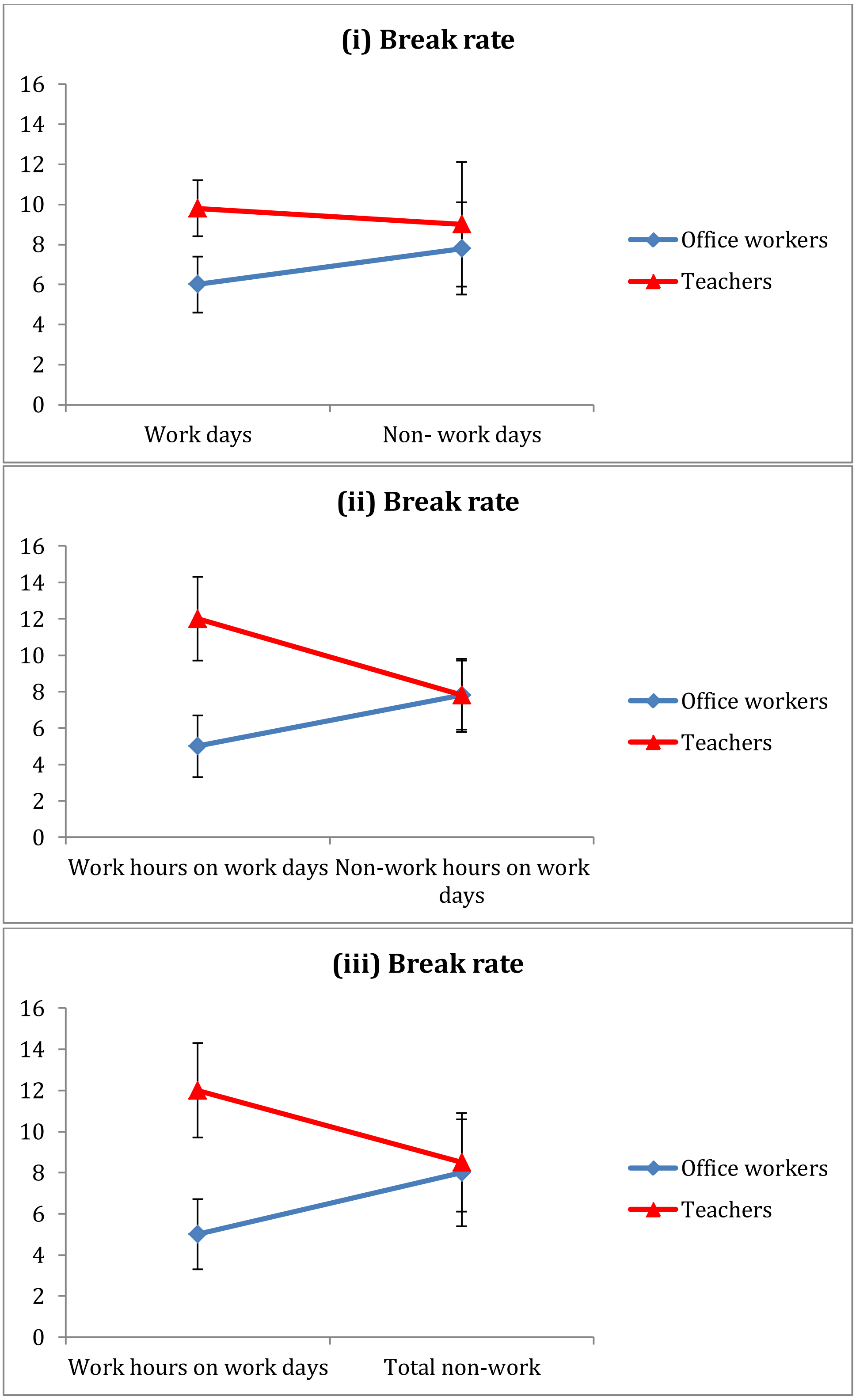


Figure 7.6: Comparison of break rate (breaks/sed hour) [mean ± SD] on (i) Work days and non-work days, (ii) Work hours on work days and non-work hours on work days and (iii) Work hours on work days and total non-work time for teachers and office workers



7.3.7 Self-reported musculoskeletal symptoms

49 of the 50 office workers and 12 of the 17 teachers completed the modified Nordic Musculoskeletal Questionnaire. There was no significant difference in the percentage of participants reporting pain in the different body regions between teachers and office workers with the exception of knee pain, where significantly more teachers reported knee pain ($p = 0.003$) (Table 7.8). For teachers, knee pain (58% of participants) was most frequently reported whereas office workers reported neck (44% of participants) and lower back (44% of participants) pain most frequently. The distribution of reported symptoms in terms of body regions is illustrated in Figure 7.7.

Figure 7.7: Distribution of self-reported musculoskeletal pain for office workers and teachers

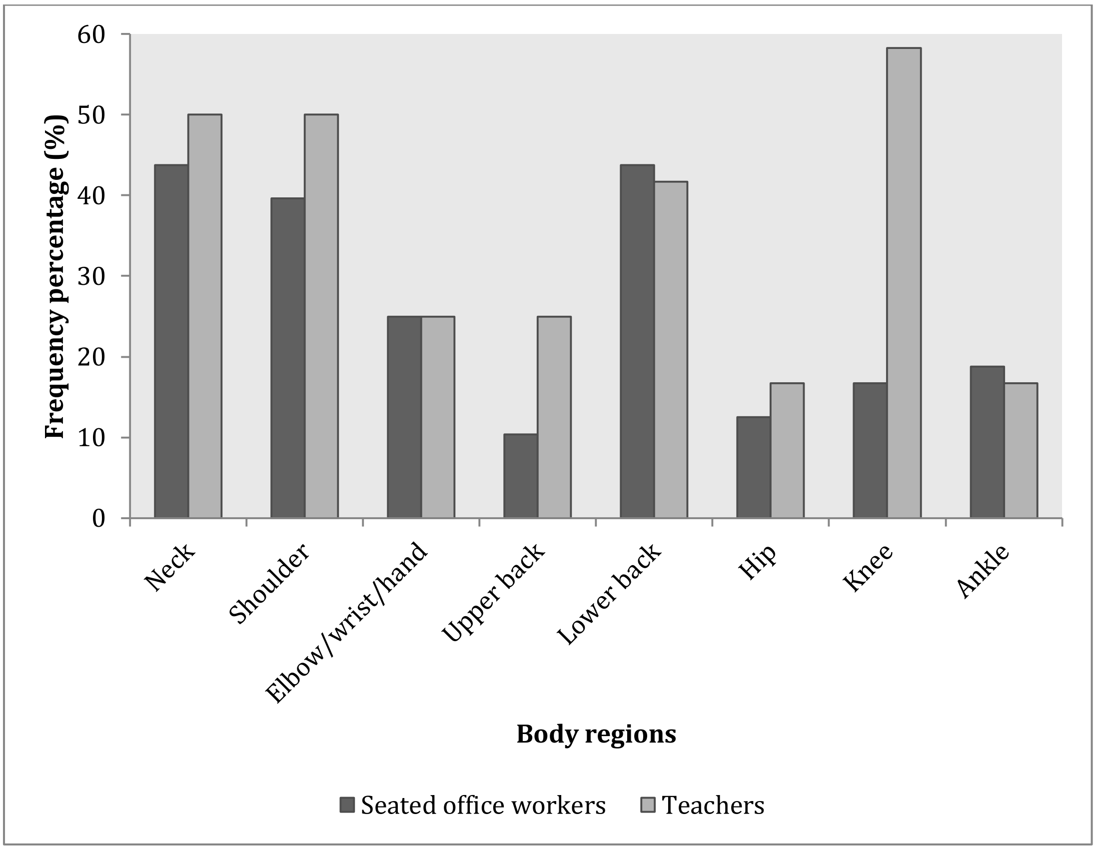


Table 7.8: Percentage of participants reporting musculoskeletal pain in the different body regions for teachers and office workers

Body regions	Teachers (%)	Office workers (%)	P
Neck	50	44	0.700
Shoulder	50	40	0.516
Elb/wrist/hand	25	25	0.999
Upper back	25	10	0.187
Lower back	42	44	0.897
Hip	17	13	0.706
Knee	58	17	0.003
Ankle	17	19	0.869

7.4 Discussion

7.4.1 Main findings

1. Sedentary exposure and physical activity of teachers

- The physical activity and sedentary behaviour of teachers during work hours is characterised by frequent short bouts of sedentary time and light activity with only a small proportion of working hours spent in sustained sedentary time.

2. Comparison between teachers and office workers

- Teachers were less sedentary and participated in more light activity than office workers on work days and during work hours and participated in less MVPA during non-work periods on work days compared to office workers.
- Teachers had less sustained sedentary time and more breaks in sedentary time than office workers on work days and during work hours.
- Importantly, there was no difference in sedentary time, light activity, MVPA, sustained sedentary time and break rate between teachers and office workers on non-work days or for total non-work time.
- For teachers, work sedentary time contributed a lower proportion of overall weekly sedentary time compared to office workers.
- Teachers spent a greater proportion of the work day and work hours in short bouts (bouts 0-<5 and bouts 5-<10 mins) of sedentary time and

light activity and a smaller proportion of the work day and work hours on work days in sustained sedentary time compared to office workers.

- Teachers also spent a greater proportion of the work day and work hours in short bouts (0-<5 mins) of MVPA compared to office workers.

3. Self-reported musculoskeletal pain

- Knee pain was most frequently reported by the teachers whereas office workers reported neck and lower back pain most frequently.
- A significantly greater proportion of teachers reported knee pain compared to office workers.

7.4.2 Discussion

The overall amount and pattern of exposure of sedentary time and physical activity at work and during non-work periods was compared between a sample of school teachers and the office workers who participated in Study 1 of this thesis. Importantly, while there were differences in the overall amount and pattern of exposure of sedentary time and light activity during work hours, there was very little difference in activity levels between teachers and office workers in non-work periods. These findings are consistent with other studies that have found that sedentary workers have similar activity patterns to active workers during non-work periods (Schofield et al., 2005; Tigbe et al., 2011) suggesting that sedentary workers are not 'compensating' for greater occupational sedentary time by increasing leisure time physical activity.

In the present study, for teachers, work contributed 36% of overall weekly sedentary time (office workers 49%), with teachers sedentary for 4.8 hours/day during work hours compared to office workers who were sedentary for 7.3 hours/day during work hours. This 2.5 hour daily difference in sedentary time at work highlights the different sedentary occupational exposure between teachers and office workers.

When considering total weekly sedentary time, office workers were sedentary for 8.0 hours more over one week than teachers. Therefore, as activity levels were similar during non-work periods, much of the additional sedentary time for office workers is likely to be from sedentary time accumulated during work hours. Further, as sedentary behaviour is associated with cardiometabolic risk factors (Camhi et al., 2011; Clark et al., 2011; Healy, Mathews, et al., 2011) the high occupational sedentary exposure of office workers suggests that office workers may be at greater risk to poor health when compared to teachers.

The greatest contrast in activity pattern between teachers and office workers was for sustained sedentary time and break rate during work hours. Population studies that have examined the health consequences of prolonged sitting suggest that excessive sitting is harmful (Chau, van der Ploeg, et al., 2012; Dunstan, Howard, et al., 2012; Mummery et al., 2005), although it is not known what amount of sustained sedentary time is detrimental to health. (Camhi et al., 2011; Clark et al., 2011; Healy, Mathews, et al., 2011). As teachers were exposed to a much lower level of uninterrupted sedentary time, it may be that teachers are at less risk of the health consequences associated with prolonged sedentary exposure. Future research should explore the health patterns between occupational groups that are exposed to different amounts of sedentary time and physical activity.

There was a different pattern of musculoskeletal pain distribution in the small group of teachers that completed the musculoskeletal pain questionnaire. A greater proportion of teachers reported knee pain when compared to office workers. It may be that as teachers spend more time kneeling/sitting on the floor or standing with hyperextended knees which may contribute to a higher risk of developing lower quadrant pain. Occupational kneeling, heavy lifting and squatting have been found to be associated with the development of knee pain and osteoarthritis of the knee (Fransen, Agaliotis, Bridgett, & Mackey, 2011). However, due to the small number of participants in the present study it is not possible to draw conclusions about the extent of musculoskeletal symptoms of teachers. Further, there was no assessment of the intensity or duration of musculoskeletal symptoms so that only the pattern of distribution of pain could be assessed. Nevertheless, it is important to consider the impact of different activity levels on the musculoskeletal symptoms of workers particularly when implementing programmes that aim to change activity levels. To date, the relationship between musculoskeletal pain and sedentary behaviour is unclear (Heneweer, Staes, Aufdemkampe, van Rijn, & Vanhees, 2011; Janwantanakul, Sitthipornvorakul, & Paksaichol, 2012). Study 4 of this thesis examines whether the introduction of a work based intervention aimed at reducing occupational sedentary behaviour and encouraging light, incidental activity can also modify musculoskeletal symptoms of office workers.

In the only study that has specifically examined the physical activity of teachers it was found that for teachers in South India occupational physical activity accounted for 41% of daily energy expenditure (Vaz & Bharathi, 2004). In the present study, if light intensity activity and MVPA are considered, occupational physical activity accounted for 61% of work day activity. It is difficult to assess if the results are consistent between studies as self-report rather that accelerometer derived measures of activity were used in the previous study.

7.4.3 Strengths and limitations

This study, for the first time used accelerometers to assess the overall amount and pattern of exposure of sedentary time and physical activity of school teachers at work and during non-work periods. Limitations include a small sample size of teachers from a single school and low response rate from the teachers completing the musculoskeletal survey.

7.4.4 Conclusion

Sedentary behaviour of teachers during work hours was characterised by overall less sedentary time and sedentary time broken up by frequent short bouts of light activity when compared to office workers. Importantly, there was no difference in sedentary time or activity levels on non-work days or for total non-work time between teachers and office workers. This study highlights the important differences in sedentary exposure pattern between two occupational groups that share many of the same skills and work tasks and suggests that office workers may be at a greater risk for poor health, compared to teachers, as a consequence of occupational sedentary exposure. In addition, this study demonstrated that work can have a more positive activity profile, which should be encouraged for office workers.

Selected results from study 2 have been published in:

Parry, S. and Straker, L. "Comparison of the pattern of sedentary exposure of school teachers and office workers" Poster, International Congress on Physical Activity and Public Health in Rio De Janeiro, Brazil March 2014

8.0 Study 3 - Is the use of a sit-stand workstation associated with differences in sedentary time and physical activity of office workers at work and during non-work hours? Results from the sit-stand workstation sub-group of office workers

8.1 Introduction

The use of a sit-stand workstation is seen as an alternative to solely standing or sitting workstations to reduce musculoskeletal discomfort (Davis et al., 2009; Hedge & Ray, 2004; Roelofs & Straker, 2002) and more recently to potentially reduce occupational sedentary behaviour (Parry & Straker, 2013).
Sit-stand workstations have been used for a number of years in some countries to address musculoskeletal issues and been shown to have a long term impact on sedentary behaviour (Karakolis & Callaghan, 2014; Toomingas & Gavhed, 2008). More recently there is renewed interest in sit-stand workstations, as intervention studies have found that the introduction of a desktop sit-stand workstation can reduce sitting time (Alkhajah et al., 2012; Healy et al., 2013; Neuhaus et al., 2014).

A group of volunteers that agreed to participate in Study 1 were using an electronically height-adjustable sit-stand workstation. The participants had requested a sit-stand workstation from the occupational health officer within the organisation as each individual had a musculoskeletal complaint that was aggravated by prolonged sitting. As these participants were not using a conventional chair and desk arrangement, it was anticipated that activity levels would be different from the seated office workers group and therefore, the data from this group were analysed separately and included in this comparison study. It is important to note that these participants chose to use a sit-stand workstation for pre-existing medical reasons. As it was not the original intention of Study 1 to compare activity levels between seated and sit-stand office workers, no additional data from the sit-stand group was taken. Consequently, there is no information about how long each individual in the sit-stand group had been using the sit-stand workstation or the frequency of use, nor was there specific details about individual musculoskeletal complaints. The only information available was that this group had each requested a sit-stand workstation.

The aim of the present study was to compare total sedentary time, light activity and MVPA and pattern of exposure of sedentary time, light activity and MVPA of seated office workers and office workers that were using a sit-stand workstation due to a musculoskeletal complaint. A secondary aim was to compare the distribution of self-reported musculoskeletal pain between seated office workers and sit-stand office workers.

8.2 Method

8.2.1 Procedure and statistical analysis

Design, recruitment, ethics, organisaton and procedure were the same as described in Study 1. Only accelerometer and musculoskeletal data for seated and sit-stand office workers are presented in this chapter. Paired t-tests were used to compare time in activity levels between work and non-work days and between work hours on work days and non-work periods. In addition, independent t-tests or chi squared tests assessed participant characteristics (age, BMI and gender) between seated and sit-stand office workers. Independent t-tests were used to compare activity levels between seated and sit-stand office workers. Activity analyses were calculated using percentage of wear time for each time period. Kruskal-Wallis Test was used to assess differences in musculoskeletal pain between seated and sit-stand office workers. All analyses were performed using PASW Statistics 18, critical alpha level of 0.05.

8.3 Results

8.3.1 Participant characteristics

Eight participants that were using a sit-stand workstation (63% males) with a mean age of 37.9 ± 9.1 (mean ± SD) years and BMI of 25.3 ± 3.3 kg/m^2 were included in the analysis. Data from the 50 seated office workers that participated in Study 1 were also used in the present study. There were no significant differences in age (t = -0.41, p = 0.682), BMI (t =-0.36, p = 0.720) or gender composition (χ^2 = 0.20, p = 0.907) between the sit-stand office workers and the seated office workers (Table 8.1).

Table 8.1: Comparison of participant characteristics between sit-stand office workers and seated office workers

Variable	Sit-stand workstation [n = 8]	Seated office workers [n = 50]	P for group comparison
Age (mean years; [SD]	37.9 [9.1]	36.5 [8.6]	0.682
BMI (mean kg/m^2; [SD])	25.3 [3.3]	24.8 [4.1]	0.720
Gender (n (%) male)	5 (63)	29 (58)	0.907

8.3.2 Accelerometry

Sedentary time, light activity, MVPA, sustained sedentary time (bouts>30 mins) and break rate (breaks/sedentary hour) for the sit-stand office workers are presented in Table 8.2. Figure 8.1 illustrates the distribution of sedentary time, light activity and MVPA for seated and sit-stand office workers.

Table 8.2: Sedentary, light, MVPA, sustained sedentary time (bouts>30 mins) and break rate for the sit-stand office workers. All activity time expressed as %wear time ± SD; Break rate = breaks/sedentary hour

	Type of day		Wear time on work day		Total non-work time
	Work day	Non-work days	Work hours on work days	Non-work hours on work days	
Sit-stand office workers					
Sedentary time	73.42 ± 4.10§	63.19 ± 8.02	78.94 ± 6.02‡	64.67 ± 11.06	63.39 ± 6.77
Light activity	19.97 ± 4.63§	31.42 ± 7.54	16.83 ± 5.53	24.51 ± 7.13	29.64 ± 6.52ß
MVPA	6.61 ± 3.39	5.39 ± 4.68	4.22 ± 1.60	10.82 ± 9.85	6.97 ± 3.47
Sustained sed time >30 mins	30.67 ± 10.61§	18.49 ± 7.58	37.48 ±15.60‡	20.16 ± 8.68	18.77 ± 7.08
Breaks in sedentary time	6.52 ± 1.52§	9.21 ± 1.90	5.72 ± 2.04	8.32 ± 2.24	8.99 ± 1.83ß

§ Significant difference between work and non-work days ($p<0.05$)

∞Significant difference between work hours on work days and non-work hours on work days ($p<0.001$)

ß Significant difference between work hours on work days and total non-work time ($p<0.05$)

‡Significant difference between work hours on work days and non-work hours on work days and between work hours on work day and total non-work time ($p<0.05$)

For sit-stand office workers sedentary time was proportionally greater on work days compared to non-work days ($t = 3.82$, df_{7}, $p = 0.007$), during work hours on work days compared to non-work hours on work days ($t = 2.71$, df_{7}, $p = 0.030$) and during work hours on work days compared to total non-work time ($t = 4.95$, df_{7}, $p = 0.002$) (Table 8.2, Figure 8.1). For sit-stand office workers, light activity was proportionally less on work days compared to non-work days ($t = -3.79$, df_{7}, $p = 0.007$) and during work hours on work days compared to total non-work time ($t = -3.86$, df_{7}, $p = 0.006$). The difference in light activity during work hours on work days compared to non-work hours on work days did not reach significance ($p = 0.056$) (Table 8.2, Figure 8.1). For sit-stand office workers, there was no significant difference in MVPA on work days compared to non-work days ($p = 0.637$), during work hours on work days compared to non-work hours on work days (p = 0.105) and during work hours on work days compared to total non-work time (p = 0.109) (Table 8.2, Figure 8.1).

Sustained sedentary time (bouts > 30 mins) were proportionally greater on work days compared to non-work days (t = 3.2, $df_{7,}$ p = 0.015), during work hours on work days compared to non-work hours on work days (t = 2.52, $df_{7,}$ p = 0.040) and during work hours on work days compared to total non-work time for sit-stand office workers (t = 3.21, $df_{7,}$ p = 0.015) (Table 8.2). Break rate (breaks/sed hour) was less on work days compared to non-work days (t = -3.06, $df_{7,}$ p = 0.018) and during work hours on work days compared to total non-work time (t = -2.91, $df_{7,}$ p = 0.023), however, the difference in break rate during work hours on work days compared to non-work hours on work days for sit-stand office workers did not reach significance (p = 0.073) (Table 8.2).

8.3.3 Further accelerometry analysis – Comparison between sedentary time, light activity, MVPA, sustained sedentary time and break rate for sit-stand office workers and seated office workers

Table 8.3 presents the comparison between sit-stand office workers and seated office workers for sedentary time, light activity, MVPA, sustained sedentary time and break rate on work days, non-work days, work hours on work days, non-work hours on work days and total non-work time.

There was no significant difference in the proportion of sedentary time, light activity and break rate between sit-stand and seated office workers on work days, non-work days, during work hours on a work day, during non-work hours on a work day and during total non-work time. However, sit-stand office workers had proportionally less sustained sedentary time on non-work days (8.42% wear time, t = 2.05, df_{56}, p = 0.045) and proportionally greater MVPA on work days (-2.20% wear time, t = -2.62, df_{56}, p = 0.011), during non-work hours on work days (-4.05% wear time, t = -2.15, df_{56}, p = 0.036) and for total non-work time compared to seated office workers (-2.81% wear time, t = -2.66, df_{56}, p = 0.010).

Figure 8.1: Proportion of sedentary time, light activity and MVPA during work hours for (a) sit-stand office workers and (b) seated office workers

(a) Sit-stand office workers **(b) Seated office workers**

Table 8.3: Sedentary time, light activity, MVPA, sustained sedentary time (bouts>30 mins) and break rate (breaks/sedentary hour), for sit-stand office workers and seated office workers on work days, non-work days, work hours on work days, non-work hours on work days and total non-work time

Outcome measures	Sit-stand office workers	Seated office workers	Mean Difference	95% CI	P
Sedentary time (% wear time ± SD)					
Work days	73.42 ± 4.10	75.91 ± 6.08	2.48	-1.99, 6.97	0.271
Non-work days	63.19 ± 8.02	69.74 ± 9.32	6.55	-0.44, 13.54	0.066
Work hours on work days	78.94 ± 6.02	81.80 ± 5.65	2.86	-1.48, 7.20	0.192
Non-work hours on work days	64.67 ± 11.06	67.05 ± 8.80	2.37	-4.58, 9.32	0.497
Total non-work	63.38 ± 6.77	68.95 ± 8.73	5.56	-0.93, 12.05	0.092
Light time (% wear time ± SD)					
Work days	19.97 ± 4.63	19.68 ± 5.13	-0.29	-4.19, 3.61	0.884
Non-work days	31.42 ± 7.54	27.21 ± 8.69	-4.21	-10.75, 2.32	0.201
Work hours on work days	16.84 ± 5.53	15.27 ± 4.72	-1.57	-5.25, 2.12	0.398
Non-work hours on work days	24.51 ± 7.13	26.18 ± 8.30	1.67	-4.55, 7.90	0.592
Total non-work	29.64 ± 6.52	26.89 ± 8.00	2.98	-8.72, 3.23	0.361
MVPA (% wear time ± SD)					
Work days	6.61 ± 3.39	4.41 ± 1.99	-2.20	-3.89, -0.51	0.011
Non-work days	5.38 ± 4.68	3.05 ± 2.87	-2.33	-4.74, 0.07	0.057
Work hours on work days	4.22 ± 1.60	2.93 ± 1.72	-1.30	-2.60, 0.01	.0.051
Non-work hours on work days	10.82 ± 9.85	6.77 ± 3.74	-4.04	-7.82, -0.28	0.036
Total non-work	6.97 ± 3.47	4.16 ± 2.66	-2.81	-4.93, -0.70	0.010
Sustained Sedentary time (% wear time ± SD)					
Work days	30.67 ± 10.61	34.05 ± 11.61	3.38	-5.39, 12.14	0.444
Non-work days	18.49 ± 7.58	26.91 ± 11.18	8.42	0.18, 16.65	0.045
Work hours on work days	37.48 ± 15.60	41.36 ± 16.30	3.87	-8.50, 16.24	0.533
Non-work hours on work days	20.16 ± 8.68	23.19 ± 10.58	3.03	-4.88, 10.93	0.446
Total non-work	18.77 ± 7.08	25.81 ± 9.65	7.05	-0.10, 14.19	0.053
Break rate (breaks/sed hour)					
Work days	6.52 ± 1.52	5.97 ± 1.45	-0.54	-1.65, 0.57	0.332
Non-work days	9.21 ± 1.90	7.83 ± 2.33	-1.38	-3.12, 0.36	0.117
Work hours on work days	5.72 ± 2.04	5.05 ± 1.68	-0.52	-2.06, 1.02	0.314
Non-work hours on work days	8.32 ± 2.24	7.79 ± 1.99	-0.52	-2.06, 1.02	0.503
Total non-work	8.99 ± 1.83	7.78 ± 2.03	-1.20	-2.73, 0.33	0.120

8.3.4 Overall contribution of occupational sedentary time to total sedentary time

The contribution of sedentary time during work hours to total weekly sedentary time for seated and sit-stand office workers are reported in Table 8.4. For sit-stand office workers, work contributed 52.8% of their weekly sedentary time, which is significantly greater than seated office workers (4.3% weekly sedentary time, t = -2.23, df $_{56}$, p = 0.030) (Table 8.4).

Table 8.4: Contribution of work to weekly sedentary time for sit-stand office workers and seated office workers

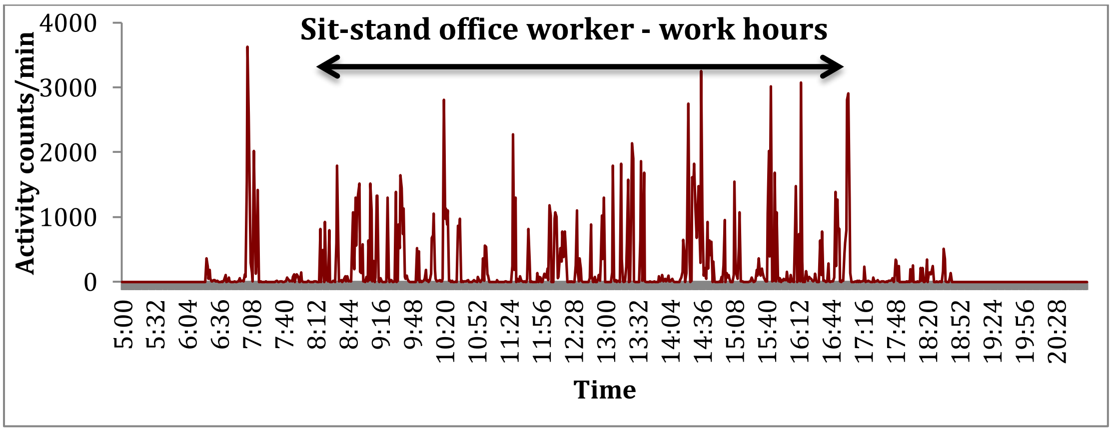
Outcome measures	Sit-stand office workers	Seated office workers	Mean Difference	95% CI	P
Total weekly sedentary hours (mean hours/week [SD])	71.39 [7.72]	75.35 [6.87]	3.96	-1.36, 9.29	0.142
Weekly work sedentary hours (hours/week [SD])	37.67 [3.94]	36.53 [4.29]	-1.14	-4.38, 2.10	0.484
Weekly non-work sedentary hours (hours/week [SD)	33.72 [5.70]	38.82 [5.90]	5.10	0.62, 9.59	0.026
Weekly work sedentary hours as % of weekly sedentary time (mean % [SD])	52.84 [4.30]	48.62 [5.20]	-4.32	-8.21, -0.48	0.030

8.3.5 Comparison of the pattern of sedentary time, light activity and MVPA between sit-stand office workers and seated office workers

The pattern of sedentary time, light activity and MVPA on work days and during work hours is described in Tables 8.5 and 8.6. Even though the overall proportion of sedentary time and light activity was not different between the sit-stand office workers and the seated office workers, there was some variation in the pattern of exposure between the two groups. Figure 8.2 illustrates the accelerometry counts/minute on a work day for one seated office worker and one office worker using a sit-stand workstation that participated in the study. The arrow on each graph indicates the working hours for each office worker. The working hours of the seated office worker was characterised by sustained bouts of sedentary time (activity counts < 91 counts/min) with relatively few periods of light (activity counts 91- ≤ 1767 counts/min), moderate (activity counts 1767≤5182 counts/min) and vigorous (activity counts 5275 counts/min) activity. In contrast, the sit-stand office worker had frequent short bouts of light activity with few bouts sustained sedentary time (Figure 8.2). The pattern of activity counts is a record of two participants on isolated days used to illustrate the differences in pattern between seated and sit-stand office workers. The pooled data analysis is presented in Tables 8.5 and 8.6. The results of the Exposure Variance Analysis, on work days and during work hours on a work days, which illustrates the comparison of the intensity (sedentary, light and MVPA) of activity and the duration of activity in bouts of 0-<5mins, 5-<10, 10-<30 mins and 30+ mins is shown in Figure 8.3.

There was no significant difference in the pattern of accumulation of sedentary time between seated and sit-stand office workers on work days ($p > 0.287$) or during work hours on a work day ($p > 0.453$). There was no significant difference in the pattern of accumulation of light activity on work days ($p > 0.055$), however, sit-stand office workers spent significantly more time in short bouts of light activity than seated office workers during work hours (light bouts 0-<5mins: -6.05% wear time, $t = -7.19$, df_{56}, $p < 0.001$; light bouts 5-<10 mins: -1.54% wear time, $t = -3.85$, df_{56}, $p < 0.001$). Sit-stand office workers also spent significantly more time in short bouts MVPA than seated office workers on work days (MVPA bouts 0-<5mins: -1.00% wear time, t = -3.17, df_{56}, p = 0.002) and during work hours (MVPA bouts 0-<5 mins -1.54% wear time, t = -3.85, df_{56}, p <0.0015-<10 mins: -1.96% wear time, t = -7.73; MVPA bouts 5<10 mins; -0.44% wear time, df_{56}, p = 0.008) (Tables 8.5 and 8.6, Figure 8.3).

Figure 8.2: Accelerometer counts (counts/min) on a work day with working hours highlighted (arrow) for a one sit-stand office worker and one seated office worker



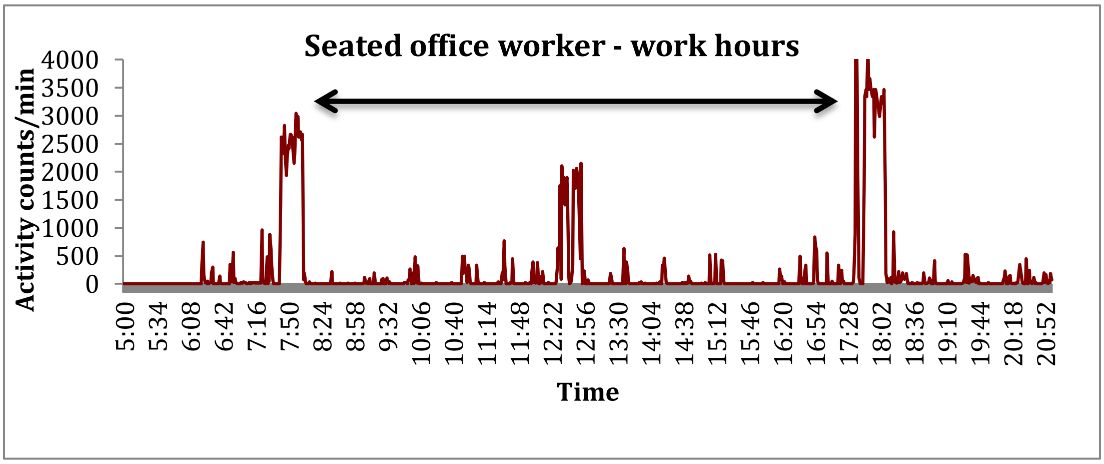


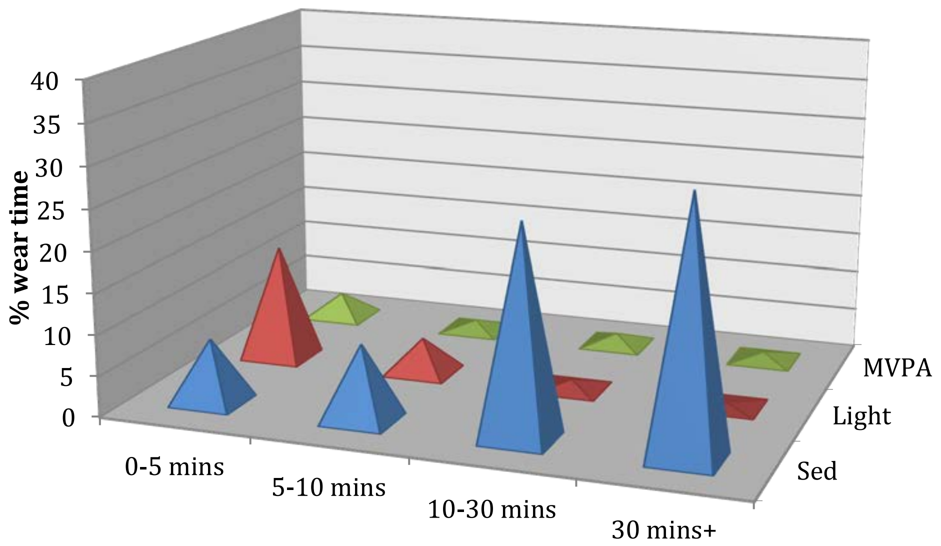
Table 8.5: Pattern of sedentary time, light activity and MVPA in bouts of 0-<5 mins, 5-<10 mins, 10-<30 mins and 30 mins+ on work days for sit-stand office workers and seated office workers

Outcome measures	Sit-stand office workers (%wear time [SD])	Seated office workers (%wear time [SD])	Mean Difference	95% CI	P
Work days bouts (mins)					
Sed time (0-<5)	7.84 [1.92]	7.27 [2.05]	-0.58	-2.12, 0.97	0.460
Sed time (5-<10)	9.29 [2.91]	8.26 [2.45]	-1.03	-2.94, 0.89	0.287
Sed time (10-<30)	25.62 [5.51]	26.33 [4.99]	0.71	-3.14, 4.57	0.713
Sed time 30+	30.67 [10.61]	34.05 [11.61]	3.38	-5.39, 12.15	0.444
Sed time 60+	10.30 [7.05]	13.31 [9.25]	3.01	-3.89, 9.88	0.383
Light time (0-<5)	14.20 [2.80]	13.39 [2.21]	-0.81	-2.55, 0.94	0.359
Light time (5-<10)	4.32 [1.65]	4.12 [2.06]	-0.20	-1.74, 1.33	0.794
Light time (10-<30)	1.10 [1.00]	2.01 [1.84]	0.91	-0.43, 2.25	0.179
Light time 30+	0.35 [0.65]	0.16 [0.47]	-0.19	-0.56, 0.19	0.316
MVPA time (0-<5)	3.04 [0.89]	2.04 [0.82]	-1.00	-1.64, -0.37	0.002
MVPA (5-<10)	1.21 [0.66]	1.15 [0.56]	-0.07	-0.51, 0.37	0.748
MVPA (10-<30)	1.41 [1.02]	0.92 [1.20]	-0.49	-1.38, 0.41	0.281
MVPA 30+	0.94 [1.86]	0.30 [0.80]	-.064	-1.40, 0.12	0.099

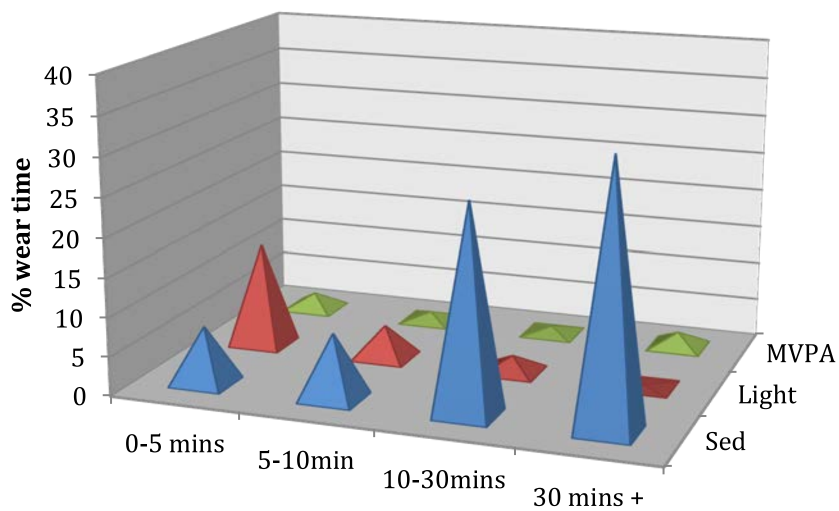
Table 8.6: Pattern of sedentary time, light activity and MVPA in bouts of 0-<5 mins, 5-<10 mins, 10-<30 mins and 30 mins+ during work hours for sit-stand office workers and seated office workers

Outcome measures	Sit-stand office workers (%wear time [SD])	Seated office workers (%wear time [SD])	Mean Difference	95% CI	P
Work hours on work day					
Sed time (0-<5)	9.93 [3.03]	6.17 [2.57]	-0.76	-2.76, 1.25	0.453
Sed time (5-<10)	8.91 [3.70]	8.01 [3.57]	-0.90	-3.64, 1.84	0.515
Sed time (10-<30)	25.62 [6.26]	26.27 [7.27]	0.64	-4.81, 6.10	0.814
Sed time 30+	37.48 [15.61]	41.36 [16.30]	3.87	-8.50, 16.24	0.533
Sed time 60+	12.93 [9.50]	16.03 [13.44]	3.09	-6.83, 13.02	0.535
Light time (0-<5)	13.35 [3.81]	7.30 [1.87]	-6.05	-7.73, -4.62	<0.001
Light time (5-<10)	3.05 [1.59]	1.51 [0.95]	-1.54	-2.34, -0.74	<0.001
Light time (10-<30)	0.44 [0.61]	0.29 [0.43]	-0.15	-0.50, 0.20	0.391
Light time 30+	0	0.04 [0.30]	0.04	-0.17, 0.26	0.693
MVPA time (0-<5)	2.95 [1.17]	0.99 [0.56]	-1.96	-2.47, -1.45	<0.001
MVPA (5-<10)	0.87 [0.52]	0.43 [0.40]	-0.44	-0.76, -0.12	0.008
MVPA (10-<30)	40 [0.44]	0.26 [0.45]	-0.14	-0.48, 0.20	0.416
MVPA 30+	0	0.06 [0.30]	0.06	-0.16, 0.27	0.608

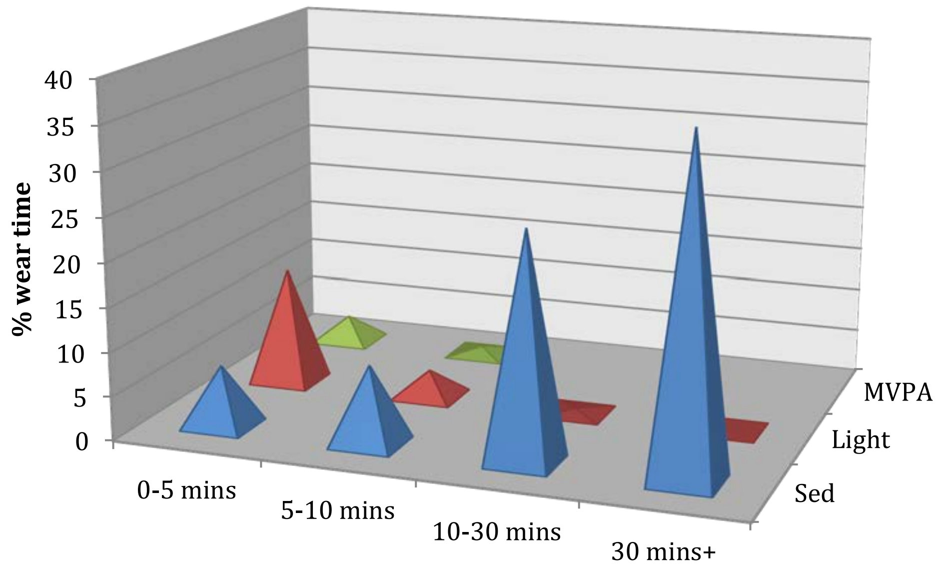
Figure 8.3: Exposure Variance Analysis showing proportion of wear time in sedentary, light and MVPA in bouts of 0-<5, 5-<10, 10-<30 and 30+ minutes for sit-stand office workers on a work days (a), seated office workers on work days (b), sit-stand office workers during work hours (c) and seated office workers during work hours (d)



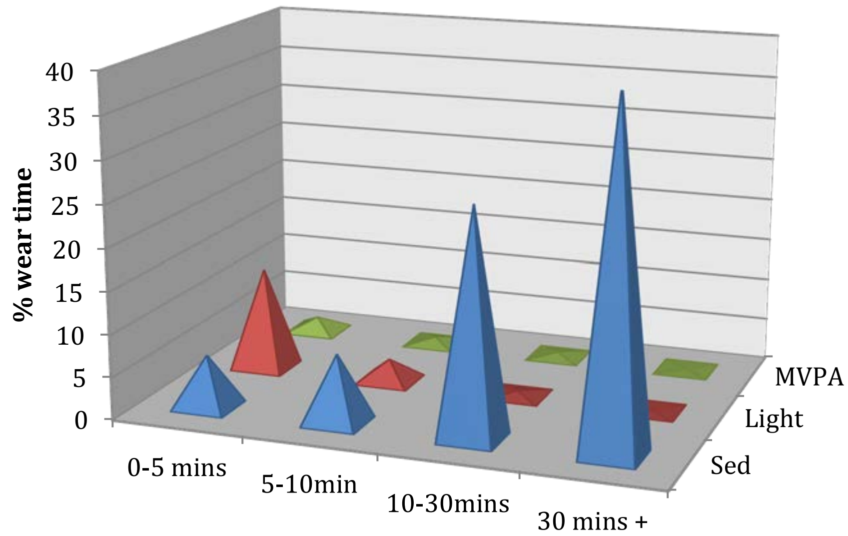
(a) Sit-stand office workers - work days



(b) Seated office workers -work days



(c) Sit-stand office workers - work hours on work days



(d) Seated office workers -work hours on work days

8.3.6 Self-reported musculoskeletal symptoms

All eight sit-stand office workers completed the Nordic Musculoskeletal Questionnaire. The distribution of reported symptoms in relation to body regions for seated and sit-stand office workers in illustrated in Figure 8.4. Shoulder pain (88%) and low back pain (63%) were most frequently reported by sit-stand office workers. A significantly greater proportion of sit-stand office workers reported shoulder, upper back and hip pain compared to seated office workers (Table 8.7).

Figure 8.4: Distribution of self-reported musculoskeletal pain for sit-stand office workers and seated office workers

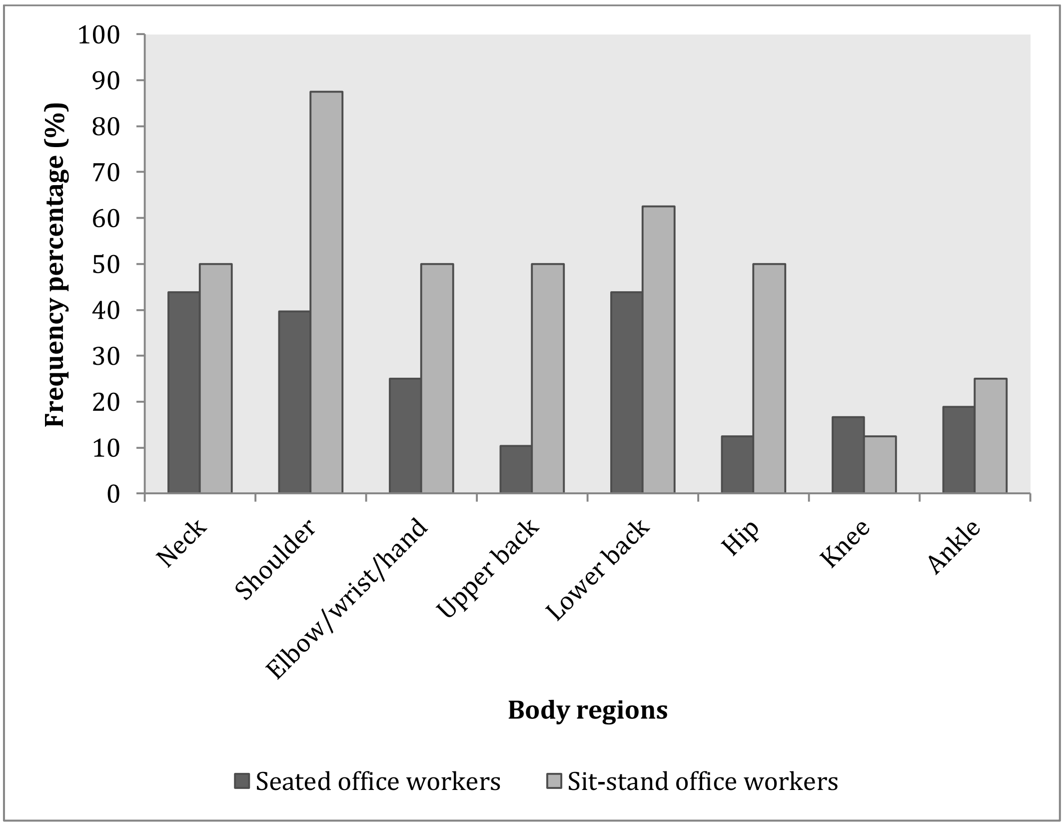


Table 8.7: Percentage of participants reporting musculoskeletal pain in the different body regions for sit-stand office workers and seated office workers

Body regions	Sit-stand office workers (%)	Seated office workers (%)	P
Neck	50	44	0.744
Shoulder	88	40	0.013
Elb/wrist/hand	50	25	0.151
Upper back	50	10	0.005
Lower back	63	44	0.329
Hip	50	13	0.011
Knee	13	17	0.768
Ankle	25	19	0.683

8.4 Discussion

8.4.1 Main findings

1. Sedentary exposure and physical activity of sit-stand office workers

- Sit-stand office workers were sedentary for a large proportion (79%) of work hours.
- Sit-stand office workers participated in light activity for 17% of working hours and MVPA 4% of working hours.

2. Comparison between sit-stand office workers and seated office workers

- There was no difference in the total amount of sedentary time, light activity and break rate during work hours and during non-work periods between sit-stand office workers and seated office workers.
- Sit-stand office workers had proportionally less sustained sedentary time on non-work days and proportionally greater MVPA on work days, during non-work hours on work days and for total non-work time compared to seated office workers.
- For sit-stand office workers, work sedentary time contributed a significantly greater proportion of overall weekly sedentary time compared to seated office workers.
- Sit-stand office workers spent more time in short bouts of light activity (bouts 0-<5 mins and bouts 5-<10 mins) compared to seated office workers during work hours.
- Sit-stand office workers also spent more time in short bouts MVPA (bouts 0-<5 mins) than seated office workers on work days and during work hours.

3. Self-reported musculoskeletal pain

- A significantly greater proportion of sit-stand office workers reported shoulder, upper back and hip pain compared to seated office workers.

8.4.2 Discussion

A small convenience sample of office workers that were using a sit-stand workstation were analysed separately to the group of seated office workers that participated in Study 1. It was anticipated that sit-stand office workers would have overall less sedentary time during work hours compared to seated office workers, however, the difference between the groups was only marginal (3% wear time, 16 less sedentary minutes during work hours). These findings contrast results from other studies that installed a desktop sit-stand computer stand onto a standard desk (Alkhajah et al., 2012; Healy et al., 2013; Neuhaus et al., 2014), which demonstrated a larger reduction in sitting time (Alkhajah et al., 2012; Healy et al., 2013; Neuhaus et al., 2014). The results from the present study were similar to the findings Gilson et al (2012) that the introduction of a standing 'hot' desk did not change occupational sedentary time (Gilson, Suppini, et al., 2012).

The lack of differences in sedentary time and physical activity the present study between sit-stand and seated office workers is surprising as the sit-stand office workers specifically requested a sit-stand workstation due to musculoskeletal problems with prolonged sitting. It was expected that the sit-stand office workers would have overall less sedentary time as pain associated with sustained sitting may have stimulated more movement. However, it may be that excessive standing may equally cause pain so that alternation between sitting and standing is reflected in there being no differences in overall sedentary time. Further, the use of an accelerometer, rather than an inclinometer based device such as the activPAL™ may account for the lack of differences as accelerometer counts do not differentiate well between sitting and standing (Kozey-Keadle et al., 2011).

Despite there being no difference in overall sedentary time, physical activity and break rate during work hours, short bouts of light activity and MVPA were more frequent for participants using the sit-stand workstation compared to seated office workers during work hours. Therefore, sit-stand office workers may be benefiting from the important health advantages of frequent short breaks of light activity (Hamilton, Hamilton, & Zderic, 2007; Swartz et al., 2011). Further, it may be that workers that stand more find it easier to move if already in the standing position. Longitudinal research that examines the frequency of sit-stand transitions and acceptability of use of sit-stand workstations is important to understand the feasibility of employing sit-stand workstations to reduce sedentary behaviour for sustained periods.

A larger proportion of the sit-stand group in this study reported current musculoskeletal pain than the seated office workers. This was to be expected as the sit-stand office workers had all requested a sit-stand workstation due to pre-existing musculoskeletal symptoms. It is not known whether the introduction of the sit-stand workstation had any impact on the level of pain/discomfort of these office workers. Previous research has indicated that the introduction of sit-stand workstations have successfully been used to reduce musculoskeletal pain (Davis et al., 2009; Hedge & Ray, 2004; Husemann et al., 2009).

8.4.3 Strengths and limitations

This study was able to reveal an accurate "snap shot" of a small group of office workers that chose to use a sit-stand workstation in free-living conditions, not under the constraint of a study protocol. As the design was observational, it was not able to detect if the use of a sit-stand workstation modified work practices or musculoskeletal pain. Due to the use a small (n = 8) convenience sample, the power was low. Even though there was sufficient power to detect the 0.4% difference in short bouts of MVPA during work hours, there was not sufficient power to detect small differences such as 2.9% difference in sedentary time observed between the groups during work hours.

8.4.4 Conclusion

While overall proportion of sedentary time, light activity, MVPA, sustained sedentary activity and break rate during work hours was not significantly different between sit-stand office workers and seated office workers, the pattern of exposure varied between the groups with sit-stand office workers having proportionally more short bouts of light activity and MVPA during work hours than seated office workers. Introducing sit-stand workstations into a conventional office environment has the potential to modify the pattern of physical activity exposure. Office workers may gain from the shared benefits of reduced cardiometabolic health risks associated with occupational sedentary behaviour and reduction in musculoskeletal symptoms.

Selected results from Study 3 have been published in:

Parry, S and Straker, L (2011) "Occupational Physical Activity of Contemporary Office Workers – Comparison Between Sitting and Standing Workstations Using Accelerometry" *Proceedings of International Behavioural Nutrition and Physical Activity Conference*, Melbourne, July 2011.

9.0 Study 4 - Introduction: Can participatory workplace interventions change sedentary behaviour, physical activity, musculoskeletal symptoms and selected work factors for office workers?

There is a growing recognition that occupational sedentary time and sustained sedentary time (or lack of breaks in sedentary time) significantly contribute to overall sedentary time (Chau, van der Ploeg, et al., 2012; Church et al., 2011; Graff-Iversen, Selmer, Sørensen, & Skurtveit, 2007; Mummery et al., 2005; Parry & Straker, 2013; Straker & Mathiassen, 2009; van Uffelen et al., 2010). Further, recent laboratory studies have found that interruption of sustained sedentary time with short bouts of treadmill (light and moderate intensity) walking resulted in improved glucose metabolism in a group of overweight individuals (Dunstan, Kingwell, et al., 2012) and increased energy expenditure in normal weight individuals (Swartz et al., 2011). These findings suggest that relatively small changes in activity levels and the pattern of activity have the potential to modify adverse health risk factors.

The workplace has conveniently and successfully been used to implement health promotion interventions (Pressler et al., 2010) and interventions aimed at the work risks associated with manual handling tasks (Straker et al., 2004) and computing tasks (Szeto, Straker, & O'Sullivan, 2009) which typically aim at reducing musculoskeletal symptoms, injuries and absenteeism (Robertson et al., 2009; Taieb-Maimon, Cwikel, Shapira, & Orenstein, 2012). Other successful workplace interventions have addressed the risks associated with alcohol, smoking and nutrition (Anderson et al., 2009; Cahill et al., 2008; Osilla et al., 2012; Ovbiosa-Akinbosoye & Long, 2011) as well as physical activity interventions that target the promotion of MVPA (Freak-Poli et al., 2011), supporting suggestions that the workplace may be a suitable site to implement programmes that target the reduction in sedentary behaviours (Owen et al., 2010).

The recognition of the importance of occupational sedentary time and the success of workplace interventions that target other health issues have highlighted the need to provide appropriate and effective workplace interventions that target the reduction in occupational sedentary time and incorporate light intensity activity into the working day (Chau et al., 2010; Kirk & Rhodes, 2011; Parry & Straker, 2013; Tremblay, Colley, Saunders, Healy, & Owen, 2010). In a review of the intervention studies that aim to reduce occupational sitting time, it was found that there were very few good quality intervention studies, with no one intervention demonstrating a significant reduction in sitting time (Chau et al., 2010). One of the potential reasons for lack of evidence of successful interventions was that sitting was mainly self-reported (Chau et al., 2010). Objectively measured sedentary time (Healy, Clark, et al., 2011) and pattern of exposure (Abbott, Straker, & Mathiassen, 2013; Chastin & Granat, 2010) may provide stronger evidence. Since the publication of the Chau et al (2010) review, a number of recent studies to reduce occupational sitting time by use of a desktop sit-stand computer stand (Alkhajah et al., 2012; Healy et al., 2013), multi-component interventions (including provision of a desktop sit-stand computer stand) (Neuhaus et al., 2014) and break-prompting software (Evans et al., 2012) that use objective, rather than self-reported, measures of sitting time have found significant reduction in sitting time and improved frequency in breaks in sedentary time at work.

There have been 3 main approaches to intervention development aimed at improving occupational physical activity and sedentary behaviour. The first traditional approach has been to incorporate MVPA into work breaks (lunch/coffee breaks) or during transport to and from work (Dishman et al., 2009; Engbers et al., 2007; Osteras & Hammer, 2006). A recent example of this approach was to examine the effects of a workplace pedometer challenge

(Freak-Poli et al., 2011). The second traditional approach has been to interrupt work with short bouts of exercise or activity breaks during work hours (Griffiths et al., 2007). This approach has been successful in reducing musculoskeletal symptoms of office workers (Andersen et al., 2010; Andersen et al., 2011). Both these approaches to physical activity interventions take workers away from their work tasks and have the potential to negatively impact on work productivity. The third, more recent approach to intervention development has been to change the way productive tasks are performed by the use of sit-stand computer stands attached to a standard desktop (Alkhajah et al., 2012; Gilson, Suppini, et al., 2012; Healy et al., 2013; Neuhaus et al., 2014) and 'Active Workstations' – walking or cycling desks (John et al., 2011; Levine & Miller, 2007; Straker et al., 2009). Incorporating some activity such as standing, walking or cycling into productive and usual work tasks may be more successful at reducing sedentary behaviours with potentially less impact on work productivity (John et al., 2009; Ohlinger et al., 2011; Straker et al., 2009; Thompson & Levine, 2011).

A potential weakness of past (pre 2010) physical activity and sedentary reduction workplace interventions has been the lack of a participatory approach to intervention development. Participative approaches aim to engage employees and develop a sense of ownership and empowerment to change by workers and managers/supervisors working together to develop and implement health related programmes (Rivilis et al., 2008). Participatory ergonomic practices (Kuorinka & Patry, 1995; Nagamachi, 1995) have been used extensively to address musculoskeletal complaints in industry (Straker et al., 2004) and office workplaces (Loisel et al., 2001; Rivilis et al., 2008; Rosecrance & Cook, 2000; van Eerd et al., 2010) but prior to the initiation of Study 4 in 2010 have not been used for sedentary behaviour interventions.

Further, past interventions may not have sufficiently taken into account the physical and psychosocial features of an organisation that could influence the physical and psychosocial well-being of workers (O'Driscoll & Cooper, 2002; Shaw et al., 2011). Organisational features could possibly impact on the ability of workers to modify their work practices in order to change physical activity and sedentary behaviour. Engaging management and supporting employees participating in a workplace intervention to reduce occupational sedentary behaviour has been found to enhance improvements in sitting time of office workers (Neuhaus et al., 2014). Therefore, characteristics of the organisation such as organisation culture may influence both the sedentary exposure of workers and the ability of workers to participate fully in workplace interventions. Further, to date, it appears that no studies have looked at the impact of workplace sedentary reduction programmes on job satisfaction. While a small number of studies have examined the relationship between work productivity and sedentary behaviour and physical activity (Grunseit et al., 2013; Strijk et al., 2013), at the time of commencement of Study 4, it appeared that no studies had explored whether the workplace sedentary reduction programmes can modify work productivity.

Some workplace physical activity and sedentary behaviour research have also examined the impact of physical activity on musculoskeletal complaints (Andersen et al., 2010; Andersen et al., 2011; Blagsted et al., 2008). However, only a few studies have explored the effect of reduced sedentary time or sitting on musculoskeletal complaints. The introduction of a sit-stand workstation has resulted in reduced self-reported musculoskeletal pain for office workers and call centre employees (Davis et al., 2009; Hedge & Ray, 2004; Husemann et al., 2009) but some office workers have reported increased musculoskeletal pain when using a desktop sit-stand computer stand (Healy et al., 2013; Neuhaus et al., 2014).

The Transtheoretical Model of Behaviour Change (Marcus et al., 1992; Nigg, 2002) has been applied to understand physical activity adoption in a number of different settings (Hall & Rossi, 2008) and with different population groups (Hass & Nigg, 2009; Kirk, Mutrie, MacIntyre, & Fisher, 2004; Plotnikoff et al., 2013) including office workers (Titze et al., 2001). It is widely accepted that people move through a series of stages in order to change physical activity behaviour (Marshall & Biddle, 2001; Schumann et al., 2003). Five stages of change have been described: Precontemplation, individuals have no intention to start exercise; Contemplation, individuals intend to start exercise in the next 6 months; Preparation, individuals are exercising but not regularly; Action, is exercising regularly for less than 6 months and Maintenance, regular exercise for greater than 6 months (Marcus et al., 1992). There have been many validation studies that examine the level of physical activity at the various stages of behaviour change (Hall & Rossi, 2008; Schumann et al., 2003), but most research has used self-reported physical activity rather than objective measures of physical activity. To date, there does not appear to be any studies that have examined the effect of interventions to reduce sedentary behaviour on attitudes changes to physical activity adoption.

Despite the mounting evidence indicating the importance of occupational sedentary exposure, at the time Study 4 was initiated there was very limited evidence demonstrating the efficacy of workplace interventions to specifically reduce sedentary time and the pattern of sedentary time exposure. Therefore, this study aimed to determine:

1. If participatory workplace programmes could reduce total sedentary time and sustained sedentary time; increase the frequency of breaks in sedentary time (break rate); and increase the frequency of light activity and MVPA on work days, non-work days, during work hours, during non-work hours on work days and during total non-work time.
2. If intervention effects were consistent across the organisations participating in the study.
3. If a participatory workplace intervention that targeted 'active office' strategies was more effective at reducing total sedentary time and sustained sedentary time; increasing the frequency of breaks in sedentary time (break rate); and increase the frequency of light activity and MVPA on work days, non-work days, during work hours, during non-work hours on work days and during total non-work time, than a participatory workplace intervention targeting non-work activity (traditional physical activity intervention) and an office ergonomics participatory intervention.

4. If participatory workplace programmes change the distribution and lifestyle impacts of self-reported musculoskeletal pain, job satisfaction and self-reported work productivity.
5. If participation in participatory workplace programmes progress participants through the stages of behaviour change to increase physical activity.

Selected results from Study 4 have been published in:

Parry, S., Straker, L., Gilson, N. D. and Smith, A. J. (2013). "Participatory workplace interventions can reduce sedentary time for office workers - a randomised controlled trial." PLoS ONE **8**(11): e78957

Parry, S., Straker, L., Gilson, N. D. and Smith, A. J. (2013) "Can participatory workplace interventions aimed at changing sedentary time also reduce musculoskeletal symptoms in office workers?" Human Factors and Ergonomics Society of Australia Annual Conference December, 2013

10.0 Study 4 - Method

10.1 Study Design

Randomised controlled trial with three arms. The study was registered with the Australian New Zealand Clinical Trials Registry (ANZCTR number: ACTN12612000743864).

10.2 Participants

Office workers (clerical, data entry and call centre workers) were recruited from three government organisations in Perth, Western Australia. Office workers that participated in office bound/desk duties for six or more hours per day and working four or more days a week were invited to take part in the study. Volunteers were only excluded from participating in the study if they were unable to wear an accelerometer due to disability or if they were confined to a wheelchair.

10.2.1 Recruitment and randomisation

Organisations were invited directly to participate in the study. It was anticipated that some of the organisations that participated in Study 1 would continue and enrol in Study 4. However, none of the organisations were available to take part in another study. E-mail requests seeking organisations that were interested in being involved in an intervention study to reduce sedentary behaviour and promote workplace physical activity were sent to members of the Human Factors and Ergonomics Society of Australia (Western Australian branch). From this initial e-mail contact, the organisations were sourced.

To recruit participants within each participating organisation, workplace meetings at each organisation were arranged to discuss the study protocol and logistics of running the study. After the initial meeting with supervisors/

managers, human resources or occupational health staff, a research proposal was presented to each organisation's management. Following approval from management for each organisation, staff recruitment meetings were scheduled. Prior to the recruitment meetings, the three groups within each organisaton were randomly assigned, using simple randomisation (drawn from a hat 1:1:1 allocation ratio) into one of three interventions: A 'active office work' intervention, B 'traditional physical activity' or C 'office ergonomics' intervention.

A similar recruitment process to Study 1 occurred whereby potential participants attended a recruitment meeting that was scheduled into a regular monthly staff meeting. After management approval and before the scheduled recruitment meetings, each organisation identified 3 groups within the organisaton, based on physical proximity. At Organisaton 1, the groups were working on separate floors within the same building. At Organisaton 2, the groups were at distant locations on the same floor of a very large building and at Organisation 3, the 3 groups were at separate workplaces in different locations within the metropolitan region of Perth. Meetings were attended by all staff members and supervisors that worked together in a team (approximately 10-30 people). At the recruitment meeting, a detailed description of the study protocol and procedure was presented to the staff by the author. As the groups were already randomised, the explanation of the study related directly to the intervention that had been randomly assigned to the particular group. At the end of the recruitment meeting, all those attending the meeting were invited to participate in the study. In order to get sufficient volunteers, recruitment meetings were repeated so that final intervention groups consisted of participants from 2-3 work teams within each organisation. Volunteers were given 'Participant Information and Consent' form (Appendix M) to complete and asked to complete the baseline surveys (see below).

10.2.2 Ethics Statement

All participants provided informed consent and ethics approval was obtained from the Human Research Ethics Committee, Curtin University (HR20/2007).

10.3 Description of organisations

The three government organisations that participated in the study were all Commonwealth Government organisations and had many branches spread across Australia. The nature of the office work, work demands, culture and other organisational features varied between the organisations. Organisation 1 was mainly concerned with processing of large complicated files. At times, employees were required to make phone calls to verify information in documents that were being processed. Workers had a flexible work day and could manage their own working hours and breaks. Organisation 2 was a busy call centre that handled simple calls that lasted less than a minute to more long complicated calls that could last many minutes. Workers were scheduled 'data processing days' every 3-4 days to provide some job variation. In Organisation 2, all work meetings, work hours and breaks were scheduled from the national office located in another city resulting in very little autonomy or flexibility for the employees. Further, productivity and call volume as well as compliance with non-scheduled breaks were monitored daily and were reported on a weekly basis. Organisaton 3 was also a data processing centre where employees were required to process a set number of scanned documents each day. If needed, workers were also required to make out-going calls to clarify details of documents that were being processed and to assist in the call centre. Work hours, breaks and meetings were scheduled on site and were strictly controlled. Work productivity and compliance were also monitored in this organisation.

10.4 Description of interventions

Groups allocated to Intervention A, 'active office work' developed workplace interventions with the aim of modifying the way that office workers completed their work tasks by increasing incidental (light intensity) office activity and reducing the amount of sedentary time during work hours. In addition, Intervention A aimed to alter the pattern of exposure of sedentary time by encouraging regular breaks in sustained sedentary periods. Participants in Intervention A also had access to a single 'Active Workstation' at their workplace which consisted of an electronically height adjustable desk that had an integrated treadmill (A7TR78928H, Steelcase, Sydney, Australia; Organisations 1 and 3) or a treadmill and upright stationary cycle ergometer (LF-2850, Exertec Air Bike, Pennsylvania, USA; Organisation 2) (Appendix N: Photos of Active Workstation). Participants had individual coaching about how to safely use the Active Workstation. Participants were advised to use the Active Workstation for short periods several times throughout the day, commencing with 10 minutes and slowly building up to 30 minutes per session. Group leaders assisted where necessary to timetable use of the Active Workstation. The workstation was equipped with a computer terminal and telephone so that normal work duties could be performed while using the Active Workstation, participants just needed to log onto the computer provided.

Groups allocated to Intervention B, 'traditional physical activity' focused on developing strategies to promote light and moderate intensity physical activity in breaks between productive work periods (coffee and lunch breaks) and encourage the use of active transport before and after work. Participants in Intervention B were all provided with a pedometer (Yamix Digi-walker SW700, Tokyo, Japan) to monitor their daily steps and as a motivational tool. Intervention C 'office ergonomics', focused on computer workstation design and setup, 'active' sitting (gently moving while sitting) and breaking up seated computer tasks. Participants in Intervention C had access to an 'air cushion' that could be placed on their regular chair to encourage active sitting. The intention was for this condition to provide an active control comparison. Table 10.1 lists the intervention details as determined by the intervention groups following the workplace meetings.

Table 10.1: List of interventions determined by each intervention group

*** Interventions common across intervention groups**

Intervention A **Active office work**	Intervention B **Traditional physical activity**	Intervention C **Office ergonomics**
Active Workstation: aim for all volunteers to have 30 minutes daily access	**Pedometer Challenge:** increase walking during the work day	**“Active” sitting:** spending some time perching on edge of chair, encouraging movement during sitting
Standing or exercises between calls/document processing*	Promote active transport -walk instead of bus	Taking breaks from sitting*
Walk and talk meetings*	Walk and talk meetings*	Standing meetings*
Active e-mails – personally delivering information rather than sending an e-mail*	Short frequent walks during breaks, lunchtime, to and from work*	Use of “piano stool” – reinforcing active sitting
Increase incidental activity in and around workplace – take longer routes to printer, scanner etc	Increase use of stairs	Use of air cushion

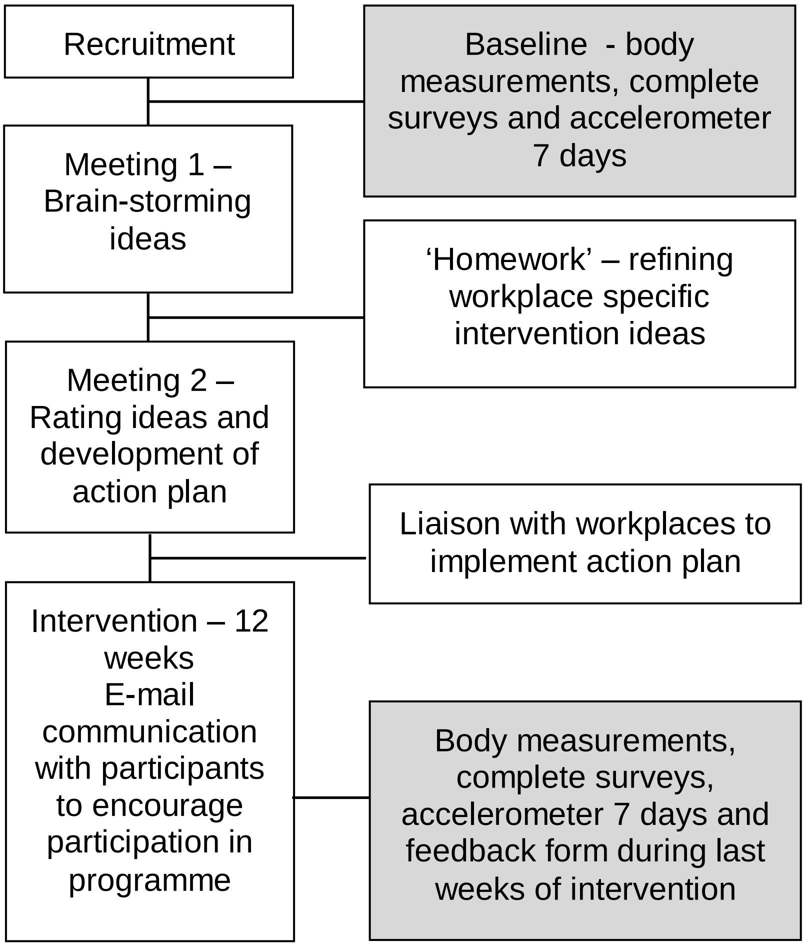
10.5 Procedure

Participants from all three intervention groups were asked to attend two structured meetings at their workplace in order to discuss and develop interventions. A participatory approach to intervention development was used (Straker et al., 2004) to deliver interventions that were tailored to the specific needs of the workplace and the employee participants had ownership of the intervention. Prior to the first workplace meeting, baseline body measurements (height, weight and waist girth) were taken and participants were asked to complete the IPAQ (www.ipaq.ki.se), modified Nordic Musculoskeletal Questionnaire (Dickinson et al., 1992; Kuorinka et al., 1987), Warr-Cook-Wall Job Satisfaction Survey (Warr et al., 1979), modified Health and Work Performance Questionnaire (Kessler et al., 2003) (outlined below and in Study 1) and Readiness for Physical Activity survey (Marcus et al., 1992) and to wear an Actigraph GT3X (ActiGraph, Pensacola, USA) accelerometer for 7 days (Troiano et al., 2008). The accelerometer was set to record data using a 60 second epoch (Welk et al., 2004) and attached with an elastic belt to be worn over the right hip (Welk, 2002) for all waking hours. Activities, accelerometer wear time, any time periods that the accelerometer was removed (e.g. bathing, swimming or contact sports), waking hours and most importantly, work hours (from the time seated at a desk/workstation until leaving the workplace) were recorded in a simple activity diary (Appendix G). Participants were given full written instructions about how to correctly wear the accelerometer and complete the activity diary (Appendix F).

All participants were encouraged to attend both structured work meetings. The first meeting reviewed the study background and procedure of the study which was then followed by a 'brain storming' exercise where participants put forward options to promote their specific intervention (active office, traditional physical activity and office ergonomics). Participants were encouraged to think broadly about specific strategies and were then given a 'homework' sheet to complete detailing any further ideas that had not yet been discussed (Appendix O). Those unable to attend the meeting were e-mailed the hand-outs provided to all the participants, which summerised the contents of the meeting. During the second meeting, participants shared their ideas and rated the potential strategies in terms of feasibility to implement and perceived effectiveness of the intervention. For example, one group in Intervention B suggested that the workplace should provide a table tennis table in a common area that could be used by all staff during work hours. The feasibility was rated as fair because even though the organisation would not provide the table tennis table, the social club had funds that could purchase a table. However, the effectiveness to the group was ranked as low, as very few participants were interested in playing table tennis during work hours. At the end of the second meeting, an action plan was developed and communicated to the team leaders and management to assist in implementation of the strategies.

Following the workplace meetings, there was e-mail correspondence with team leaders and managers to facilitate the purchase of equipment such as pedometers, stools and air cushions. The Active Workstation that was used by intervention Group A from each organisation was provided on-loan to each workplace from Curtin University and remained at each site for the duration of the intervention period. Within 4-6 weeks of the final meeting, all intervention strategies were in place and the intervention phase commenced. The intervention period lasted 12 weeks and throughout this period, in order to maintain contact and motivate participants, regular e-mails were sent to all participants by the author. The e-mails were tailored to each specific intervention condition (active office, traditional physical activity and office ergonomics). For example, participants in Intervention A were encouraged to use the Active Workstation or to increase inter-office incidental activity. Each intervention group was sent the same number of e-mails. During the last 2-3 weeks of the intervention, participants had body measurements taken, completed the surveys again, wore an accelerometer for a further 7 days and were asked to complete a simple feedback form (Appendix P) to assess participation rate as well as strengths and barriers for each specific intervention (see Figure 10.1).

Figure 10.1: Procedure diagram – recruitment, intervention and follow-up



10.6 Outcome measures

The primary outcome measures were total sedentary time and sustained sedentary time on work days, non-work days, work hours on work days, non-work hours on work days and total non-work time following the intervention period. Secondary outcomes included total light, MVPA, frequency of breaks in sedentary time on work days, non-work days, work hours on work days, non-work hours on work days and total non-work time. Further, changes in BMI, waist girth, distribution and impacts of self-reported musculoskeletal pain, work productivity, job satisfaction and attitude to physical activity following the intervention were also assessed.

10.6.1 Self-report measures

The modified Nordic Musculoskeletal Questionnaire (Kuorinka et al., 1987), Warr-Cook-Wall Job Satisfaction Survey (Warr et al., 1979) and Health and Performance Questionnaire (Kessler et al., 2003) described in Chapter 4 of this thesis were used again in Study 4. Participants were asked to complete surveys at baseline and following the intervention period. In addition, participants were asked to complete the following Readiness for Physical Activity Survey before and after the intervention, based on the 'Stages of Change' model (Marcus et al., 1992):

Which of the following statements best describes you? (please tick one)

☐ **I currently do not exercise, and do not intend to start exercising in the next 6 months**

☐ **I currently do not exercise, but I am thinking about starting exercise in the next 6 months**

☐ **I currently exercise some, but not regularly (3 or more times per week for 20 minutes or more each time)**

☐ **I currently exercise regularly (3 or more times per week for 20 minutes or more each time)**

☐ **I have exercised regularly in the past, but I am not doing so currently**

The 5 items in the survey represent the stages of change in attitude to physical activity - Precontemplation, Contemplation, Preparation, Action and Relapse.

For the purposes of analysis, the changes in the stages were described as "adopters", participants that progressed one or more stages; "stables", participants that did not regress or progress a stage and "relapsers", participants that regressed one or more stages (Titze et al., 2001).

10.6.2 Qualitative feedback

All participants were asked to complete a tailored feedback form following the intervention period. The feedback form asked participants about the frequency of participation in aspects of the intervention, best and worst aspects of the intervention and recommendations to other work groups. Completion of the form was optional (Appendix P).

10.7 Data processing

The Actigraph data were downloaded onto a research computer using the manufacturer provided *Actilife 5* software (Actilife Data Analysis Software, Pensacola Florida, USA). Activity count data were then processed using a custom program written in LabVIEW (v 8.6.1 National Instruments, Texas, USA). The same process of Exposure Variance Analysis (Mathiassen, 2006; Straker et al., 2014) was used for processing the activity counts as the one described for Study 1 (Chapter 4). The Freedson et al (1998) and Matthews et al (2008) count per minute cut points for sedentary (< 100 counts/min), light (100 ≤ 1951 counts/min), moderate (1951 ≤ 5275 counts/min) and vigorous (> 5275 counts/min) were used in the analyses. Activity bout durations (0≤5mins, 5≤10mins, 10≤30mins, 30≤60 mins and 60+ mins), minimum wear time (500 mins/day) (Jago et al., 2010; Steele et al., 2009), valid days (minimum 3 work days and 1 non-work day) (Trost et al., 2005; Ward et al., 2005) and non-wear time (120 minutes) were the same as used in Study 1. A break in sedentary time was defined as accelerometer counts above 100 counts/minute for greater than one minute during sedentary periods (Healy, Dunstan, Salmon, Cerin, et al., 2008), as used in Study 1.

10.8 Statistical Analysis

Independent t-tests or chi-squared tests assessed participant characteristics (age, BMI, gender and waist girth) and baseline activity levels between participants that completed the study with sufficient data and those who did not complete the study. One-way ANOVA or chi-squared tests compared baseline differences between organisations and between intervention groups. Repeated measures t-tests were used to test overall effect (changes in activity levels, BMI and waist girth) of any intervention for all participants. Linear regression models (ANCOVA) for each outcome were used to estimate the magnitude and corresponding 95% confidence intervals of intervention effects, with the post-intervention measures as the dependent variable, the 3-level categorical variables 'organisation' and 'intervention' as independent variables and the corresponding baseline measure as a covariate. This allowed intervention effects to be adjusted for differences between organisations. Activity analyses were calculated using percentage of wear time for each time period. McNemar test was used to assess changes in musculoskeletal pain, job satisfaction, work productivity and readiness for physical activity following the intervention period. All analyses performed using PASW Statistics 18, critical alpha level of 0.05.

11.0 Study 4 - Results

11.1 Participants

133 office workers (82% female) aged between 20 and 65 years (41.3 ± 11.0 years) with a BMI of 28.4 ± 6.4 kg/m^2 and waist girth of 92.6 ± 14.0 cm (male: 100.0 ± 13.7 cm; female 90.9 ± 13.7 cm) volunteered to participate in this study and completed the baseline measurements (Table 11.1).

Table11.1. Participant characteristics at baseline

	Conditions			
Variable	**Intervention A (n=49)**	**Intervention B (n=30)**	**Intervention C (n=54)**	**All Subjects (n=133)**
Age (mean years; [SD])	39.4 [11.2]	45.2 [11.6]	40.8 [10.1]	41.3 [11.0]
Gender (n (% female))	36 (74)	25 (83)	48 (89)	109 (82)
BMI (mean; [SD])	28.0 [5.1]	28.4 [6.5]	28.7 [7.4]	28.4 [6.4]
Waist girth (cm [SD])	91.9 [13.0]	92.7 [16.3]	93.3 [13.7]	92.6 [14.0]

28 participants withdrew from the study during or after the workplace meetings and therefore did not continue with the workplace intervention. In addition, 14 participants did not want to complete the follow up analysis (body measurements and wearing accelerometer), 3 sets of accelerometer data were damaged due to equipment failure and 2 participants moved workplaces. 24 data sets did not have sufficient work or non-work days to be included in the analyses. Figure 11.1 shows the flow of the participants into the intervention groups by organisation at baseline allocation, follow up and analysis. As shown in Figure 11.1, 62 participants (82% female; 43.5 ± 6.4 years; BMI 28.0 ± 6.4 kg/m^2; waist girth: male 96.8 ± 8.0 cm; female 90.3 ± 13.0 cm) had complete data sets and were included in the analyses (Table 11.2). There was no significant difference in BMI, waist girth, time in baseline activity on work days, non-work days and during work hours between those included in the analyses

and those not included. However, participants not included in the analyses were significantly younger and wore their accelerometers for less time on work days and non-work days (Table 11.2).

Figure 11.1. Distribution of participants by intervention group and organisation at baseline, follow-up and analysis

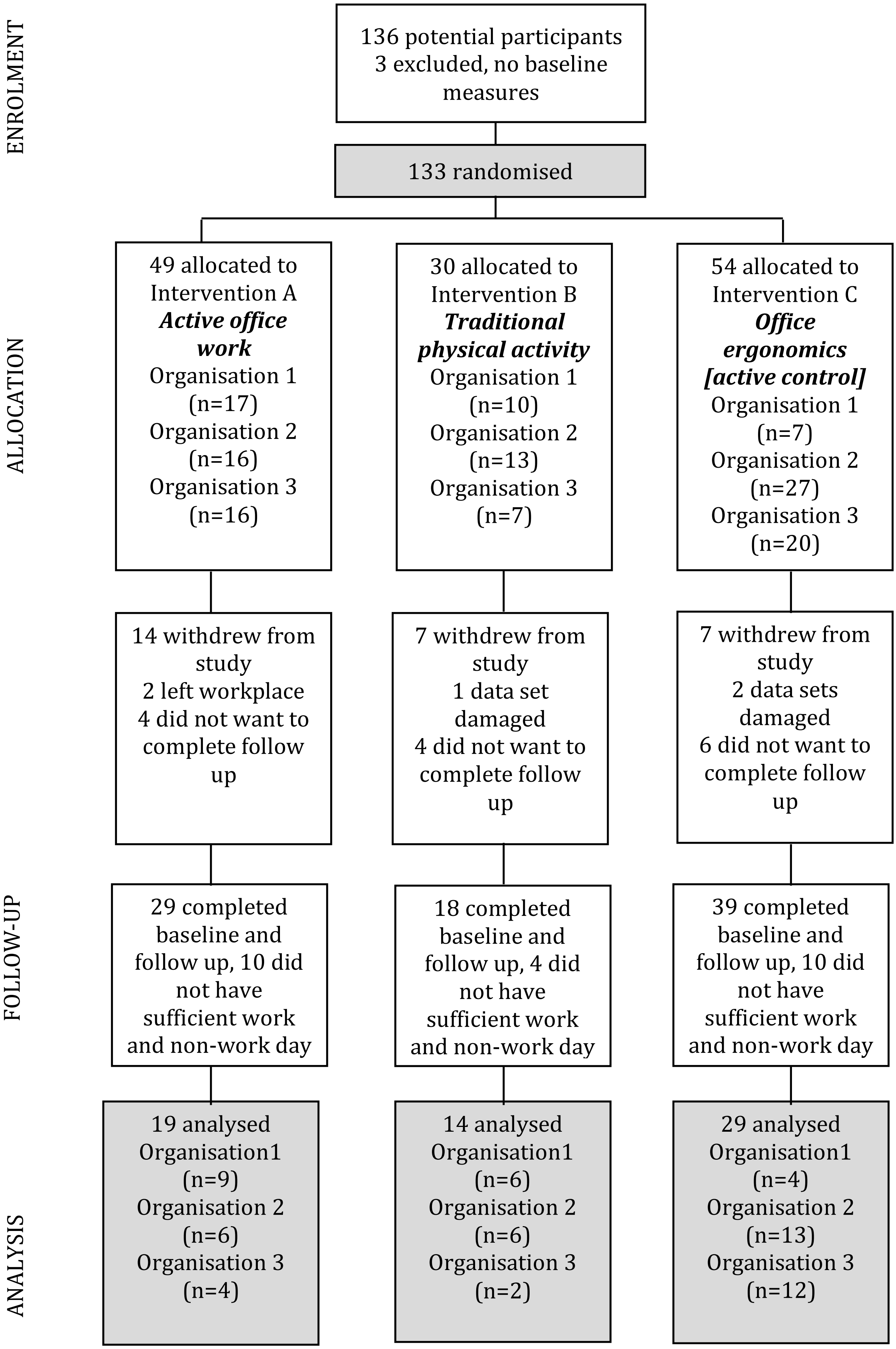


Table 11.2. Comparison of participant characteristics and activity levels at baseline between participants that were analysed and those not included in analysis

Variable	Analysed Participants (n=62)	Non-analysed Participants (n=71)	Mean Change	95% CI	P for group comparison
Age (mean years; [SD])	43.5 [9.5]	39.3 [11.9]	-4.2	-7.9, -0.4	0.029
Gender (n (%) female)	50 (81)	59 (83)	-2.5	-11, 16	0.714
BMI (mean kg/m2; [SD])	28.0 [6.4]	28.7 [6.4]	0.7	-1.7, 2.8	0.550
Waist girth - male (cm; [SD])	96.8 [8.0]	103.6 [16.6]	6.5	-4.4, 18.0	0.219
Waist girth - female (cm; [SD])	90.3 [13.0]	91.4 [14.4]	1.0	-4.7, 6.5	0.695
Wear time work day (mean mins; [SD])	921.9 [83.8]	862.5 [87.3]	-59.3	-88.8, -29.9	<0001
Wear time non-work day (mean mins; [SD])	835.6 [95.4]	797.9 [83.5]	-37.7	-70.4, -5.1	0.024
Wear time work hours (mean mins; [SD])	501.8 [65.3]	495.7 [42.8]	-6.1	-24.8, 12.6	0.521
Sedentary time work day (%wear time; [SD])	72.85 [7.06]	72.50 [6.50]	-0.36	-2.68, 1.97	0.762
Light time work day (%wear time; [SD])	23.85 [6.37	23.93 [6.00]	0.94	-2.04, 2.20	0.939
MVPA work day (%wear time; [SD])	3.30 [1.83]	3.57 [2.05]	0.42	-0.39, 0.94	0.419
Break rate work day (breaks/sed hr; [SD])	7.81 [2.45]	7.96 [2.64]	0.15	0.73, -1.02	0.744
Sedentary time non-work day (%wear time; [SD])	63.71 [9.97]	64.29 [10.28]	0.55	-3.12, 4.23	0.767
Light time non-work day (%wear time; [SD])	33.51 [9.45]	32.81 [9.88]	-0.71	-4.22, 2.81	0.691
MVPA non-work day (%wear time; [SD])	2.78 [2.61]	2.94 [2.42]	0.16	-0.76, 1.07	0.735
Break rate non-work day (breaks/sed hr; [SD])	9.86 [3.13]	10.14 [3.51]	0.28	0.92, -1.49	0.642
Sedentary time work hours (%wear time; [SD])	78.29 [8.41]	76.87 [9.12]	-1.41	-4.44, 1.61	0.357
Light time work hours (%wear time; [SD])	19.14 [7.75]	20.74 [8.13]	1.60	-1.14, 4.33	0.249
MVPA work hours (%wear time; [SD])	2.60 [1.67]	2.38 [1.80]	-0.19	-0.78, 0.41	0.543
Break rate work hours (breaks/sed hr; [SD])	6.95 [3.20]	7.64 [3.53]	0.69	0.47, -1.85	0.785

11.2 Sedentary time, light activity and MVPA following the intervention period

11.2.1 Intervention effect across all participants: Accelerometer determined sedentary time, sustained sedentary time, light activity, MVPA and break rate on work days, non-work days, work hours on work days, non-work hours on work days and total non-work time

Sedentary time, sustained sedentary time, break rate, light intensity activity and MVPA before and after the intervention period for all participants are presented in Table 11.3. Figure 11.2 illustrates the changes in sedentary time, sustained sedentary time and break rate for all participants before and after the intervention on work days and during work hours.

There was a significant reduction in the percentage of sedentary time on work days (-1.60% wear time, $t = 2.87$, df_{61}, $p = 0.006$), during work hours (-1.71% wear time, $t = 2.54$, df_{61}, $p = 0.014$) (Figure 11.2(a)) and during non-work hours on work days (-1.93% wear time, $t = 2.56$, df_{61}, $p = 0.013$) (Table 11.3). The estimated increase of 0.26% in sedentary time on non-work days and 0.40% reduction in sedentary time during total non-work periods were not statistically significant (Table 11.3). The reduction in sedentary time on work days of 1.60% is equivalent to 14 less sedentary minutes on work days and the reduction in sedentary time during work hours of 1.71% is equivalent to 8 less sedentary minutes during work hours.

The estimated reduction in sustained sedentary time on work days (2.08%), during work hours (3.24%) (Figure 11.2(b)) and during non-work hours on work days (0.98%) were not statistically significant. Similarly, the estimated increase in sustained sedentary time on non-work days (0.92%) and during total non-work periods (0.24%) were also not statistically significant (Table 11.3).

Table 11.3: Sedentary time, sustained sedentary time (bouts>30 mins), break rate (breaks/sedentary hour), light activity and MVPA for all participants before and after intervention on work days, non-work days, work hours on work days, non-work hours on work days and total non-work time

Outcome measures	Baseline (% wear time ± SD)	Post-intervention (% wear time ± SD)	Mean Change	95% CI	P
Sedentary time					
Work days	72.85 ± 7.06	71.25 ± 7.27	-1.60	-0.48, -2.72	0.006
Non-work days	63.71 ± 9.97	63.97 ± 10.57	0.26	-3.00, 2.48	0.849
Work hours on work days	78.29 ± 8.41	76.6 ± 8.6	-1.71	-0.37, -3.06	0.014
Non-work hours on work days	66.33 ± 7.54	64.40 ± 7.98	-1.93	-0.42, -3.44	0.013
Total non-work	64.60 ±8.47	64.20 ± 9.05	-0.40	1.63, -2.43	0.694
Sustained Sedentary time					
Work days	24.37 ± 12.73	22.29 ± 13.16	-2.08	0.47, -4.62	0.108
Non-work days	18.04 ± 11.82	18.96 ± 11.95	0.92	-4.21, 2.38	0.582
Work hours on work days	28.98 ± 19.34	25.74 ± 18.66	-3.24	0.63, -7.11	0.099
Non-work hours on work days	18.75 ± 10.03	17.77 ± 10.81	-0.98	1.57, -3.52	0.445
Total non-work	18.42 ± 9.99	18.66 ± 10.45	0.24	2.77, -2.30	0.852
Break rate					
Work days	7.81 ± 2.45	8.45 ± 2.86	0.64	1.08, 0.20	0.005
Non-work days	9.86 ± 3.13	9.93 ± 3.30	0.07	-0.85, 0.71	0.850
Work hours on work days	6.95 ± 3.20	7.67 ± 3.41	0.72	1.29, 0.15	0.015
Light time					
Work days	23.85 ± 6.37	24.81 ± 6.48	0.97	2.11, -0.18	0.098
Non-work days	33.51 ± 9.48	33.42 ± 9.98	-0.09	-2.43, 2.62	0.943
Work hours on work days	19.14 ± 7.75	20.63 ± 7.86	1.49	2.87, 0.10	0.036
Non-work hours on work days	29.50 ± 7.06	30.18 ± 7.03	0.68	2.12, -0.75	0.346
Total non-work	32.17 ± 8.06	32.35 ± 8.52	0.18	2.07, -1.71	0.848
MVPA					
Work days	3.29 ± 1.83	3.93 ± 2.34	0.64	1.13, 0.14	0.012
Non-work days	2.78 ± 2.61	3.93 ± 2.34	1.15	2.01, 0.30	0.009
Work hours on work days	2.57 ± 1.83	2.79 ± 1.83	0.22	0.69, -0.24	0.334
Non-work hours on work days	4.18 ± 2.93	5.43 ± 3.91	1.25	2.21, 0.29	0.011
Total non-work	3.23 ± 2.21	3.45 ± 2.28	0.22	0.91, -0.47	0.529

There was a significant increase in the break rate for all participants on work days (0.64 breaks/sed hour, t = -2.90, df_{61}, p = 0.005), during work hours (0.72 breaks/sed hour, t = -2.52, df_{61}, p = 0.015) (Figure 11.2(c)) and during non-work hours on a work day (0.71 breaks/sed hour, t = -2.46, df_{61}, p = 0.017) (Table 11.3).

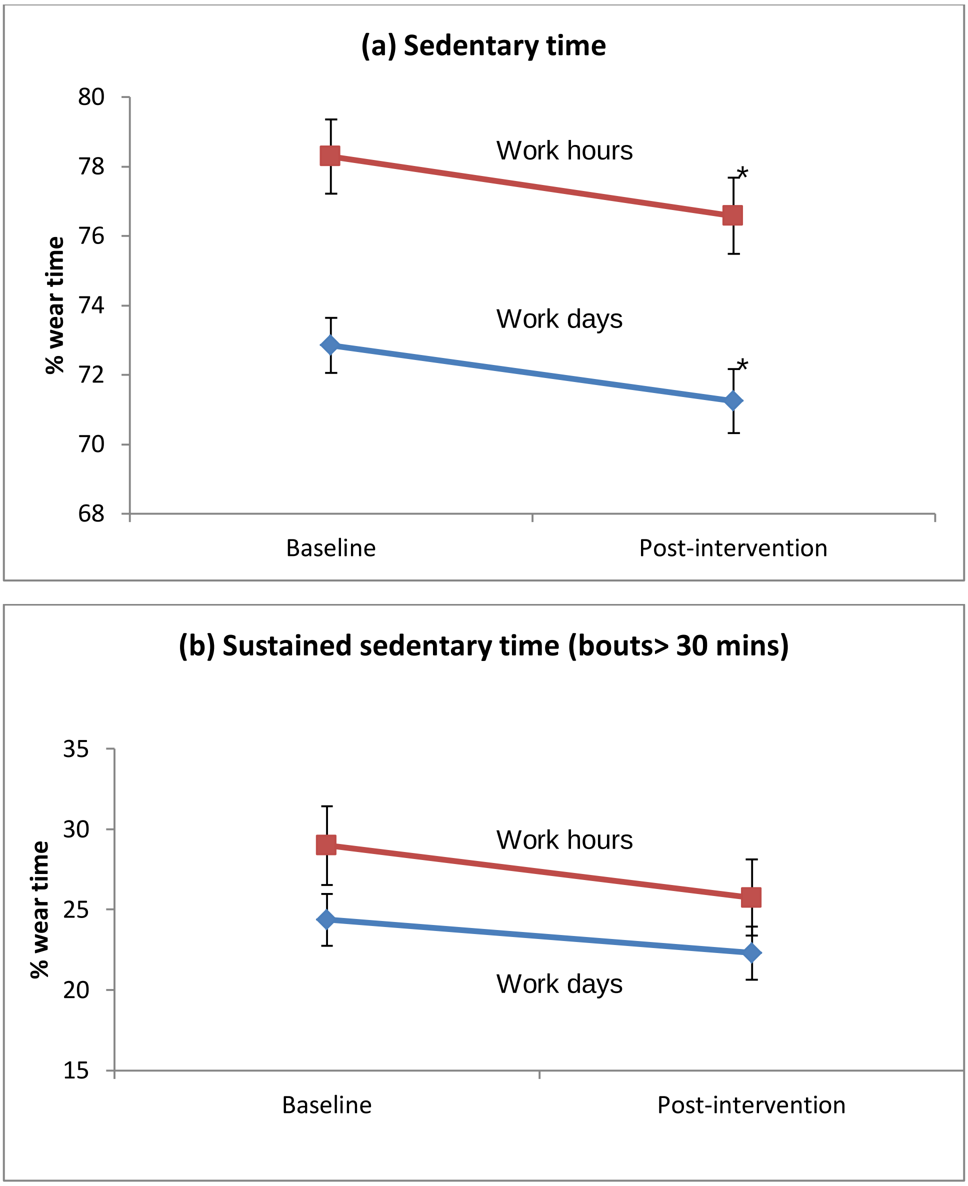
There was a significant increase in the percentage of light activity during work hours (1.49% wear time, t = -2.15, df_{61}, p = 0.036). However, the estimated increases in light activity on work days (0.97%), non-work hours on work days (0.71%) and during total non-work time (0.26%) were not statistically significant. Similarly, the estimated reduction in light activity (0.09%) on non-work days was not statistically significant (Table 11.3). The 1.49% increase in light activity during work hours is equivalent to 7 more light intensity minutes during work hours.

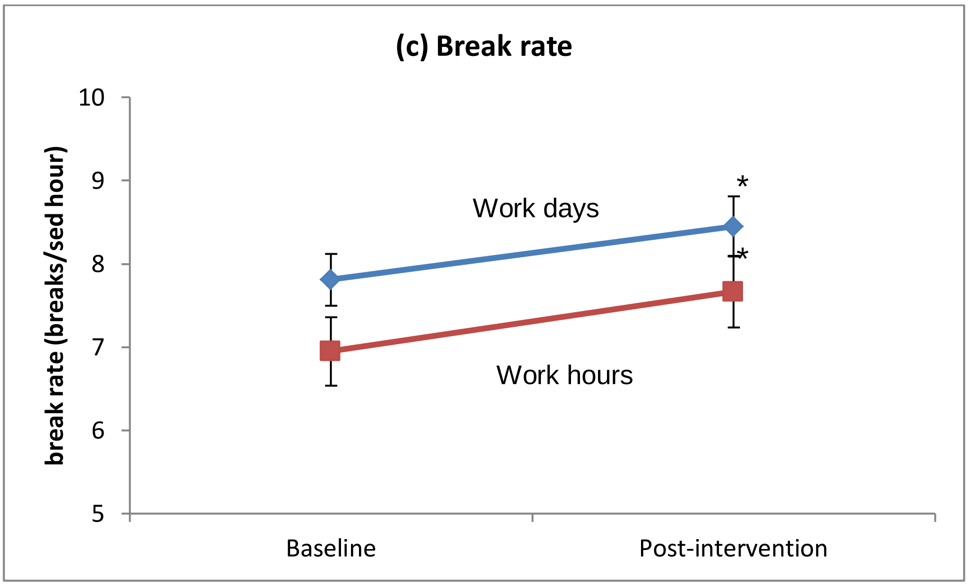
There was a significant increase in MVPA on work days (0.64% wear time, t = -2.58, df_{61}, p = 0.012), non-work days (1.15% wear time, t = -2.69, df_{61}, p = 0.009) and non-work hours on a work day (1.25% wear time, t = -2.61, df_{61}, p = 0.011). The estimated increases in MVPA during work hours (0.22%) and total non-work time (0.22%) were not statistically significant (Table 11.3).

The results and discussion comparing self-reported sitting time and total MVPA (bouts > 10 mins) over a whole week are presented in Appendix Q of this thesis.

In summary, when considering all participants, following the intervention period, there was a significant reduction in sedentary time on work days, during work hours and during non-work hours on work days; there was a significant increase in the break rate on work days, during work hours and during non-work hours on work days; there was a significant increase in light activity during work hours and a significant increase in MVPA on work days, non-work days and non-work hours on work days.

Figure 11.2: Sedentary time (a), sustained sedentary time (b) and break rate (c) on work days and during work hours for all participants at baseline and following the intervention (mean ± SE); * p < 0.05





11.2.2 Effects between organisations: Accelerometer determined sedentary time, sustained sedentary time, light activity, MVPA and break rate on work days, non-work days, work hours on work days, non-work hours on work days and total non-work time

At baseline, there were no significant differences between the participants in the different organisations for BMI ($F_{2,59}$ = 0.07, p = 0.936), age ($F_{2,59}$ = 0.47, p = 0.629) and gender (χ^2= 0.31, p=0.856). However, there were significant differences between the three organisations for wear time during work hours ($F_{2,59}$ = 5.02, p = 0.010), sedentary time on work days ($F_{2,59}$ = 4.11, p = 0.021) and during work hours ($F_{2,59}$ = 3.80, p = 0.028), MVPA on work days ($F_{2,59}$ = 7.10, p = 0.002) and during work hours ($F_{2,59}$ = 5.02, p = 0.010) and break rate during work hours ($F_{2,59}$ = 3.18, p = 0.049) (Table 11.4). Therefore linear regression analyses, adjusted for organisation and baseline measures, were used to assess intervention effects between the organisations.

Table 11.4: Comparison of participant characteristics and activity levels at baseline between participants from the 3 Organisations

Variable	Org 1 (n=19)	Org 2 (n=25)	Org 3 (n=18)	P for group comparison
Age (mean years; [SD])	41.7 [9.4]	44.0 [10.1]	44.6 [9.2]	0.629
Gender (n (%) female)	15 (79)	21 (84)	14 (78)	0.856
BMI (mean kg/m2; [SD])	28.6 [4.9]	27.9 [7.5]	28.1 [6.7]	0.936
Waist girth - male (cm; [SD])	99.5 [9.3]	96.0 [10.2]	94.8 [8.0]	0.727
Waist girth - female (cm; [SD])	92.6 [11.1]	88.6 [14.7]	91.3 [15.2]	0.691
Wear time work day (mean mins; [SD])	953.9 [65.9]	895.2 [66.8]	925.0 [109.9]	0.067
Wear time non-work day (mean mins; [SD])	857.5 [71.9]	821.5 [113.8]	832.1 [89.7]	0.463
Wear time work hours (mean mins; [SD])	530.9 [48.4]	473.3 [75.4]	510.7 [50.7]	0.010
Sedentary time work day (%wear time; [SD])	70.9 [7.0]	71.6 [7.6]	76.7 [4.8]	0.021
Light time work day (%wear time; [SD])	25.5 [6.7]	24.4 [6.9]	21.3 [4.4]	0.106
MVPA work day (%wear time; [SD])	3.6 [1.7]	4.0 [1.9]	2.1 [1.2]	0.002
Break rate work day (breaks/sed hr; [SD])	8.4 [2.5]	8.2 [2.7]	6.6 [1.5]	0.031
Sedentary time non-work day (%wear time; [SD])	63.1 [9.0]	65.7 [10.0]	61.5 [10.8]	0.404
Light time non-work day (%wear time; [SD])	34.1 [9.2]	31.5 [9.3]	35.6 [10.0]	0.366
MVPA non-work day (%wear time; [SD])	2.7 [1.7]	2.8 [2.2]	2.8 [3.8]	0.997
Break rate non-work day (breaks/sed hr; [SD])	10.0 [3.4]	9.7 [3.0]	9.9 [3.2]	0.946
Sedentary time work hours (%wear time; [SD])	75.5 [8.4]	77.4 [9.3]	82.5 [5.3]	0.028
Light time work hours (%wear time; [SD])	21.5 [8.4]	19.7 [8.4]	15.9 [4.9]	0.078
MVPA work hours (%wear time; [SD])	3.0 [1.4]	3.0 [2.0]	1.6 [1.0]	0.010
Break rate work hours (breaks/sed hr; [SD])	7.8 [3.3]	7.4 [3.6]	5.4 [1.9]	0.049

After adjusting for baseline measures and type of intervention, pre- to post-intervention changes in sedentary time, sustained sedentary time, light activity, MVPA and break rate for work days, non-work days, work hours, work hours on work days and for total non-work time, it was found that sedentary time during work hours differed by organisation with Organisation 1 responding most to interventions and Organisation 3 responding least (Table 11.5(i)). It was estimated that the reduction in sedentary time (% wear time) during work hours (adjusted for type of intervention and baseline sedentary time) was -4.07, -1.26 and 0.14 for Organisations 1, 2 and 3 respectively; which equated to an adjusted difference of 2.80 (95%CI:-0.75, 6.36, p=0.120) between Organisations 1 and 2, and 4.21 (95%CI: 0.66, 7.76, p=0.021) between Organisations 1 and 3 (Table 11.5(i)). It was also found that MVPA differed by organisation during work hours. It was estimated that the increase in MVPA (% wear time) during work hours (adjusted for type of intervention and baseline MVPA) was 0.97, 0.42 and -0.53 for Organisations 1, 2 and 3 respectively; which equated to an adjusted difference of -0.27 (95%CI:-1.39, 0.85, p=0.630) between Organisations 1 and 2, -1.21 (95%CI: -2.26, -0.17, p=0.024) between Organisations 1 and 3 and -0.94 (95%CI: -1.84,-0.04,p=0.040) between Organisations 2 and 3 (Table 11.5(ii)).

In summary, following the intervention period, both sedentary time and MVPA during work hours differed significantly by organisation with participants in Organisation 1 responding most to the interventions.

Table 11.5(i): Results of multivariable linear regression analysis for sedentary time, sustained sedentary time and break rate during work hours

Outcome measures	Adjusted Pre- to post- intervention change[1] (95% CI)	Group Differences in change (REF - group) (β(95% CI))	P
Sedentary time work hours (% wear time)			
Intervention			0.325[2]
Active Office - A	-3.09 (-5.82,-0.35)	REF	
Physical Activity - B	-0.57 (-3.54,2.40)	-2.52 (-6.84,1.80)	0.248
Office Ergonomics - C	-1.37 (-2.86,-0.13)	-1.72 (-4.94,1.50)	0.289
Organisation			0.043[2]
Organisation 1	-4.07 (-6.70,-1.43)	REF	
Organisation 2	-1.26 (-3.32,-0.79)	2.80 (-0.75,6.36)	0.120
Organisation 3	0.14 (-1.71,2.00)	4.21 (0.66,7.76)	0.021
Sustained sedentary time (sedentary bouts> 30 mins) work hours (% wear time)			
Intervention			0.485[2]
Active Office - A	-2.87 (-9.23,3.49)	REF	
Physical Activity - B	1.17 (-7.24,9.58)	-4.04 (-15.55,7.48)	0.486
Office Ergonomics - C	-5.60 (-10.29,-0.91)	2.73 (-5.22,0.69)	0.495
Organisation			0.046[2]
Organisation 1	-8.64 (-14.65,-2.64)	REF	
Organisation 2	-3.84 (-9.03,1.35)	4.81 (-2.81,12.43)	0.212
Organisation 3	3.31 (-3.49,10.11)	11.95 (2.55,21.35)	0.014
Break Rate (breaks/ sedentary hour) work hours			
Intervention			0.382[2]
Active Office - A	0.85 (-0.33,2.02)	REF	
Physical Activity - B	0.02 (-1.14,1.18)	0.83 (-0.95,2.61)	0.355
Office Ergonomics - C	0.97 (0.24,1.69)	-0.12 (-1.57,1.33)	0.871
Organisation			0.058[2]
Organisation 1	1.75 (0.72,2.78)	REF	
Organisation 2	0.45 (-0.51,1.42)	-1.30 (-2.82,0.22)	0.094
Organisation 3	-0.01 (-0.86,0.84)	-1.76 (-3.20,-0.31)	0.018

[1] Intervention estimates adjusted for baseline and organisation, Organisation estimates adjusted for baseline and intervention
[2]Omnibus p-value for overall group difference

Table 11.5(ii): Results of multivariable linear regression analysis for light and moderate/vigorous physical activity time during work hours

Outcome measures	Adjusted Pre- to post- intervention change[1] (95% CI)	Group Differences in change (REF - group) (β(95% CI))	P
Light activity work hours (% wear time)			
Intervention			0.616[2]
Active Office - A	2.53 (-0.42,5.49)	REF	
Physical Activity - B	0.29 (-2.75,3.33)	2.24 (-2.31,6.80)	0.328
Office Ergonomics - C	1.38 (-0.06,2.81)	1.16 (-2.23,4.54)	0.497
Organisation			0.124[2]
Organisation 1	3.57 (0.84,6.29)	REF	
Organisation 2	1.07 (-1.12,3.27)	-2.50 (-6.26,1.26)	0.189
Organisation 3	-0.14 (-1.95,1.68)	-3.71 (-7.30,-0.11)	0.044
Moderate-vigorous activity work hours (% wear time)			
Intervention			0.136[2]
Active Office - A	0.97 (0.06,1.88)	REF	
Physical Activity - B	0.04 (-0.89,0.98)	0.93 (-0.47,2.33)	0.189
Office Ergonomics - C	-0.17 (-0.66,0.31)	1.15 (0.02,2.27)	0.047
Organisation			0.032[2]
Organisation 1	0.69 (-0.14,1.51)	REF	
Organisation 2	0.42 (-0.28,1.11)	-0.27 (-1.39,0.85)	0.630
Organisation 3	-0.53[3] (-1.03,-0.02)	-1.21 (-2.26,-0.17)	0.024

[1] Intervention estimates adjusted for baseline and organisation, Organisation estimates adjusted for baseline and intervention
[2]Omnibus p-value for overall group difference
[3]Also significantly different to Organisation 2 by -0.94 (95%CI: -1.84,-0.04,p=0.040)

11.2.3 Effects between interventions: Accelerometer determined sedentary time, sustained sedentary time, light activity, MVPA and break rate on work days, non-work days, work hours on work days, non-work hours on work days and total non-work time

There were no significant differences in BMI ($F_{2,59}$ = 0.28, p = 0.754), age ($F_{2,59}$=0.03, p=0.969), gender (χ^2= 4.25, p=0.119) or wear time during work hours ($F_{2,59}$=2.71, p=0.075) between participants in the three intervention groups. However, there were significant differences between the intervention groups at baseline in sedentary time ($F_{2,59}$ = 4.93, p = 0.010), light intensity activity ($F_{2,59}$ = 3.52, p = 0.036), MVPA ($F_{2,59}$ = 3.51, p = 0.036) and break rate ($F_{2,59}$ = 5.31, p = 0.008) on work days and in sedentary time ($F_{2,59}$ = 4.21, p = 0.020), light intensity activity ($F_{2,59}$ = 3.41, p = 0.040) and break rate ($F_{2,59}$ = 5.16, p = 0.009) during work hours (Table 11.6). Therefore linear regression analyses, adjusted for organisation and baseline measures, were used to assess differences in the effect of type of intervention.

Table 11.6: Comparison of participant characteristics and activity levels at baseline between participants from the 3 intervention groups

Variable	Active Office A (n=19)	Physical Activity B (n=14)	Office Ergonomics C (n=29)	P for group comparison
Age (mean years; [SD])	43.2 [9.7]	44.0 [9.8]	43.4 [9.6]	0.969
Gender (n (%) female)	13 (68)	12 (86)	25(86)	0.269
BMI (mean kg/m2; [SD])	28.4 [5.7]	27.0 [4.7]	28.6 [7.6]	0.754
Waist girth - male (cm; [SD])	98.4 [9.6]	97.8 [7.4]	93.8 [6.8]	0.623
Waist girth - female (cm; [SD])	88.7 [8.5]	88.3 [11.7]	92.4 [16.7]	0.623
Wear time work day (mean mins; [SD])	935.6 [73.8]	917.2 [73.1]	915.1 [95.59]	0.697
Wear time non-work day (mean mins; [SD])	861.3 [89.7]	827.8 [94.3]	822.5 [99.4]	0.369
Wear time work hours (mean mins; [SD])	497.8 [59.2]	535.8 [45.3]	488.1 [72.8]	0.075
Sedentary time work day (%wear time; [SD])	68.9 [7.50]	74.9 [6.6]	74.5 [6.6]	0.010
Light time work day (%wear time; [SD])	27.0 [6.7]	22.3 [4.8]	22.5 [6.4]	0.036
MVPA work day (%wear time; [SD])	4.2 [1.9]	2.8 [1.4]	3.0 [1.8]	0.036
Break rate work day (breaks/sed hr; [SD])	9.2 [2.4]	7.0 [2.2]	7.3 [2.2]	0.008
Sedentary time non-work day (%wear time; [SD])	60.0 [10.0]	65.8 [8.5]	65.1 [10.2]	0.152
Light time non-work day (%wear time; [SD])	36.8 [9.5]	32.0 [8.4]	32.1 [9.7]	0.152
MVPA non-work day (%wear time; [SD])	3.2 [1.7]	2.2 [1.4]	2.8 [1.4]	0.577
Break rate non-work day (breaks/sed hr; [SD])	11.1 [3.1]	9.2 [2.9]	9.4 [3.2]	0.120
Sedentary time work hours (%wear time; [SD])	73.9 [9.8]	80.7 [5.9]	80.0 [7.5]	0.020
Light time work hours (%wear time; [SD])	22.8 [9.3]	16.9 [5.1]	17.8 [7.0]	0.040
MVPA work hours (%wear time; [SD])	3.3 [1.8]	2.5 [1.7]	2.1 [1.5]	0.050
Break rate work hours (breaks/sed hr; [SD])	8.8 [3.5]	5.9 [2.5]	6.3 [2.9]	0.009

There were no differences between interventions for sedentary time, sustained sedentary time, breaks and light physical activity on work days. For MVPA on work days it was estimated that Interventions A, B and C resulted in an increase in MVPA (% wear time) on work days (adjusted for organisation and baseline MVPA) of 1.36, 1.06 and -0.16 for interventions A, B and C respectively; the adjusted difference of -1.52 between A and C (95%CI: -2.69, -0.35, $p = 0.012$) was significant but the adjusted difference between A and B of 0.30 (95%CI: -1.07, 1.67, $p = 0.665$) was not significant (Table 11.7 (i) and (ii)).

Table 11.7 (i): Results of multivariable linear regression analysis for sedentary time, sustained sedentary time and break rate on work days

Outcome measures	Adjusted Pre- to post- intervention change[1] (95% CI)	Group Differences in change (REF - group) (β(95% CI))	P
Sedentary time work days (% wear time)			
Intervention			0.207[2]
Active Office - A	-3.19 (-5.26,-1.12)	REF	
Physical Activity - B	-0.75 (-3.12,1.62)	-2.44 (-5.64,0.76)	0.132
Office Ergonomics - C	-0.96 (-2.62,0.70)	2.24 (-0.53,5.00)	0.111
Organisation			0.508[2]
Organisation 1	-2.57 (-4.56,-0.59)	REF	
Organisation 2	-1.55 (-3.32,-0.21)	-1.02 (-3.70,1.66)	0.447
Organisation 3	0.78 (-3.03,1.47)	1.80 (-4.90,1.31)	0.251
Sustained sedentary time (sedentary bouts> 30 mins) work days (% wear time)			
Intervention			0.323[2]
Active Office - A	-3.70 (-8.26,0.87)	REF	
Physical Activity - B	1.38 (-3.89,6.64)	-5.07 (-12.10,1.95)	0.154
Office Ergonomics - C	-2.60 (-6.29,1.10)	1.10 (-4.99,7.19)	0.719
Organisation			0.2672
Organisation 1	-8.64 (-14.65,-2.64)	REF	
Organisation 2	-3.84 (-9.03,1.35)	-2.84 (-8.83,3.14)	0.345
Organisation 3	3.31 (-3.49,10.11)	-5.58 (-12.39,1.23)	0.106
Break Rate (breaks/ sedentary hour) work days			
Intervention			0.542[2]
Active Office - A	0.85 (-0.01,1.71)	REF	
Physical Activity - B	0.18 (-0.81,1.17)	0.67 (-0.67,2.00)	0.319
Office Ergonomics - C	0.77 (0.08,1.46)	-0.08 (-1.23,1.07)	0.889
Organisation			0.371[2]
Organisation 1	1.08 (0.26,1.90)	REF	
Organisation 2	0.31 (-0.42,1.05)	0.76 (-0.35,1.88)	0.174
Organisation 3	0.41 (-0.52,1.34)	0.66 (-0.62,1.95)	0.640

[1] Intervention estimates adjusted for baseline and organisation, Organisation estimates adjusted for baseline and intervention
[2]Omnibus p-value for overall group difference

Table 11.7(ii): Results of multivariable linear regression analysis light and moderate/vigorous physical activity time on work days

Outcome measures	Adjusted Pre- to post- intervention change[1] (95% CI)	Group Differences in change (REF - group) (β(95% CI))	P
Light activity work days (% wear time)			
Intervention			0.263[2]
Active Office - A	2.07 (-0.004,4.14)	REF	
Physical Activity - B	-0.54 (-2.92,1.83)	2.61 (-0.56,5.77)	0.104
Office Ergonomics - C	1.03 (-0.65,2.70)	-1.04 (-3.80,1.72)	0.454
Organisation			0.420[2]
Organisation 1	1.98 (-0.31,3.99)	REF	
Organisation 2	0.47 (-1.31,2.25)	1.52 (-1.20,4.23)	0.269
Organisation 3	0.10 (-2.13,2.33)	1.88 (-1.21,4.97)	0.229
Moderate-vigorous activity work days (% wear time)			
Intervention			0.024[2]
Active Office - A	1.36 (0.49,2.24)	REF	
Physical Activity - B	1.06 (-0.04,2.09)	0.30 (-1.07,1.67)	0.665
Office Ergonomics - C	-0.16 (-0.87,0.55)	-1.52 (-2.69,-0.35)	0.012
Organisation			0.373[2]
Organisation 1	0.67 (-0.18,1.51)	REF	
Organisation 2	1.23 (0.45,2.01)	-0.27 (-1.39,0.85)	0.630
Organisation 3	0.38 (-0.62,1.37)	-1.21 (-2.26,-0.17)	0.024

[1] Intervention estimates adjusted for baseline and organisation, Organisation estimates adjusted for baseline and intervention
[2]Omnibus p-value for overall group difference

On non-work days, it was estimated that Interventions A, B and C resulted in a reduction in sedentary time (% wear time) (adjusted for organisation and baseline sedentary time) of -4.85, 5.29, and 1.58 respectively; the adjusted difference of 6.43 between A and C (95%CI: 0.70, 12.16, p = 0.029) and the adjusted difference between A and B of -10.14 (95%CI: -16.59, -3.69, p = 0.003) were significant (Table 11.8(i)).

Similar results were found for sustained sedentary time on non-work days: it was estimated that Interventions A, B and C resulted in a reduction in sustained sedentary time (% wear time) from Interventions A, B and C (adjusted for organisation and baseline sustained sedentary time) of -4.79, 3.53 and 3.38 respectively; the adjusted difference of 8.17 between A and C (95%CI: 1.37, 14.97, p = 0.019) and the adjusted difference between A and B of –8.32 (95%CI: -16.23, -0.38, p = 0.040) were significant (Table 11.8(i)).

Significant intervention effects were found for break rate on non-work days: it was estimated that Interventions A, B and C resulted in an increase in break rate from Interventions A, B and C (adjusted for organisation and baseline break rate) of 1.48, -0.80 and -0.51 respectively; the adjusted difference of -1.99 between A and C (95%CI: -3.73, -0.26, p = 0.025) and the adjusted difference between A and B of 2.28 (95%CI: 0.32, 4.25, p = 0.024) were significant (Table 11.8(i)).

Significant intervention effects were also found for MVPA on non-work days: it was estimated that Interventions A, B and C resulted in an increase in MVPA (% wear time) from Interventions A, B and C (adjusted for organisation and baseline MVPA) of 1.28, -1.39 and -0.62 respectively; the adjusted difference of -1.90 between A and C (95%CI: -2.95, -0.86, p = 0.001) and the adjusted difference between A and B of 2.67 (95%CI: 1.48, 3.87, p = 0<001) were significant (Table 11.8(ii)).

Table 11.8 (i): Results of multivariable linear regression analysis for sedentary time, sustained sedentary time and break rate on non-work days

Outcome measures	Adjusted Pre- to post- intervention change[1] (95% CI)	Group Differences in change (REF - group) (β(95% CI))	P
Sedentary time non-work days (% wear time)			
Intervention			0.008[2]
Active Office - A	-4.85 (-9.15-0.56)	REF	
Physical Activity - B	5.29 (0.40,10.17)	-10.14 (-16.59,-3.69)	0.003
Office Ergonomics - C	1.58 (-1.91,5.07)	6.43 (0.70,12.16)	0.029
Organisation			0.450[2]
Organisation 1	0.14 (-4.03,4.31)	REF	
Organisation 2	-0.86 (-4.56,2.85)	1.00 (-4.65,6.66)	0.726
Organisation 3	2.73 (-1.86,7.32)	-2.58 (-8.91,3.74)	0.416
Sustained sedentary time (sedentary bouts> 30 mins) non-work days (% wear time)			
Intervention			0.040[2]
Active Office - A	-4.79 (-9.93,0.36)	REF	
Physical Activity - B	3.53 (-2.45,9.51)	-8.32 (-16.23,-0.38)	0.040
Office Ergonomics - C	3.38 (-0.79,7.55)	8.17 (1.37,14.97)	0.019
Organisation			0.969[2]
Organisation 1	0.21 (-4.80,5.21)	REF	
Organisation 2	0.78 (-3.65,5.22)	-0.58 (-7.36,6.21)	0.865
Organisation 3	1.14 (-4.32,6.59)	-0.93 (-8.48,6.62)	0.806
Break Rate (breaks/ sedentary hour) non-work days			
Intervention			0.036[2]
Active Office - A	1.48 (0.18,2.79)	REF	
Physical Activity - B	-0.80 (-2.29,0.69)	2.28 (0.32,4.25)	0.024
Office Ergonomics - C	-0.51 (-1.57,0.55)	-1.99 (-3.73,-0.26)	0.025
Organisation			0.731[2]
Organisation 1	0.02 (-1.24,1.29)	REF	
Organisation 2	0.40 (-0.71,1.52)	-0.38 (-2.10,1.33)	0.656
Organisation 3	-0.25 (-1.63,1.13)	0.27 (-1.64,2.18)	0.776

[1] Intervention estimates adjusted for baseline and organisation, Organisation estimates adjusted for baseline and intervention
[2]Omnibus p-value for overall group difference

Table 11.8 (ii): Results of multivariable linear regression analysis for light and moderate/vigorous physical activity on non-work days

Outcome measures	Adjusted Pre- to post- intervention change[1] (95% CI)	Group Differences in change (REF - group) (β(95% CI))	P
Light activity non-work days (% wear time)			
Intervention			0.054[2]
Active Office - A	3.51 (-0.62,7.64)	REF	
Physical Activity - B	-4.06 (-8.77,0.65)	7.57 (-1.38,13.76)	0.017
Office Ergonomics - C	-0.86 (-4.23,2.51)	-4.37 (-9.89,1.16)	0.119
Organisation			0.586[2]
Organisation 1	-0.29 (-4.31,3.73)	REF	
Organisation 2	0.86 (-2.71,4.44)	-1.16 (-6.62,4.31)	0.189
Organisation 3	-1.98 (-6.42,2.45)	1.69 (-4.42,7.80)	0.582
Moderate-vigorous activity non-work days (% wear time)			
Intervention			0<0.001[2]
Active Office - A	1.28 (0.49,2.06)	REF	
Physical Activity - B	-1.39 (-2.31,-0.48)	2.67 (1.48,3.87)	0<0.0001
Office Ergonomics - C	-0.62 (-1.27,0.03)	-1.90 (-2.95,-0.86)	0.001
Organisation			0.116[2]
Organisation 1	0.12 (-0.66,0.90)	REF	
Organisation 2	0.07 (-0.62,0.76)	0.05 (-1.00,1.11)	0.918
Organisation 3	-0.93 (-1.783,-0.81)	1.06 (-0.12,2.23)	0.078

[1] Intervention estimates adjusted for baseline and organisation, Organisation estimates adjusted for baseline and intervention
[2]Omnibus p-value for overall group difference

There were no significant intervention effects during work hours Table 11.5(i) and (ii)) however, it was estimated that Interventions A, B and C resulted in a reduction in sustained sedentary time (% wear time) during non-work hours on work days from Interventions A, B and C (adjusted for organisation and baseline sustained sedentary time) of -5.34, 2.34 and 0.12 respectively; the adjusted difference of 5.45 between A and C was not significant (95%CI: -0.23, 11.13, p = 0.060) but the adjusted difference between A and B of –7.68 (95%CI: -14.02, -1.33, p = 0.019) was significant (Table 11.9(i)). Similarly, significant intervention effects were also found for MVPA during non-work periods on work days: it was estimated that Interventions A, B and C resulted in an increase in MVPA (% wear time) from Interventions A, B and C (adjusted for organisation and baseline MVPA) of 2.25, 2.30 and -0.16 respectively; the adjusted difference of -2.41 between A and C (95%CI: -4.55, -0.27, p = 0.028), but the adjusted difference between A and B of 0.05 was not significant (95%CI: -2.55, 2.46, p = 0.971) (Table 11.9(ii)).

Table 11.9(i): Results of multivariable linear regression analysis for sedentary time, sustained sedentary time and break rate for non-work hours on work days

Outcome measures	Adjusted Pre- to post- intervention change[1] (95% CI)	Group Differences in change (REF - group) (β(95% CI))	P
Sedentary time non-work on work days (% wear time)			
Intervention			0.231[2]
Active Office - A	-3.90 (-6.64-1.16)	REF	
Physical Activity - B	-0.91 (-4.05,2.23)	-2.99 (-7.11,1.13)	0.151
Office Ergonomics - C	-1.05 (-3.31,1.21)	2.86 (-0.84,6.55)	0.127
Organisation			0.930[2]
Organisation 1	-1.82 (-4.49,0.86)	REF	
Organisation 2	-2.34 (-4.74,0.06)	0.52 (-3.12,4.16)	0.776
Organisation 3	-1.70 (-4.66,1.25)	-0.11 (-4.19,3.96)	0.957
Sustained sedentary time (sedentary bouts> 30 mins) non-work on work days (% wear time)			
Intervention			0.044[2]
Active Office - A	-5.34 (-9.56,-1.11)	REF	
Physical Activity - B	2.34 (-2.56,7.24)	-7.68 (-14.02,-1.33)	0.019
Office Ergonomics - C	0.12 (-3.41,3.64)	5.45 (-0.23,11.13)	0.060
Organisation			0.883[2]
Organisation 1	-0.79 (-4.98,3.40)	REF	
Organisation 2	-0.33 (-4.12,3.44)	-0.46 (-6.23,5.31)	0.873
Organisation 3	-1.75 (-6.33,2.82)	0.96 (-5.35,7.27)	0.762
Break Rate (breaks/ sedentary hour) non-work on work days			
Intervention			0.344[2]
Active Office - A	1.25 (0.16,2.35)	REF	
Physical Activity - B	0.04 (-1.22,1.30)	1.21 (-044,2.86)	0.146
Office Ergonomics - C	0.72 (-0.18,1.62)	-0.53 (-2.00,0.94)	0.470
Organisation			0.884[2]
Organisation 1	0.61 (-0.47,1.69)	REF	
Organisation 2	0.52 (-0.44,1.48)	0.09 (-1.37,1.55)	0.905
Organisation 3	0.88 (-0.30,2.07)	-0.27 (-1.91,1.36)	0.739

[1] Intervention estimates adjusted for baseline and organisation, Organisation estimates adjusted for baseline and intervention
[2]Omnibus p-value for overall group difference

Table 11.9(ii): Results of multivariable linear regression analysis for light and moderate/vigorous physical activity for non-work hours on work days

Outcome measures	Adjusted Pre- to post- intervention change[1] (95% CI)	Group Differences in change (REF - group) (β(95% CI))	P
Light activity non-work on work days (% wear time)			
Intervention			0.145[2]
Active Office - A	1.82 (-0.64,4.28)	REF	
Physical Activity - B	-1.68 (-4.52,1.16)	-0.65 (-3.98,2.67)	0.696
Office Ergonomics - C	1.17 (-0.88,3.22)	2.85 (-0.72,6.42)	0.115
Organisation			0.855[2]
Organisation 1	0.90 (-1.53,2.32)	REF	
Organisation 2	-0.02 (-2.17,2.14)	0.92 (-2.37,4.21)	0.580
Organisation 3	0.43 (-2.22,3.07)	0.47 (-3.19,4.14)	0.797
Moderate-vigorous activity non-work on work days (% wear time)			
Intervention			0.041[2]
Active Office - A	2.25 (0.64,3.86)	REF	
Physical Activity - B	2.30 (0.37,4.22)	0.05 (-2.55,2.46)	0.971
Office Ergonomics - C	-0.16 (-1.48,1.17)	-2.41 (-4.55,-0.27)	0.028
Organisation			0.217[2]
Organisation 1	-0.62 (1.13,4.01))	REF	
Organisation 2	2.57 (-0.62,0.76)	0.05 (-1.00,1.11)	0.136
Organisation 3	0.90 (-1.783,-0.81)	1.06 (-0.12,2.23)	0.986

[1] Intervention estimates adjusted for baseline and organisation, Organisation estimates adjusted for baseline and intervention
[2]Omnibus p-value for overall group difference

There were significant intervention effects for sedentary time during total non-work time: it was estimated that Interventions A, B and C resulted in a reduction in sedentary time (% wear time) (adjusted for organisation and baseline sedentary time) of -4.38, 3.32, and 0.08 respectively; the adjusted difference of 5.18 between A and C (95%CI: 0.70, 9.66, p = 0.024) and the adjusted difference between A and B of -7.70 (95%CI: -12.72, -7.69, p = 0.003) were significant (Table 11.10(i). Significant intervention effects were found for break rate during total non-work time: it was estimated that Interventions A, B and C resulted in an increase in break rate for Interventions A, B and C (adjusted for organisation and baseline break rate) of 1.34, -0.44 and -0.16 respectively; the adjusted difference of -1.50 between A and C (95%CI: -2.96, -0.03, p = 0.046) and the adjusted difference between A and B of 1.78 (95%CI: 0.12, 3.43, p = 0.036) were significant (Table 11.10(i)). Similarly, significant intervention effects were also found for MVPA during total non-work time: it was estimated that Interventions A, B and C resulted in an increase in MVPA (% wear time) for Interventions A, B and C (adjusted for organisation and baseline MVPA) of 1.61, -0.50 and -0.52 respectively; the adjusted difference of -2.13 between A and C (95%CI: -3.37, -0.89, p = 0.001) and the adjusted difference between A and B of 2.11 (95%CI: 0.67, 3.54, p = 0.005) were significant (Table 11.10(ii)).

In summary, following the intervention period there were no significant differences between the interventions for changes in sedentary time, sustained sedentary time, break rate and MVPA on work days or during work hours, with the exception of MVPA on work days, where participants from Intervention A had the greatest response. During non-work periods there were significant differences between the intervention groups for changes in sedentary time, sustained sedentary time, break rate and MVPA. Participants from Intervention A had the greatest reduction in sedentary time, sustained sedentary time and the greatest increase in break rate and MVPA. There were no significant differences between interventions for changes in light activity during work and non-work periods.

Table 11.10(i): Results of multivariable linear regression analysis for sedentary, sustained sedentary and break rate for total non-work time

Outcome measures	Adjusted Pre- to post- intervention change[1] (95% CI)	Group Differences in change (REF - group) (β(95% CI))	P
Sedentary time total non-work (% wear time)			
Intervention			0.009[2]
Active Office - A	-4.38 (-7.73-1.04)	REF	
Physical Activity - B	3.32 (-0.47,7.12)	-7.70 (-12.72,-2.69)	0.003
Office Ergonomics - C	0.80 (-1.92,3.51)	5.18 (0.70,9.66)	0.024
Organisation			0.308[2]
Organisation 1	-0.31 (-3.54,2.91)	REF	
Organisation 2	-1.66 (-4.52,1.21)	1.34 (-3.04,5.73)	0.542
Organisation 3	1.70 (-1.83,5.23)	-2.01 (-6.89,2.87)	0.412
Sustained sedentary time (sedentary bouts> 30 mins) total non-work (% wear time)			
Intervention			0.027[2]
Active Office - A	-4.63 (-8.78,-0.48)	REF	
Physical Activity - B	2.49 (-2.30,7.29)	-7.13 (-13.47,-0.78)	0.028
Office Ergonomics - C	2.36 (-1.02,5.74)	6.99 (1.47,12.41)	0.014
Organisation			0.978[2]
Organisation 1	-0.22 (-4.27,3.83	REF	
Organisation 2	0.03 (-3.55,3.61)	-0.28 (-5.74,5.25)	0.929
Organisation 3	0.41 (-4.00,4.82)	-0.63 (-6.73,5.47)	0.837
Break Rate (breaks/ sedentary hour) total non-work			
Intervention			0.063[2]
Active Office - A	1.34 (0.24,2.43)	REF	
Physical Activity - B	-0.44 (-1.69,0.81)	1.78 (0.12,3.43)	0.036
Office Ergonomics - C	-0.16 (-1.05,0.74)	-1.50 (-2.96,-0.03)	0.046
Organisation			0.817[2]
Organisation 1	0.22 (-0.85,1.28)	REF	
Organisation 2	0.48 (-0.46,1.43)	-0.27 (-1.71,1.18)	0.714
Organisation 3	0.04 (-1.12,1.20)	0.18 (-1.43,1.78)	0.827

[1] Intervention estimates adjusted for baseline and organisation, Organisation estimates adjusted for baseline and intervention
[2] Omnibus p-value for overall group difference

Table 11.10(ii): Results of multivariable linear regression analysis light and moderate/vigorous physical activity time for total non-work time

Outcome measures	Adjusted Pre- to post- intervention change[1] (95% CI)	Group Differences in change (REF - group) (β(95% CI))	P
Light activity total non-work (% wear time)			
Intervention			0.054[2]
Active Office - A	2.80 (-2.84,2.44)	REF	
Physical Activity - B	-3.15 (-6.82,0.52)	5.95 (1.13,10.76)	0.203
Office Ergonomics - C	-0.20 (-2.84,2.44)	-3.00 (-7.33,1.33)	0.171
Organisation			0.524[2]
Organisation 1	0.10 (-3.12,3.14)	REF	
Organisation 2	0.93 (-1.85,3.71)	-0.92 (-5.18,3.34)	0.667
Organisation 3	-1.49 (-4.92,1.95)	1.50 (-3.25,6.24)	0.530
Moderate-vigorous activity total non-work (% wear time)			
Intervention			0.002[2]
Active Office - A	1.61 (0.68,2.54)	REF	
Physical Activity - B	-0.50 (-1.60,0.61)	2.11 (0.67,3.54)	0.005
Office Ergonomics - C	-0.52 (-1.28,0.25)	-2.13 (-3.37,-0.89)	0.001
Organisation			0.081[2]
Organisation 1	0.28 (-0.65,1.20)	REF	
Organisation 2	0.88 (0.06,1.70)	-0.61 (-1869,0.65)	0.337
Organisation 3	-0.56 (-1.57,0.46)	0.83 (-0.57,2.23)	0.239

[1] Intervention estimates adjusted for baseline and organisation, Organisation estimates adjusted for baseline and intervention
[2]Omnibus p-value for overall group difference

11.3 Secondary outcomes

11.3.1 Intervention effect across all participants, between organisations and between interventions: BMI and waist girth

All 62 participants had baseline and post-intervention BMI data. The unadjusted estimated reduction in BMI post-intervention for all participants of 0.27 kg/m^2 was not statistically significant. 61 of the 62 participants had complete waist girth measurements. The unadjusted estimated reduction post-intervention in waist girth of 1.75 cm was significant, with the greatest reduction occurring for the males ($t = 2.91$, df_{60}, $p = 0.005$; Male: $t = 3.65$, df_{11}, $p = 0.004$; Female: $t = 1.90$, df_{48}, $p = 0.063$) (Table 11.11).

As baseline characteristics were different between the organisations and intervention groups, linear regression analysis was performed to assess changes in BMI and waist girth between organisations and intervention groups following the intervention period. Following the intervention, there were no significant differences between the interventions for changes in BMI or waist girth and there were no significant differences between the organisations for changes in BMI or waist girth (Table 11.12).

Table 11.11: BMI and waist girth for all participants before and after intervention

Outcome measures	Baseline	Post-intervention	Mean Change	95% CI	P
BMI (kg/m2 ± SD) (n=61)					
	28.18 ± 6.31	29.91 ± 6.22	-0.27	0.13, -0.67	0.188
Waist girth (cm ± SD)					
Whole group (n=48)	91.73 ± 13.02	89.98 ± 13.64	-1.75	-0.54, -2.95	0.005
Male (n=12)	96.75 ± 8.03	93.33 ± 6.80	-3.42	-1.36, -5.45	0.004
Female (n=36)	90.50 ± 13.76	89.16 ± 14.78	-1.34	0.08, -2.75	0.063

Table 11.12: Results of multivariable linear regression analysis for BMI and waist girth measurements

Outcome measures	Adjusted Pre- to post- intervention change[1] (95% CI)	Group Differences in change (REF - group) (β(95% CI))	*P*
BMI (kg/m²)			
Intervention			0.595[2]
Active Office - A	-0.23 (-0.94,0.47)	REF	
Physical Activity - B	0.48 (-0.78,0.41)	-0.28 (-1.34,0.50)	0.312
Office Ergonomics - C	-0.48 (-1.06,0.11)	-0.24 (-1.18,0.70)	0.607
Organisation			0.073[2]
Organisation 1	0.38 (-0.32,1.08)	REF	
Organisation 2	-0.18 (-0.80,0.44)	0.56 (-0.40,1.51)	0.247
Organisation 3	-0.86 (-1.62,-0.09)	1.23 (0.18, 2.29)	0.023
Waist girth (cm)			
Intervention			0.380[2]
Active Office - A	-2.28 (-4.53,-0.02)	REF	
Physical Activity - B	-0.09 (-2.81,2.63)	-2.19 (-5.67,1.30)	0.211
Office Ergonomics - C	-2.20 (-4.09,-0.32)	0.72 (-2.95,3.09)	0.962
Organisation			0.925[2]
Organisation 1	-1.88 (-4.21,0.45)	REF	
Organisation 2	-1.27 (-3.27,2.98)	-0.61 (-3.74,2.52)	0.696
Organisation 3	-1.42 (-3.88,1.03)	-0.45 (-3.87,2.52)	0.792

[1] Intervention estimates adjusted for baseline and organisation, Organisation estimates adjusted for baseline and intervention
[2]p-value for overall group difference

11.3.2 Intervention effect across all participants: Musculoskeletal pain

57 of the 62 participants completed the modified Nordic Musculoskeletal Questionnaire at baseline and 51 following the intervention period resulting in 47 complete pairs of data. The distribution of musculoskeletal pain at baseline was similar to the results of Study 1 with neck pain being reported most frequently (60% of participants) followed by shoulder (49%) and low back pain (51%). However, a higher percentage of participants reported musculoskeletal pain in these regions compared to findings in Study 1. The distribution of reported musculoskeletal pain at baseline and following the intervention are illustrated in Figure 11.3.

Figure 11.3: Distribution of self-reported musculoskeletal pain before and after the intervention period

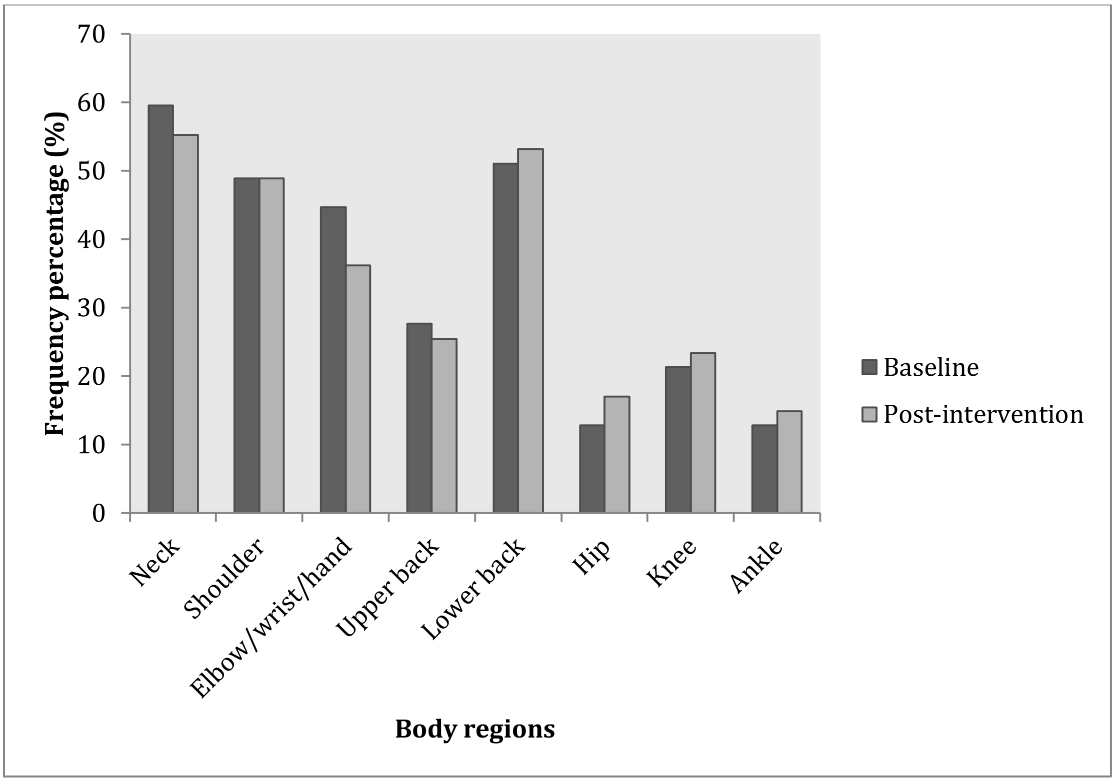


Table 11.13 reports the percentage of participants reporting musculoskeletal pain in different body regions at baseline and post-intervention. Following the intervention, there appeared to be a reduction in the percentage of participants

reporting neck pain (4% participants reporting neck pain, p = 0.791), no change in reported shoulder pain and an apparent increase in percentage of participants reported low back pain (2% participants reporting increased low back pain, p = 0.999). The number of body regions with reported musculoskeletal pain before and after the intervention is illustrated in Figure 11.4. 24% of participants reported reduced number of body regions with musculoskeletal pain, 42% had no change in number of body regions and 33% reported increased number of body regions with musculoskeletal pain (Figure 11.5).

Table 11.13: Percentage (number) of participants reporting musculoskeletal pain in different body regions at baseline and following the intervention period

Body regions	Baseline % (n)	Post-intervention % (n)	***P***
Neck	60 (28)	55 (26)	0.791
Shoulder	49 (23)	49 (23)	0.999
Elb/wrist/hand	45 (21)	36 (17)	0.388
Upper back	28 (13)	26 (12)	0.999
Lower back	51 (24)	53 (25)	0.999
Hip	13 (6)	17 (8)	0.625
Knee	21 (10)	23 (11)	0.999
Ankle	13 (6)	15 (7)	0.999

Figure 11.4: Reported musculoskeletal pain in relation to number of body regions before and after the intervention period

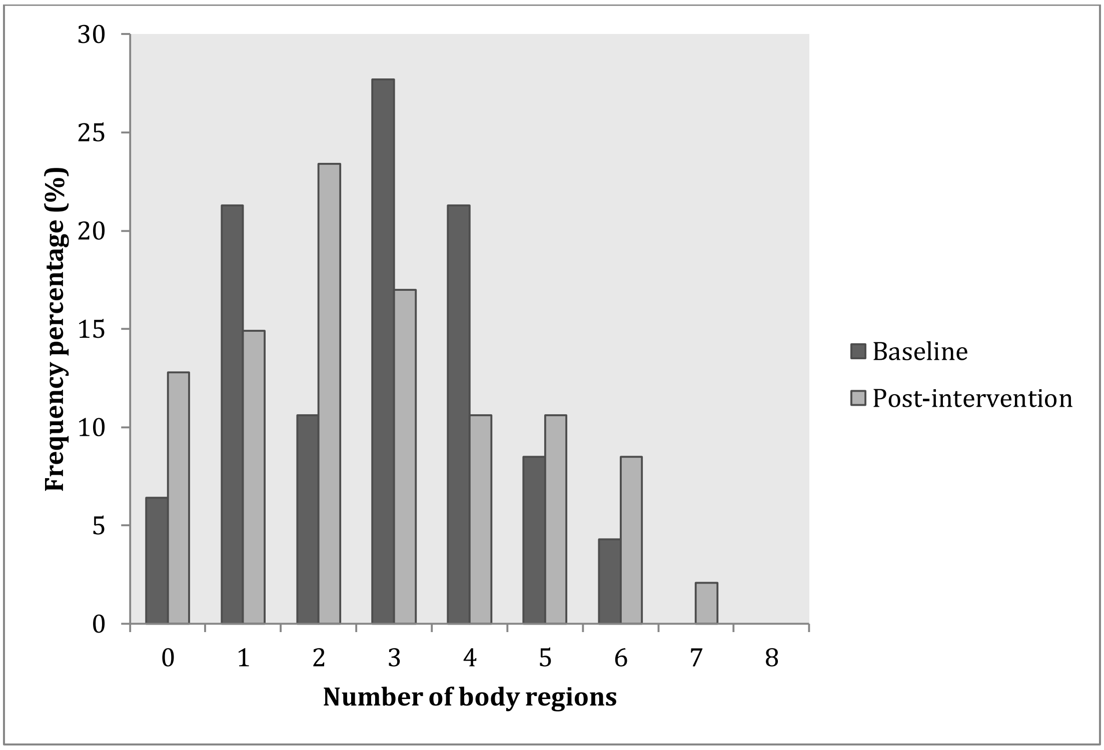
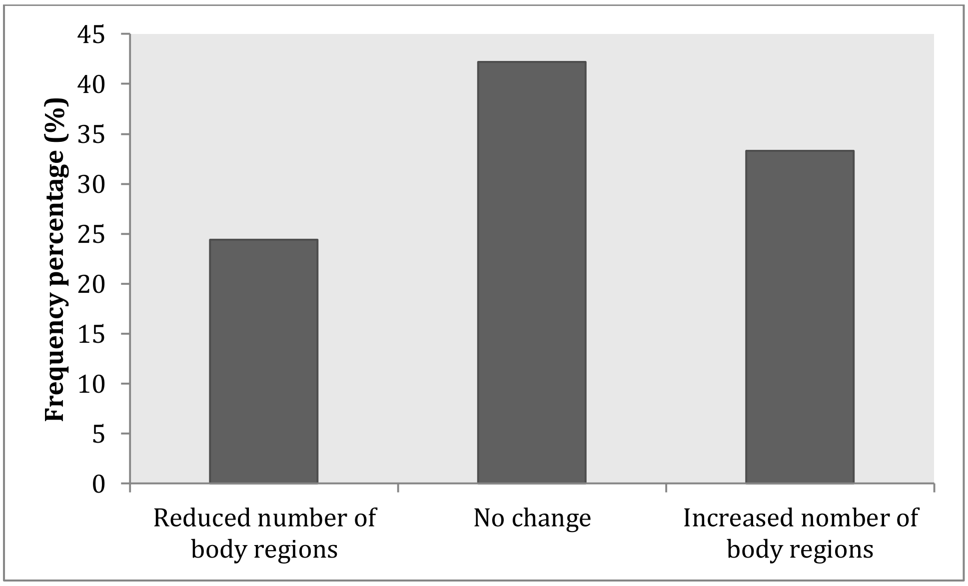


Figure 11.5: Change in reported number of body regions with musculoskeletal pain following the intervention



Following the intervention period there was no significant difference in the number of participants reporting that work contributed to their reported musculoskeletal pain (75% of participants at baseline and 66% following the intervention, p = 0.999). As reported in Table 11.14, there were no significant changes in the impacts of musculoskeletal pain on work and leisure physical activity and the need to see a health professional or to take medication following the intervention period.

Table 11.14: Self-reported impacts of musculoskeletal pain on work physical activity, leisure physical activity, need to see a health professional and need to take medication

Impact	Baseline % (n)	Post-intervention % (n)	P
Reduced work physical activity	28 (13)	21 (10)	0.549
Reduced leisure activity	47 (22)	36 (17)	0.180
Seen by health professional	60 (28)	55 (26)	0.754
Need to take medication	51 (24)	49 (23)	0.999

11.3.3 Intervention effects between organisations and between interventions for musculoskeletal pain

This distribution of self-reported musculoskeletal pain at baseline and following the intervention period for the 3 Organisations and the 3 intervention groups is presented in Appendix R of this thesis.

11.3.4 Intervention effect across all participants: Readiness for Physical Activity

58 participants completed the Readiness for Physical Activity Survey at baseline and 52 participants following the intervention period resulting in a total of 49 complete pairs of data. For 39% of participants that completed the survey, there was no change in their attitude to physical activity and they were classified as 'stable'. 45% of participants moved to a more positive stage of change in physical activity, this group were 'adopters' and 16% of participants moved to a more negative stage of change in physical activity, this group was classified as 'relapse' (Figure 11.6). Table 11.15 reports the percentage of participants that fall into each category of adopter, stable and relapse for all participants and the distribution in each Intervention group. As the number of participants in each intervention group varied, there was no further analysis of the data.

Figure 11.6: Change in Readiness for Physical activity – difference between baseline and post-intervention attitude: 'adopter' - progressed one or more stages; 'stable' – no change and 'relapse' – regressed one or more stages

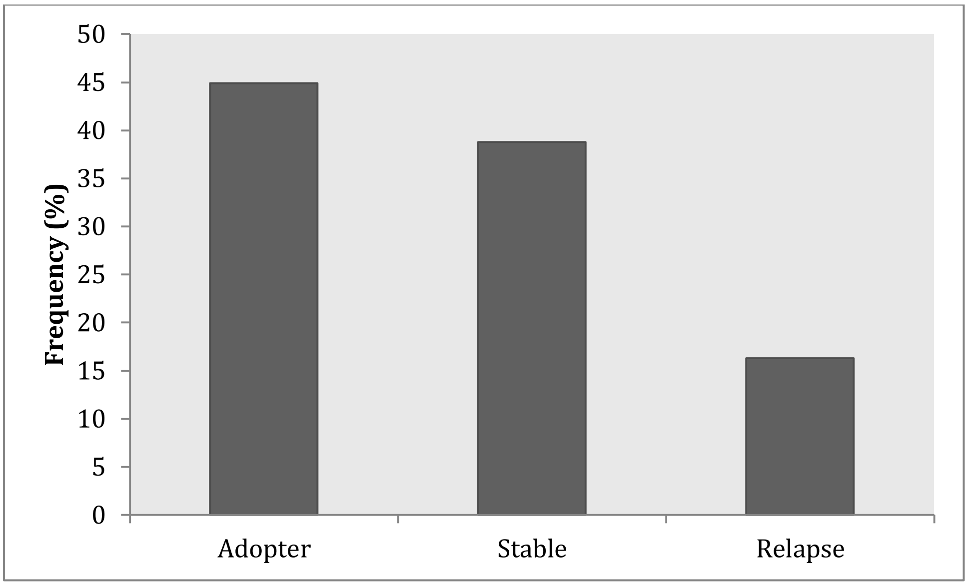


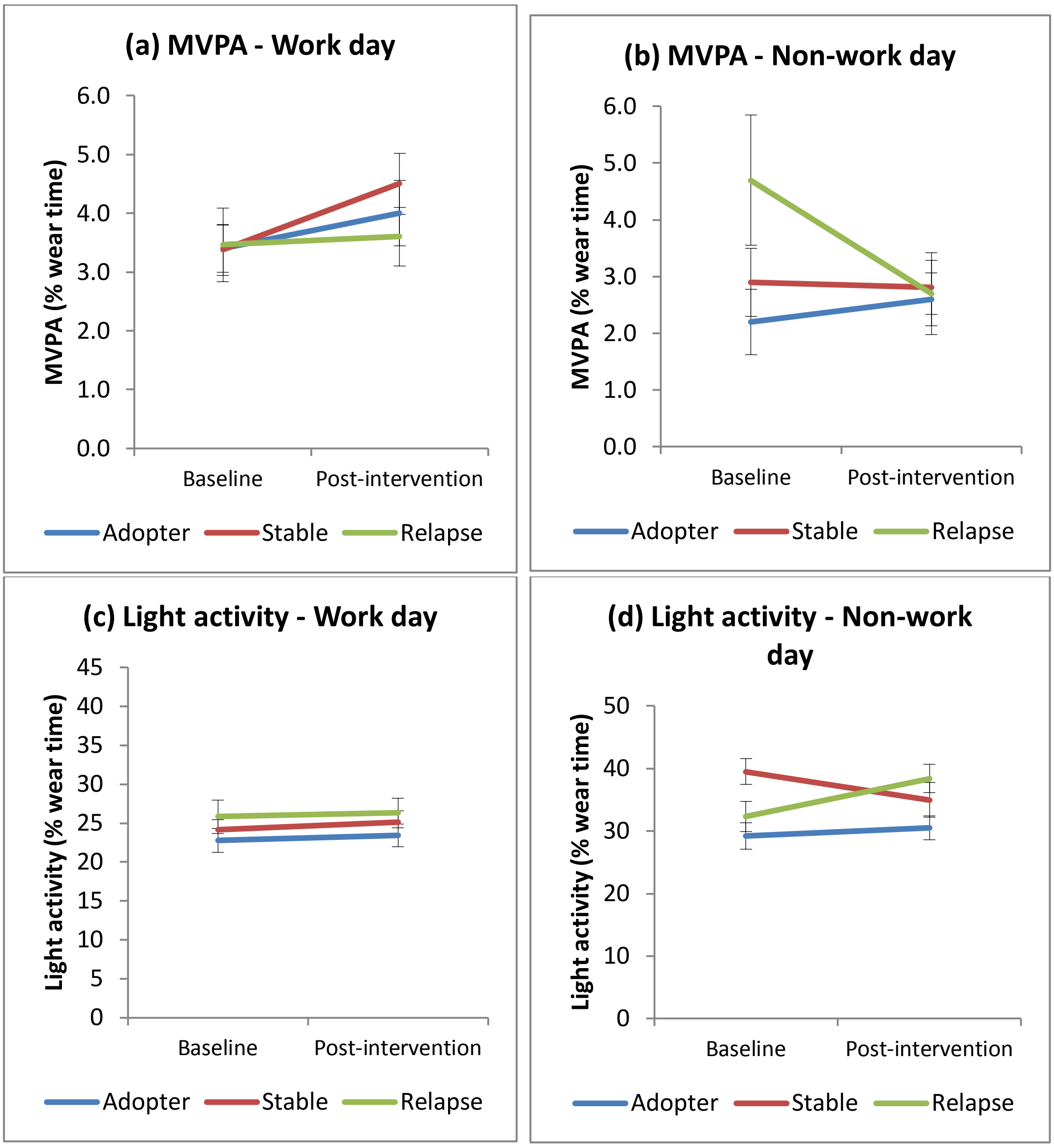
Table 11.15: Percentage (number) of participants in Adopter, Stable and Relapse group following the intervention period for each intervention group and all subjects

	Intervention A (n=14) % (n)	Intervention B (n=12) % (n)	Intervention C (n=23) % (n)	All Subjects (n=49) % (n)
Adopter	43 (6)	33 (4)	52 (12)	45 (22)
Stable	29 (4)	50 (6)	39 (9)	39 (19)
Relapse	29 (4)	17 (2)	9 (2)	16 (8)

11.3.5 Differences in MVPA and light activity based on attitude to physical activity

Figure 11.7 illustrates the MVPA and light activity (% wear time) for those participants that completed the Readiness for Physical Activity survey classified into the groups of 'adopters', 'stable' and 'relapse'. In each group, there was an apparent increase in MVPA on work days following the intervention period, with a significant increase in MVPA in the 'stable' group (1.11% [9.9 mins] t = -2.28, df_{16}, p = 0.035). On non-work days, MVPA appeared to increase in the 'adopter' group (0.42% [3.6 mins]) and reduced minimally in the 'stable' group (0.01% [0.1 mins]) and more so in the 'relapse' group (1.92% [16.2 mins]). For light activity on work days, there was an apparent small increase in light activity (adopter: 0.64% [5.7 mins]; stable: 0.90% [8.0 mins] and relapse: 0.52% [4.6 mins]). On non-work days, there appeared to be an increase in light activity for the adopter group (1.33% [11.2 mins]) and the relapse group (6.10% [51.5mins]) and decreased in the stable group (4.53% [38.3]). None of these changes were statistically significant.

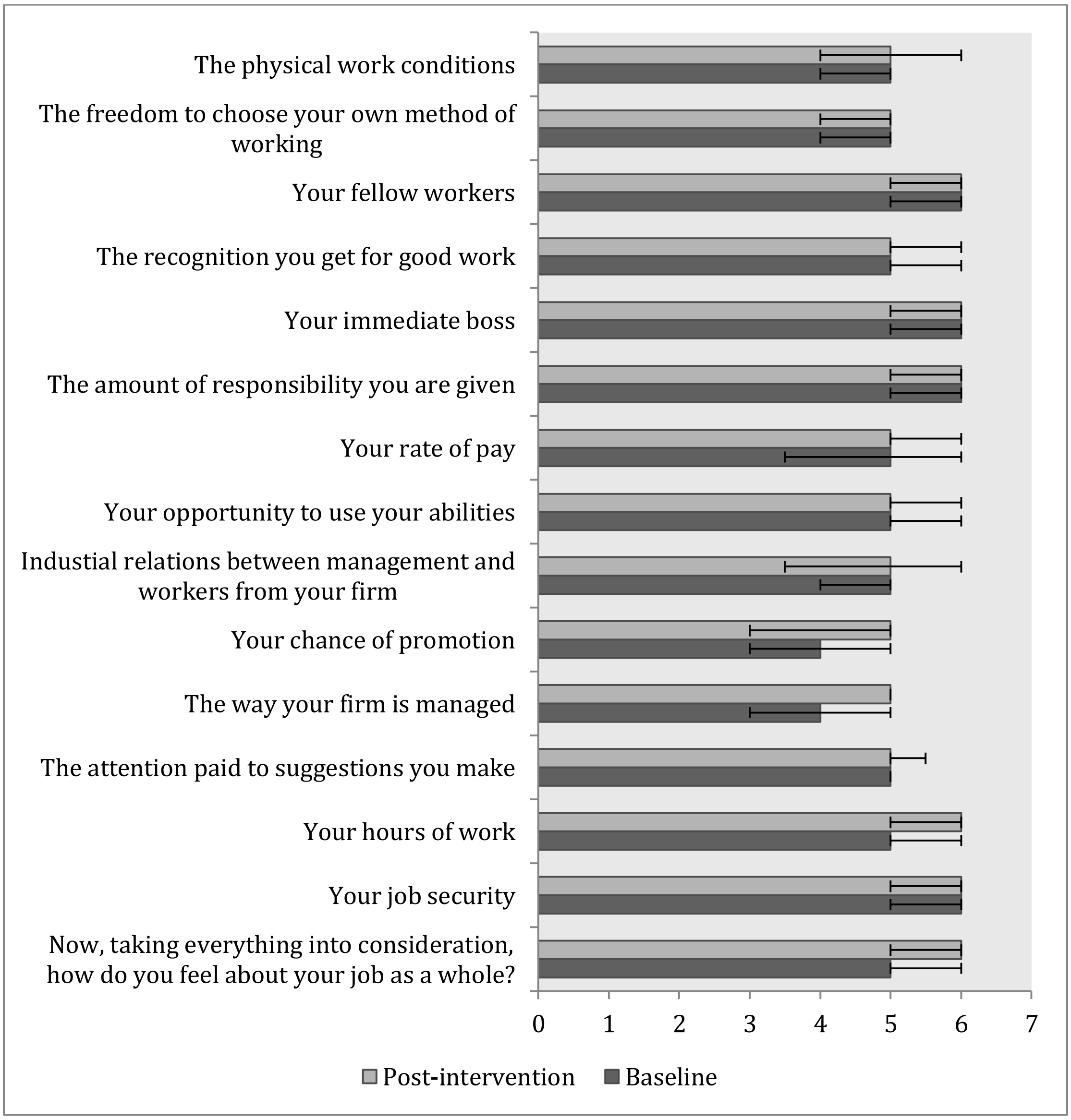
Figure 11.7: Changes in MVPA on a work day (a) and non-work day (b) and light activity on a work day (c) and non-work day (d) for the groups 'adopter', 'stable' and 'relapse' at baseline and post-intervention (% wear time ± SE)



11.3.6 Intervention effect across all participants: Job satisfaction

Of the 62 participants, 58 participants completed the Job Satisfaction Survey at baseline and 52 participants following the intervention period. There were a total of 49 complete pairs of data. The median and interquartile range for each question is illustrated in Figure 11.8. Total job satisfaction score (sum of all 15 questions to a maximum of 105) ranged from 47-92 at baseline with a mean score of 75 ± 9 and following the intervention scores ranged from 48-95 with a mean score of 77 ± 11. There was no significant difference between the total job satisfaction before and after the intervention (t = -1.67, df_{48}, p = 0.102).

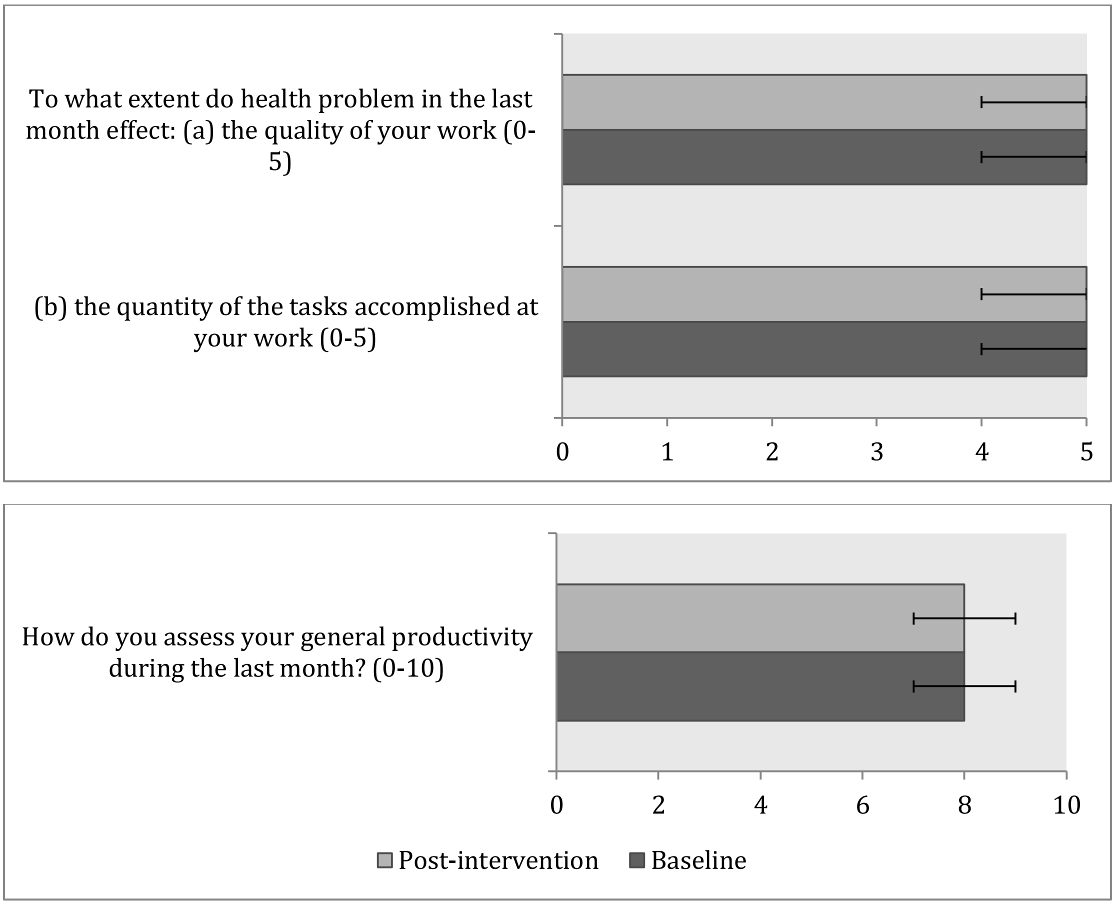
Figure 11.8: Median and interquartile range for each question of the Job Satisfaction Survey, 1 = extremely dissatisfied; 4 = not sure and 7 = extremely satisfied at baseline and following the intervention period



11.3.7 Intervention effect across all participants – Self - reported health related work productivity for all participants

Of the 62 participants, 49 participants completed the Health and Work Performance Questionnaire before and after the intervention period. In general the participants rated their work productivity as high (Figure 11.9). There was no change in self-reported work productivity following the intervention (p = 0.566) (Figure 11.9).

Figure 11.9: Health and Work Performance Questionnaire at baseline and following the intervention period (median and interquartile ranges)



11.4 Feedback from participants following the intervention

Of the 62 participants that completed the study with sufficient accelerometer data, 50 participants provided written feedback. In addition, 12 participants that were not included in the activity analyses (due to insufficient accelerometer data) provided written feedback. Comments from these 12 participants have been included in the overall feedback as the participants fully participated in the study. In total, feedback was provided by 19 participants from Intervention A, 14 participants from Intervention B and 29 participants from Intervention C. Feedback has been summarised in Tables 11.16-11.18. Note that the participation feedback is the combined feedback from all organisations, and not all organisations participated in exactly the same interventions. For example, only Organisation 1 purchased stools to use for Intervention C. However, Intervention A groups from each organisation had access to an Active Workstation, Intervention B groups from each organisation had access to a pedometer and Intervention C groups from each organisation had the option of using an air cushion. Also note that not all feedback forms were complete. Some participants just provided written feedback about some aspects of the interventions, without completing the participation section and some aspects of the participation were left blank by the participants.

Overall, participation in the most novel intervention strategies such as the Active Workstation, 'active e-mails' and standing meetings was reported as low. The most positive aspects of the intervention were being made aware of the sedentary lifestyle associated with office work. Negative aspects of the interventions reported were difficulties in using the Active Workstation and inconvenience of wearing the accelerometers. Recommendations to other work groups include providing flexible work conditions and encouragement to participate in workplace interventions.

Table 11.16 (i) Feedback from participants in Intervention A - Reported participation in aspects of the intervention

Reported participation in aspects of the intervention						
Aspect (number of participants with access to intervention)	**More than an hour each day**	**Less than an hour each day**	**2-3 times a week**	**Occasionally**	**Never**	**No response**
ACTIVE WORK STATION (19)			2	6	7	4
Increase use of stairs (6)			3	2	1	0
Active e-mails (9)		1	1	2	5	0
Changing default printers where possible (9)	2	1	1	3	1	1
Walking/standing between calls (10)	3		1	3	1	2
Increase activity around workplace – take longer routes to printer etc (19)	4	2	3	6	1	3
Pedometer challenge to monitor increases in incidental activity (9)	3	1	1	3		1
“Rest end stretch” software (9)				1	6	2

Table 11.16 (ii) Feedback from participants in Intervention A - Summary of best aspects and worst aspects

Note: Numbers in brackets indicate number of participants with the same response

Feedback on participation in the study	
Best Aspects	**Worst Aspects**
• Reminded me to move • Active Workstation (2) • Awareness of physical activity at work and outside of work hours (9) • Promotes healthy living (3) • Reduced stress and slept better • Participating as a group/with colleagues • Awareness of small changes that can make a difference • Pedometer challenge at work • Less back pain • Got me moving more at work	• ***Intervention Aspects*** • Getting hot when using Active Workstation • Location of Active Workstation (not central) • Too many calls to use Active Workstation enough • Hot weather (2) • Not having the time to participate in physical activity due to being too busy • Rest and Stretch software • The management really only gave it 'lip service'. We were all pressured to still perform at very high rates and felt we could not afford to take the time to set up the Active Workstation and take walk breaks • Disruption due to changing work station

	• ***<u>Research Aspects</u>*** • Remembering to wear accelerometer/pedometer – bulky and unflattering under clothes (3)

Table 11.16 (iii) Feedback from participants in Intervention A - Summary of recommendations for other work groups

Recommendations for other work groups?
• Look at different ways to increase daily steps/activity • Shorter study period • More exercise equipment • More formal/competitive pedometer challenge amongst colleagues • Flexibility of work to enhance a balance of health/activity • Better air conditioning/ fans (with use of Active Workstation) • Active Workstation needs to be easier to set up and use quickly. It took too long and so people did not use it for that reason. It is easy to say they 'can't fire you' but long after the project is complete performance measures are reviewed and can influence pay and promotion

Table 11.17 (i) Feedback from participants in Intervention B - Reported participation in aspects of the intervention

Reported participation in aspects of the intervention						
Aspect (number of participants with access to intervention)	**More than an hour each day**	**Less than an hour each day**	**2-3 times a week**	**Occasionally**	**Never**	**No response**
Increase use of stairs (11)			2	6	1	2
Active e-mails (9)				2	5	2
Pedometer challenge (14)	4		3	3	1	3
Short planned walks during breaks (14)	1	3	7	3		0
Use of Active Workstation (5)				2	3	0
Standing meetings (6)				2	2	1
Increase active transport (walking to walk, parking further away) (9)		1	5	3		0

Table 11.17 (ii) Feedback from participants in Intervention B - Summary of best aspects and worst aspects

<table>
<tr><th colspan="2">Feedback on participation in the study</th></tr>
<tr><th>Best Aspects</th><th>Worst Aspects</th></tr>
<tr><td rowspan="2">
• Discussion of ways to increase activity – hopefully it would changes our ways
• Motivation to increase physical activity at work or while travelling to work
• Didn't gain much because already active
• Awareness of inactive lifestyle that accompanies clerical work (4)
• Awareness of the difference in the amount of daily steps taken when allowed enough time for a proper lunch break
• Pedometer challenge motivated me to reach a goal each day
</td><td>
• <u>Intervention Aspects</u>
• Not having enough time to do activities
• Being overloaded with work and feeling that you can't take a proper lunch break
• Only few opportunities to use stairs
• Meetings are maximum 2 hours per month so standing meetings not suitable and need to take notes at meetings
• Breaks only allowed to go to the toilet or grab a drink – can't go for a walk
• Weather – heat in December
• Realisation that I am less active than I thought
</td></tr>
<tr><td>
• <u>Research Aspects</u>
• Remembering to wear accelerometer (2)
• Use of activity diary (2)– don't really understand why it is necessary to write things down when accelerometer is recording everything
</td></tr>
</table>

Table 11.17 (iii) Feedback from participants in Intervention B - Summary of recommendations for other work groups

Recommendations for other work groups?
• More team activities • Incentives to participate in activity • Pedometer challenge (2) • Use of stairs • Stand and stretch software reminders – also walk to printer • More ideas/techniques for increasing exercise

Table 11.18 (i) Feedback from participants in Intervention C - Reported participation in aspects of the intervention

Reported participation in aspects of the intervention						
Aspect (number of participants with access to intervention)	**More than an hour each day**	**Less than an hour each day**	**2-3 times a week**	**Occasionally**	**Never**	**No response**
Taking breaks from sitting (10)	6			3	1	0
Air cushion (29)	8		7	13	1	0
"Active sitting" (29)	10	7	4	6	2	0
Stools (7)	2		1	2	1	1
Meetings in different settings e.g standing (19)		1		5	13	0

Table 11.18 (ii) Feedback from participants in Intervention C - Summary of best aspects and worst aspects

Feedback on participation in the study	
Best Aspects	**Worst Aspects**
• Air cushion instantly corrected my posture and reduced pain in shoulders and neck • Air cushion reduced stiffness in my back (2) • Awareness of sedentary lifestyle (12) • Air cushion (4) • Active sitting (5) • Being part of a group • Trying out different activities and seeing the differences that they made (4) • Prospects of discoveries to help people who work in this environment • The results • Being able to give feedback into how our workplace could change to support a more active lifestyle • Being able to sit up straight and developing a good posture • Stool (2)	• ***Intervention Aspects*** • Remembering new habits to take more frequent breaks • More individual feedback following accelerometer use • Awareness of inactivity • Aching if used air cushion too long/unable to sit on cushion for too long (4) • ***Research Aspects*** • Remembering to wear the accelerometer (9) • Finding clothes to hide accelerometer • Finding time for meetings • Questionnaires (3)

Table 11.18 (iii) Feedback from participants in Intervention C - Summary of recommendations for other work groups

Recommendations for other work groups?
• The whole programme – it makes you aware and then supported small changes that can make a world of difference • More contact and exercises • Air cushion can be used for both sitting and back rest that relieves the pressure • Participate! (3) • Give it a try (2) • Air cushions (2) • Be open to new ideas • More detailed diary • The stools – I found them more comfortable • Active sitting (2) • More meetings – especially during the implementation time to check progress and keep everyone motivated (2)

12.0 Study 4 - Discussion

12.1 Main findings

This study examined three workplace interventions to reduce sedentary time, sustained sedentary time and encourage light activity of office workers using a participatory approach to intervention development and implementation. In addition, this study explored the impact of sedentary behaviour and physical activity workplace interventions on self-reported musculoskeletal pain, job satisfaction, and work productivity. The main findings following the intervention period were:

1. Intervention effects across all participants

- There was a small reduction in sedentary time and concurrent increase in light intensity activity during work hours.
- There was an increase in the break rate on work days, during work hours and during non-work hours on work days.
- There was a small increase in MVPA on work days, non-work days and non-work hours on a work day.
- There was a reduction in self-reported sitting time.

2. Effects between organisations

- Sedentary time and MVPA during work hours differed significantly by organisation with Organisation 1 responding most to the interventions.

3. Effects between interventions

- None of the 3 interventions (active office, traditional physical activity and office ergonomics) were clearly more effective at improving sedentary behaviour during work hours.
- During non-work periods, intervention effects differed by intervention with participants from Intervention A having the greatest reduction in sedentary time, sustained sedentary time and the greatest increase in break rate and MVPA compared to the other intervention groups.
- None of the 3 interventions were more effective at improving light activity during work hours and during non-work periods.

- Participants from Intervention A had a significant improvement in MVPA on work days when compared to the other intervention groups.

12.2 Secondary Outcomes following the intervention period

1. BMI and waist girth

- There was reduced waist girth (1.75cm) across all participants but no significant differences in the changes in BMI or waist girth between organisations or as a result of the different interventions.

2. Self-reported musculoskeletal pain

- There was no difference in percentage of participants reporting musculoskeletal pain in the different body regions.
- There was no difference in the reported number of body regions experiencing musculoskeletal pain.
- There was a trend for self-reported musculoskeletal pain to have less impact on work and leisure physical activity, the need to take medication and to see a health professional.

3. Readiness for physical activity

- 45% of participants moved to a more positive stage of behaviour change in physical activity.
- Activity changes were not consistent with stage of change group.

4. Job satisfaction

- There was high job satisfaction at baseline and no change in overall job satisfaction score.

5. Self-reported work productivity

- There was high self-reported work productivity at baseline and no change in self-reported work productivity.

6. Participant feedback

- Participation in the interventions varied between the interventions groups:
    - **Intervention A**: There was no consistent use of the Active Workstation; there was good participation in increasing incidental office activity.

- **Intervention B:** There was good participation in the pedometer challenge and there was reported increased use of stairs.
- **Intervention C:** There was very high participation in the interventions, especially 'active sitting' and the use of air cushions.

- Overall the feedback was positive across the interventions. Being made aware of the sedentary nature of office work and having the opportunity to participate in novel ways to change sedentary behaviour were cited frequently as the best aspects of the intervention.
- Barriers to participating in the interventions included lack of time to take active breaks, work stress and changing work habits.

12.3 Discussion

12.3.1 Intervention effects across all participants

Overall, there was a small but significant reduction in sedentary time and a concurrent increase in light activity during work hours, with no significant change to MVPA. There was also an increased break rate during work hours. As there was no change in MVPA, it is likely that the reduction in sedentary time was replaced by light activity.

While the interventions resulted in improved occupational sedentary behaviour, these changes were small, 1-2% of activity during working hours. Presently, it is not known what amount of sedentary time will adversely affect health, that is, what is the minimally clinically important difference. A number of population studies have explored the relationship between sedentary time and adverse health. Healy et al (2011) using NHANES data found that in the most sedentary sub-group, for every one hour/day increase in sedentary time, waist circumference increased by 1.4 cm. George et al (2013) using Australian data found that self-reported sitting in excess of 4 hours/day increased the risk of developing chronic diseases (heart disease, diabetes, cancer, elevated blood pressure) and sitting greater than 6 hours/day increased the risk of developing diabetes. Further, Camhi et al (2011) using NHAMES accelerometry data found that for increases in light activity of 30 minutes, there were lower odds of between 35-54% for reduced blood cholesterol and waist circumference. In the present study, sedentary time reduced on average by 8 minutes and light activity increased by an average of 7 minutes during work hours. It is not known whether changes of this magnitude are sufficient to change the health risks associated with occupational sedentary behaviour. However, recent laboratory studies have demonstrated that 28 minutes of light intensity treadmill walking in bouts of 2 minutes resulted in positive effects on glucose metabolism (Dunstan, Kingwell, et al., 2012). Further, alternating between 30 minutes of sitting and standing over an 8-hour day, for 5 days in simulated office conditions resulted in improved glucose metabolism in overweight office workers (Thorp et al., In Press). These findings suggest that small changes such as the findings from the present study have the potential to positively impact the health of sedentary office workers.

Healy et al (2011) using NHANES accelerometer data found that for the sub-group with the greatest number of breaks in sedentary time, waist girth was 4.1 cm less when compared to the group with the least breaks. Breaks in sedentary time were also found to be positively associated with inflammatory markers. Similarly, Carlson et al (In Press) using accelerometer data from the Canadian Health Measures Survey (CHMS) found that for each additional 10 breaks/day there was an associated 0.83 cm reduction in waist girth. In the present study there was an improvement in break rate of 0.7 breaks/sedentary hour during work hours that equated to an extra 5 breaks in sedentary time during work hours. Healy et al (2013) found that following a multicomponent intervention aimed at reducing occupational sitting, there was an increase in nearly 2 sit-stand transitions per hour of sitting measured by activPAL™. It is difficult to compare the magnitude of these findings as different motion sensors were used, however both interventions improved breaks in sedentary time, which is likely to have a positive impact on health. Currently, it is uncertain as to what level of uninterrupted sedentary time will adversely affect health, future research could investigate the dose-response for breaks in sedentary time required to effect meaningful health benefits.

In the present study, following the intervention the greatest reduction in sedentary time (1.9%) and greatest increase in MVPA (1.3%) was during non-work hours on work days. This time period was the most active period for participants in Study 1, which is similar to the findings for other office workers (Thorp et al., 2012). Activity changes during this time could reflect the increased use of active transport, domestic duties or leisure activities, however no details about specific non-work activities were assessed in the present study. It may be that this time period is the most flexible for office workers. All participants in Study 4 were employed in government jobs where work practices were regulated which may have made it difficult to fully participate in the interventions. Further, it may be that the strong workplace messages to be less sedentary and more active are carrying over into non-work time. Time use studies about specific activities during non-work hours may be useful in developing and tailoring health promotion interventions.

12.3.2 Intervention effects between organisations

Following the intervention period, sedentary time and MVPA differed by organisation during work hours with participants in Organisation 1 responding the most to the interventions. Organisation 1 had the most flexibility in work practices and therefore arguably, it had the greatest potential to change. Organisations 2 and 3 involved call centre and data processing work and showed the least change in sedentary time, sustained sedentary time and break rate during work hours. In these organisations, productivity and work compliance measures were monitored regularly and employees had little opportunity to vary their work tasks or even when to take lunch and coffee breaks. Workplace practices within Organisations 2 and 3 were extremely regimented so that varying office tasks to incorporate incidental activity, such as taking longer walks to the printer, were difficult to implement. Further, feedback from the participants indicated that these interventions were not fully supported by team leaders/management within the organisation.

Organisational features such as support within the organisation from managers, flexibility of working hours and job demands have been found to influence the implementation of workplace health programmes (Crump et al., 1996; McLellan et al., 2009; Taitel et al., 2008). Even though management and participants were aware of the intervention options, changing the organisational culture in Organisations 2 and 3 had limited success. Recently, Neuhaus et al (2014) found that by engaging and supporting management in a multi-component intervention that included the provision of a desktop sit-stand computer stand, there was a greater reduction in sitting time than the provision of a desktop sit-stand computer stand alone. In the present study, even though there was support expressed from the management and the organisation hierarchy, to effect changes in work practices within the government organisations that participated in this study, it may require stronger external support such as government sedentary behaviour guidelines. Emerging sedentary guidelines are recognising the need to not only reduce sitting time and break up prolonged sitting but also to limit screen time (Tremblay, LeBlanc, et al., 2011; Tremblay, Warburton, et al., 2011). The implementation of the new Australian Physical Activity and Sedentary Behaviour Guidelines (Commonwealth of Australia, 2014a) in large government organisations may be particularly important to effect meaningful changes in sedentary behaviour in this most sedentary group of office workers.

12.3.3 Effects between interventions

There are a number of potential reasons why it did not appear that one intervention (active office, traditional physical activity or office ergonomics) was clearly more superior to the other interventions in terms of changing sedentary behaviour during work hours. All participants undertook workplace meetings to develop workplace and intervention specific interventions as part of the participatory approach. Participants were encouraged to think broadly and suggest intervention ideas that could be included in the group interventions. Consequently, as part of this consulting process, there were overlapping intervention ideas between the intervention groups. Therefore, some of the intervention strategies implemented were common across the intervention groups.

In addition, the active office and traditional physical activity interventions were similar for most participants as only a few participants chose to use the Active Workstation and then usually for only short periods. Therefore, while both intervention approaches encouraged reduced sedentary behaviour and increased occupational activity during work hours, it was not possible to differentiate whether changes in sedentary behaviour and activity occurred during work tasks or during non-productive (breaks) between the active office and traditional physical activity intervention groups.

Further, many of the participants in Intervention Group A were resistant to using the Active Workstation. Feedback from the participants indicated that there were a number of barriers to using the Active Workstation, namely, the time taken to log on and off their regular computer, an unfamiliar workstation and perceived loss of productive work time. In addition, the use of a shared workstation may encounter other logistical issues such as interruption of work flow to accommodate movement between the Active Workstation and the regular desk, provision of equal access for all workers to the Active Workstation and the noise impact on workers near to the shared Active Workstation (Tudor-Locke et al., 2013).

Laboratory studies indicate that the use of an Active Workstation may reduce work productivity of some office based tasks (John et al., 2009; Ohlinger et al., 2011; Straker et al., 2009). Replacing a standard desk with an Active Workstation (John et al., 2011; Koepp et al., 2013) or incorporating a sit-stand computer stands onto standard desks (Alkhajah et al., 2012; Healy et al., 2013) has recently been found to be more successful in improving occupational sedentary behaviour that the provision of a standing 'hot' desk (Gilson, Suppini, et al., 2012) or an isolated Active Workstation such as the one used in the present study.

A variety of different interventions have been effective in reducing sedentary behaviour of office workers (Alkhajah et al., 2012; Evans et al., 2012; Freak-Poli et al., 2011; Healy et al., 2013). Aspects of each intervention approach (active office, traditional physical activity and ergonomic) may have equally contributed to the overall improvement in sedentary behaviour of the whole group. It may be that interventions were appropriately matched to each intervention group, demonstrating the success of the tailored participatory approach. Therefore, implementing a variety of interventions tailored to the specific requirements of an organisation may facilitate the success of sedentary behaviour workplace interventions.

Even though the interventions were aimed at occupational sedentary behaviour, there were significant changes in sedentary time, sustained sedentary time, break rate and MVPA during non-work periods, with participants from Intervention A responding the most during non-work. It is possible that messages from work to reduce sedentary time were carried over into non-work hours. Feedback from participants indicated that participants understood messages to reduce sedentary time at work but there was an inability to fully participate at work due to lack of work flexibility, fear of loss of productivity or time to participate during work hours. It appears that the message to reduce sedentary behaviour was heard but restraints within the organisaton may have limited participation. Therefore, workplace interventions may have an overflow effect into non-work periods, particularly if there are barriers to participation at work (Crump et al., 1996; McLellan et al., 2009; Taitel et al., 2008).

It was anticipated that the interventions presented in Intervention A that targeted incidental activity such as increasing inter-office activity, taking more breaks, standing or walking while working, would change light activity considerably. However, there was no difference in the change in light activity during work hours or non-work periods between the intervention groups. Even though participants in Intervention A appeared to have an increase in light activity, this change was not significant. Feedback from participants in Intervention A indicated that participation in improving incidental activity was low and this may explain why Intervention A was no different to the other interventions at improving light activity. It may also be that interventions that target increasing light activity at work are more difficult to implement (Healy et al., 2013) and novel interventions such as the use of the Active Workstation are still seen as quite 'radical' by participants. James Levine has pioneered the concept of 'active offices' with the provision of Active Workstations and installation of walking tracks in offices in the United States (Levine, 2012). In Australia, increasingly, there is a shift to "Activity Based Working" (ABW) where employees do not have assigned desks or offices but instead staff can choose where to work in 'pods' using mobile devices. Large Australian companies (Commonwealth Bank; Bank West) have shifted to ABW primarily to improve productivity, retain staff and reduce costs (Belby, 2013; Cortis, 2013) but to date there does not appear to be any research that has documented the potential health gains, such as reduced sedentary behaviour, or the possible negative impacts such as increased musculoskeletal symptoms from poor ergonomic considerations, from adopting ABW. Future research should consider the health impacts the ABW.

12.3.4 BMI and waist girth

In the present study, following the intervention period, there was no significant change in BMI, which is consistent with other recent intervention studies (Alkhajah et al., 2012; Healy et al., 2013). However, there was a significant reduction in waist girth (1.75 cm) for all participants following the intervention. Other intervention studies (Alkhajah et al., 2012; Healy et al., 2013) to reduce sedentary behaviour did not find changes in waist girth following the interventions.

Increased frequency of breaks in sedentary behaviour has been found to be associated with reduced waist girth (Carlson et al., In Press; Healy, Clark, et al., 2011; Healy, Dunstan, Salmon, Cerin, et al., 2008) and it may be that the interventions implemented in the present study, which encourage breaks in sedentary behaviour could have contributed to the reduction on waist girth of the participants. The present study demonstrated that small changes in activity and sedentary behaviour could impact health risk factors, such as waist girth.

12.3.5 Musculoskeletal changes following the intervention

While the interventions appeared to have positive impacts on musculoskeletal symptoms, these changes were not statistically significant. There was a tendency for reduced frequency of participants reporting pain in the upper quadrant but there was also a tendency for increased frequency of pain in the lower back and legs. Similarly, it appeared that some participants reported fewer regions of musculoskeletal pain. The findings from the present study are consistent with other studies that have examined the impact on musculoskeletal pain following the introduction of sit-stand workstations (Davis et al., 2009; Healy et al., 2013; Heneweer et al., 2009; Neuhaus et al., 2014), indicating that there may be a potential tradeoff between improving sedentary behaviour and physical activity while balancing the changes in musculoskeletal pain. Future workplace interventions that encourage changes to physical activity even lower intensity activity such as standing or incidental light activity, should consider the potential adverse impacts on lower quadrant musculoskeletal pain (Davis et al., 2009; Ebara et al., 2008). Providing appropriate low impact standing surfaces, footwear advice and activity guidelines may need to be considered (Hughes, Nelson, Matz, & Lloyd, 2011; Y. Lin, Chen, & Cho, 2012).

It is possible that pre-existing musculoskeletal symptoms of participants may have influenced the findings. Office workers report a high prevalence of musculoskeletal pain (Harcombe & McBride, 2009; Huysmans, 2012; Widanarko et al., 2011) and baseline findings from the present study were consistent with the findings from other groups of office workers (Harcombe & McBride, 2009; Janwantanakul et al., 2008), indicating that a high proportion of office workers had musculoskeletal pain prior to the intervention. The presence of musculoskeletal pain has the potential to influence physical activity and sedentary behaviour (Heneweer et al., 2009; Husemann et al., 2009) with some office workers choosing more occupational activity such as the use of a sit-stand work station, as described in Chapter 8 of this thesis, while others may choose to reduce occupational activity. Future research should consider the impact of pre-existing musculoskeletal pain on the success of sedentary behaviour interventions for office workers and further, and the long term effects on musculoskeletal pain by modifying activity and sedentary behaviour.

12.3.6 Readiness for physical activity

Previous research that has examined the change in readiness to participate in physical activity has used self-reported measures of physical activity to assess changes in physical activity (Titze et al., 2001). The present study appears to be the first study to examine accelerometer determined light and MVPA and attitude change to physical activity. Overall, 45% of participants moved to a more positive phase of readiness to participate in physical activity, which is consistent with the findings that for all participants, there was an overall increase in physical activity and reduction in sedentary behaviour. It is also consistent with feedback from participants that there was a greater awareness of exposure to occupational sedentary behaviour that may have resulted in the improved attitude to physical activity.

The use of an objective measure of sedentary time and physical activity enabled the assessment of whether attitude changes to physical activity were matched by changes to physical activity levels. With the exception of MVPA on work days for the stable group, there was no significant difference in activity levels between the adopters, stable and regression groups, indicating that the readiness for change survey did not accurately represent activity levels of the participants. Even though attitude change may not have been reflected in activity change, it would appear that nearly half the participants reported improved motivation to participate in physical activity that ultimately may lead to a greater involvement in physical activity.

12.3.7 Self-reported job satisfaction

Following the intervention period, there was no impact on self-reported job satisfaction for all participants. It may be that as job satisfaction was reported as high at baseline, the influence of the workplace intervention was not sufficient to change job satisfaction. It is also possible that the survey instrument (Warr et al., 1979) was not sensitive enough to detect small changes in job satisfaction. A more comprehensive assessment of job satisfaction may reveal changes to job satisfaction not detected by the survey used in the present study.

12.3.8 Self-reported work productivity

In the present study self-reported work productivity was high at baseline and there was no significant change following the intervention period. It may be that the HPQ was not sensitive enough to detect small changes in productivity as the modified version used in the present study consisted of only 3 questions.

Further, at each of the organisations that participated in this study, productivity measures that included work output and compliance with work task targets were measured on a daily basis. Negotiations with the organisations to access this information failed due to privacy and ethical issues. Future large workplace sedentary behaviour interventions should consider as part of the design, a means to access the productivity of employees in workplaces where these measures are taken. Particularly in large government organisations, decisions on access to employee productivity information may be a lengthy and complex process. Importantly, if it was able to be shown that a reduction in occupational sedentary behaviour did not reduce work productivity or if it indeed productivity improved, it is likely that organisations would be supportive of workplace changes that promote sedentary behaviour reduction.

12.4 Strengths and limitations

A strength of this study was that it was a randomised controlled trial that examined a variety of different interventions to reduce occupational sedentary behaviour during work hours and also during non-work periods. The participatory approach to intervention development resulted in interventions that were tailored to the workplace. Previous sedentary behaviour workplace interventions have used convenience samples of university employees (Alkhajah et al., 2012; Evans et al., 2012; Gilson et al., 2009; Neuhaus et al., 2014) whereas in the present study, attempts were made to modify the work practices of office workers in typical situations where there was little flexibility to their work environment and therefore, this study had high external validity

Limitations of this study include a modest sample size with a high attrition rate, with only half the number of participants completing the study that were planned based on initial power calculations. Even though the there was sufficient power to detect the 1.7% difference in sedentary time during work hours across all participants, it did not provide sufficient power to detect the small differences such as the 2.5% observed between intervention groups during work hours. Future intervention studies to reduce sedentary behaviour of office workers may consider the addition of posture sensors to assess changes in sedentary behaviour as these may be a more sensitive tool to assess the efficacy of work-based interventions. Further, the number of interventions strategies and similarities between interventions as implemented as well as the imbalance between group sizes within each organisation meant that the efficacy of a particular intervention strategy and the effect on musculoskeletal pain of a particular intervention could not be determined. In addition, there was no long term follow up which would have been useful to assess the stability and sustainability of the interventions.

12.5 Conclusion

A participatory approach to intervention development and implementation resulted in small changes in occupational sedentary behaviour in a group of office workers particularly vulnerable to risks associated with prolonged sedentary exposure. While it has been advocated that a reduction in sedentary behaviour could reduce musculoskeletal pain, this study was unable to demonstrate this effect. In order to achieve meaningful and sustained changes in occupational sedentary behaviour of office workers, further support from within organisations may be needed and this may be achieved through further development and implementation of sedentary guidelines. Important directions for future research include matching intervention strategies to organisation features, revising workplace guidelines to incorporate the knowledge of the importance of sedentary behaviour in the reduction of cardiometabolic risk factors, longitudinal intervention studies and the establishment of a dose-response relationship between occupational sedentary behaviour and health outcomes, including work-related musculoskeletal pain.

13.0 Overall thesis discussion

The computerisation of modern offices has meant that traditional office work practices have changed, with a common consequence being the reduction in incidental office activity. Increased occupational sedentary exposure is often compounded by increased leisure time sedentary pursuits such as using the internet on a mobile device. Unlike some other occupational groups, such as teachers or health professionals, office workers generally have limited flexibility to conduct their work in positions other than sitting and may thus be particularly vulnerable to health risks associated with sedentary behaviour. Therefore, the studies for this thesis specifically targeted office workers.

This thesis brought together key elements from different disciplines in a unique way to contribute to the growing sedentary behaviour research base and provide an original perspective to the development of interventions aimed at improving sedentary behaviour of contemporary office workers. Further, this thesis explored the important relationship between sedentary behaviour, physical activity and musculoskeletal pain and whether modifications to sedentary behaviour and physical activity would impact on musculoskeletal pain.

13.1 Contributions to knowledge

This thesis aimed to address the eight gaps in the literature that were identified in Chapter 2:

1. The need for comprehensive quantification of physical activity and sedentary behaviour of contemporary office workers using accelerometry.
2. The need to explore the physical activity and sedentary behaviour of office workers compared to other occupational groups.

3. There is a paucity of literature that describes the association between objectively measured physical activity and sedentary behaviour and musculoskeletal pain of office workers.
4. There is a paucity of literature that has examined potential correlates to occupational physical activity and sedentary behaviour such as job satisfaction, work productivity and stage of readiness to participate in physical activity.
5. The need to examine the physical activity and sedentary behaviour of office workers using a sit-stand workstation in free-living conditions.
6. There does not appear to be any workplace intervention studies aimed at reducing sedentary behaviour and increasing physical activity of office workers that applied a participatory approach to intervention development.
7. There is a paucity of research that examines whether workplace interventions to reduce sedentary behaviour will change musculoskeletal pain.
8. At the time of conducting the studies for this thesis, there did not appear to be any studies that had assessed whether interventions aimed at reducing sedentary behaviour were successful in different organisations.

This final chapter of the thesis will bring together the findings from the four studies of the thesis and discuss how this thesis contributed to filling in the gaps in the literature.

13.1.1 Comprehensive quantification of physical active and sedentary behaviour of contemporary office workers

The comprehensive examination of physical activity and sedentary behaviour of office workers in Study 1, for the first time specifically analysed the pattern of exposure of sedentary time, light activity and MVPA of office workers at work and during non-work periods. It is evident from the results of Study 1 that office work is characterised by high occupational exposure to sedentary time and prolonged bouts of sustained sedentary time, with only a small proportion of brief or sustained bouts of light activity during work hours. With the growing understanding of the relationship between sedentary behaviour and cardiometabolic risk factors, two distinct health paradigms are evident. It appears to be important to participate in sufficient MVPA to maintain good health, such as participation in 150-300 minutes per week of moderate intensity activity (Commonwealth of Australia, 2014a, 2014b; Dishman, Wahburn, & Heath, 2004; Pate et al., 1995; Welk, 2002), but in addition, it is arguably equally important to limit exposure to sedentary behaviours (Dunstan, Howard, et al., 2012; George et al., 2013; Healy, Mathews, et al., 2011; Katzmarzyk et al., 2009; Katzmarzyk & Lee, 2012; van der Ploeg et al., 2012). Public health campaigns and health guidelines have traditionally focused on the small proportion of the day participating in MVPA rather than addressing the large proportion of the day participating in sedentary behaviours. Therefore, as occupational sedentary time contributed nearly half of overall weekly sedentary time for office workers, health promotion campaigns should also emphasise reducing overall sedentary exposure and breaking up sedentary time, particularly during work hours.

The new Australian Physical Activity and Sedentary Behaviour Guidelines (2014a), address the need to minimise sedentary behaviour and importantly recognise the contribution of occupational sedentary behaviour by specifically encouraging more incidental activity at work. It is currently unclear what level of sedentary exposure during work hours is reasonable, especially when considering that there may be equally high levels of sedentary behaviour during non-work periods. However it is likely that current office work practices are not a 'safe system of work' as they encourage excessive occupational sitting (Straker et al., In Press).

There are no definitive sedentary guidelines that specifically recommend safe and reasonable sedentary exposure. Canadian sedentary guidelines for children and youth recommend limiting screen time and prolonged sitting (Tremblay, LeBlanc, et al., 2011) and other recommendations include taking a break from sitting every 30 minutes (Dunstan, Howard, et al., 2012). The ergonomics literature has advocated that postural variation is important for maintaining musculoskeletal health (Mathiassen, 2006; Straker & Mathiassen, 2009). Recommended breaks from sedentary work of 5-10 minutes every hour

(Comcare, 2008; Occupational Safety & Health Administration; Ontario Ministry of Labour) were intended to give workers sufficient break from sedentary posture and sustained muscle loading to prevent musculoskeletal disorders (Toomingas et al., 2012). It is not known whether a similar break frequency and duration would be sufficient to negate the potential cardiometabolic consequences of sustained sedentary behaviour. Occupational health practitioners have expressed the need for sedentary thresholds in order to implement appropriate intervention programmes (Gilson, Straker, & Parry, 2012).

While there have been a number of studies that have examined the physical activity and sedentary behaviour of office workers (Ryan et al., 2011; Thorp et al., 2012; Toomingas et al., 2012), Study 1 for the first time, provided a detailed analysis of the overall amount and pattern of exposure of light intensity activity of office workers. Study 1 confirmed the reciprocal relationship between sedentary time and light activity (Healy et al., 2007; Healy, Wijndaele, et al., 2008) but also highlighted that this relationship existed during work hours for office workers (Clemes, O'Connell, et al., 2014). Study 2 also found that there was a reciprocal relationship between sedentary time and light activity for teachers during work hours. As MVPA contributed only a small proportion of the working day, it is therefore important to take advantage of the interplay between sedentary and light activity in reducing occupational sedentary behaviour.

13.1.2 Physical activity and sedentary behaviour of office workers compared to other occupational groups

It appears that Study 2 was the first study to examine the physical activity and sedentary behaviour of school teachers using accelerometers. While overall, office workers were more sedentary than teachers, what was more surprising was the striking difference in the pattern of exposure of physical activity and sedentary behaviour during work hours. Office workers were sedentary in bouts of 30 or more minutes for 41% of working hours whereas for teachers sustained sedentary time was only 9% of working hours. Therefore office

workers, when compared to teachers may be at a greater risk of the potential health risks associated with sustained sedentary exposure.
Additionally, there was no difference in the total amount or pattern of exposure of physical activity or sedentary behaviour between teachers and office workers during total non-work time. Therefore, office workers are not 'compensating' for sustained occupational activity by increasing leisure time physical activity.

The other distinguishing feature of occupational activity between teachers and office workers was that teachers participated in more overall light intensity activity (teachers: 34%; Office workers 15%) and a greater proportion of short bouts (0-5 minutes) of light activity during working hours compared to office workers (Light bouts 0-5 minutes: teachers 22%; office workers 7%). Given the health benefits of participation in light intensity activity (Dunstan, Kingwell, et al., 2012; Healy et al., 2007; Swartz et al., 2011), these findings highlight that compared to office workers, teachers may be at less risk of poor cardiometabolic health due to less sedentary behaviour and greater light intensity activity at work. While office work is task specific and may not allow for the same level of incidental activity provided while teaching, Study 2 demonstrated that a group of teachers that share many of the same work tasks as office workers can be more active and less sedentary during work hours.

13.1.3 Association between objectively measured physical activity and sedentary behaviour and musculoskeletal pain of office workers

There is a limited understanding of the relationship between musculoskeletal pain and sedentary behaviour. It has been suggested that both excessive physical activity and sedentary behaviour can contribute to the development of musculoskeletal pain (Heneweer et al., 2009). For example, office workers from Study 3 chose to use a sit-stand workstation due to musculoskeletal pain that was aggravated by excessive sitting. One of the limitations of previous research has been that only self-report measures of physical activity or sitting have been used (Lin et al., 2011; Roffey et al., 2010). It appears that Study 1 was the first study to examine the relationship between accelerometer derived sedentary time and physical activity and self-reported musculoskeletal pain. A high proportion of office workers in Study 1 reported upper quadrant pain. However, there did not appear to be a correlation between the proportion of sedentary time or physical activity and self-reported musculoskeletal pain. As the data in Study 1 was cross-sectional, it was not possible to examine the causal relationship between activity and musculoskeletal pain. Importantly, the relationship between musculoskeletal pain and activity may be bi-directional so that the presence of musculoskeletal pain could also impact participation in physical activity and sedentary behaviour.

13.1.4 Potential correlates to occupational physical activity and sedentary behaviour

Study 1 appears to be the first study that has explored the relationship between job satisfaction and physical activity and sedentary behaviour. Further, it also examined the important relationship between work productivity and physical activity and sedentary behaviour. While Study 1 did not find an association between job satisfaction and physical activity or sedentary behaviour there was a moderate association between accelerometer derived light intensity activity and overall work productivity. These findings from Study 1 could imply that office workers that are more active are more productive or conversely that increased work productivity improves light activity in office workers. As there was only a moderate sample that completed the work productivity survey (HPQ) with sufficient accelerometer data, more research is needed to determine if this relationship is consistent. If it is clearly established that there is a correlation between light intensity activity and work productivity it may encourage workplaces to implement interventions that promote light intensity activity.

13.1.5 Physical activity and sedentary behaviour of office workers using a sit-stand workstation in free-living conditions

Study 3 appears to the first study that has observed the overall amount and pattern of exposure of physical activity and sedentary behaviour of office workers that chose to use a sit-stand workstation due to pre-existing musculoskeletal pain. In Study 3, the small group of office workers that used a sit-stand workstation did not demonstrate reduced sedentary time or increased light activity during work hours, however the sit-stand office workers spent more time in short bouts of light activity during work hours when compared to seated office workers (light bouts 0-<5 minutes: sit-stand office workers 13% wear time; seated office workers 7% wear time, light bouts 5-<10 minutes: sit-stand office workers 3% wear time; seated office workers 1.5% wear time). Study 3 highlighted that the use of a sit-stand workstation has the potential to change the pattern of activity that may independently influence health outcomes (Dunstan, Kingwell, et al., 2012; Hamilton et al., 2007; Healy, Dunstan, Salmon, Cerin, et al., 2008; Swartz et al., 2011).

Other research findings indicate that sit-stand workstations are effective for reducing sitting time and increasing standing time of office workers (Alkhajah et al., 2012; Healy et al., 2013) but there is little evidence that the use of a sit-stand workstation can modify overall occupational activity (steps) or light activity (Healy et al., 2013; Neuhaus et al., 2014). It may be that standing and participation in light activity both result in a beneficial physiological state but the magnitude of the effect is different. Therefore, improving sedentary behaviour of office workers may need to involve a number of different approaches that not only reduce sitting, but also promote light activity.

13.1.6 Participatory approach to the development of workplace interventions aimed at reducing sedentary behaviour and increasing physical activity

In Study 4, for the first time, a participatory approach was used to develop and implement a number of different interventions to reduce occupational sedentary behaviour and increase occupational light intensity activity. Rather than applying a predetermined list of interventions, employees, team leaders and managers had the opportunity to provide input into the type of programmes that would best suit each workplace. Interventions included encouraging incidental office activity, walking in breaks, 'active sitting' and for some participants, the use of an Active Workstation. Participants did not have access to a sit-stand workstation. One of the unique aspects of Study 4 was that participants were offered a range of interventions to participate in. The advantage of this approach is that employees may participate in an intervention best suited to their individual preference. It was evident that only a small number of employees chose to use the Active Workstation, yet those who used it, reported high satisfaction. Similarly, in Intervention C (focused on computer workstation design and setup, 'active' sitting and breaking up seated computer tasks), a small number of participants preferred to sit on a stool whereas the majority of participants preferred to sit with an air cushion to improve active sitting. Providing a variety of interventions that have been developed by the participants and managers within an organisation may improve compliance and sustainability with workplace-based interventions that could ultimately lead to better occupational health of workers.

The overall aim of Study 4 was to explore a variety of different ways to improve occupational sedentary time and occupational light activity of office workers. At the commencement of Study 4, studies had explored a variety of different approaches to modifying sedentary behaviour of office workers (Evans et al., 2012; Freak-Poli et al., 2011; Gilson, Suppini, et al., 2012). Subsequently, a number of recent studies have compared the effectiveness of two different interventions aimed at improving occupational sedentary behaviour of office workers (Healy et al., 2013; Neuhaus et al., 2014). While Healy et al (2013) and Neuhaus et al (2014) employed multicomponent interventions (the provision of a sit-stand computer stand and individual health coaching) participants were not presented with a variety of intervention choices.

13.1.7 Impact of workplace interventions to reduce sedentary behaviour on musculoskeletal pain

One of the aims of Study 4 was to determine whether a programme aimed at reducing occupational sedentary behaviour could also modify musculoskeletal pain of office workers. Study 4 did not demonstrate a significant change in the proportion of participants reporting musculoskeletal pain following the intervention period. The modest sample size, small changes in physical activity and sedentary behaviour following the intervention period and the limitations of the musculoskeletal questionnaire, which did not rate intensity or duration of musculoskeletal pain, may have contributed to these results. It may also be that there is not a direct relationship between physical activity, sedentary behaviour and musculoskeletal pain as discussed above, and that modifying sedentary behaviour may only be effective at reducing musculoskeletal pain in certain situations, such as pain aggravated by prolonged sitting.

13.1.8 Effectiveness of workplace interventions to reduce sedentary behaviour across different organisations

Study 4 appears to be the first study that has compared the effectiveness of a workplace sedentary behaviour reduction intervention between different organisations. It was found that organisation features and work practices influenced the participation and the success of the interventions. It was clear from the results and feedback from the participants that the organisations with the most flexibility and control of work practices responded most positively to the interventions. Even though there was consultation regarding the intervention development and implementation with managers and supervisors through the participatory meetings, it was difficult to change work practices, such as introducing incidental office activity, in the most rigid organisations. Engaging managers throughout the intervention process, from implementation to completion has been recently shown to be more successful in changing sedentary behaviour of office workers than introducing an intervention alone (Neuhaus et al., 2014).

It may be very difficult to change occupational sedentary behaviour and physical activity unless workers have the ability to modify the way in which work tasks are performed or the work tasks change sufficiently to require movement such as the requirement to use a sit-stand workstation or an Active Workstation for a certain proportion of the day. It may be that until sedentary exposure limits are determined and sedentary guidelines are adopted and implemented by workplaces, sedentary workers will continue to be at risk. The results from this thesis add to the growing body of sedentary behaviour research and strengthen the urgent need to limit sedentary exposure. Organisations such as those that participated in Study 4, with a rigid, hierarchical structure are perhaps more likely to modify work practices if there is a strong regulatory influence.

13.2 Practice implications

It is important for health professionals working in the area of occupational health to understand that office workers are not only at risk of occupational musculoskeletal disorders, but also the potential adverse health risks associated with prolonged and uninterrupted sedentary behaviour. Health professionals such as physiotherapists have primarily focussed on addressing problems at an individual or community level, by preventing and managing musculoskeletal disorders as illustrated in Figure 1.2 in the introduction to this thesis. It is therefore advisable for health professionals to incorporate the evidence from sedentary behaviour research into clinical practice at all levels of interactions. This could involve: advising patients that work in sedentary occupations about the potential health risks associated with occupational sedentary behaviour; prescribing exercise programmes that include general physical activity and sedentary behaviour guidelines; advocating for regular activity breaks and reduction of sedentary behaviour within workplaces; educating patients about the health risks associated with sedentary behaviour by providing educational pamphlets/posters; getting involved in community physical activity promotional events and contribute to the further development of sedentary behaviour guidelines by conducting population surveillance and intervention research and participating in developing public health policy.

13.3 Strengths and limitations

A major strength of all four studies of this thesis is that they were conducted in free-living conditions. Conducting the real-world studies was challenging in several ways. Recruitment of large government organisations required approval from many managerial levels. The strict hierarchical structure of the organisations impacted on the scheduling of workplace meetings, provision of equipment and ultimately on the participation and success of the interventions (Study 4). Finally, conducting research in real office environments, where workers moved departments, left the workplace or may not be motivated to complete a workplace sedentary reduction programme meant that there was a high attrition rate of participants. The advantage however, of conducting research in real office workplaces was the authenticity of the studies in this thesis that accurately reflect the reality of office workers.

Other major strengths of the studies in this thesis were combining fields of research and applying an interdisciplinary approach to analysis of different aspects of health behaviours and developing interventions that target a variety of different health issues. A further strength of this thesis was that it applied a broad view of occupational health to encompass musculoskeletal health and other potential correlates to occupational sedentary behaviour.

The main strengths and limitations of the individual studies were discussed in detail in the discussion chapters on each study (Chapters 6-8 and Chapter 12) and are summerised in Table 13.1.

Table 13.1 Study strengths and limitations

Strengths	Limitations
Study 1	
• Comprehensive examination of total amount and pattern of exposure of sedentary time, light activity and MVPA of office workers at work and during non-work periods • Accelerometer derived relationship between sedentary time and physical activity and musculoskeletal pain, job satisfaction and work productivity	• Moderate sample size from just one organisation • Use of an accelerometer that measured activity but not posture • Musculoskeletal questionnaire that did not assess intensity, frequency and duration musculoskeletal pain
Study 2	
• Accelerometer measured overall amount and pattern of exposure of sedentary time and physical activity of school teachers at work and during non-work periods	• Small sample size of teachers from just one school • Low response rate from teachers completing the musculoskeletal survey
Study 3	
• Observational study of office workers using a sit-stand workstation in free-living conditions	• Observational study, rather than prospective design so it was not possible assess whether a sit-stand workstation was able to modify work practices or musculoskeletal pain
Study 4	
• Randomised controlled trial • Variety of different intervention approaches • Participatory approach to intervention development • Participants in typical work conditions	• Moderate sample size • Research sample of office workers in real work conditions limited participation in some aspects of the programme and contributed to high attrition • Use of an accelerometer that measured activity but not posture • Similarities between the interventions • Imbalance between intervention and organisation group sizes • Musculoskeletal questionnaire that did not assess intensity, frequency and duration musculoskeletal pain • No long term follow up

13.4 Future directions for research

There is now substantive evidence identifying the relationships between sedentary behaviour and health outcomes, Phase 1 of the behavioural epidemiological framework (Figure 1.3) (Owen et al., 2010). Arguably, an important research priority is to establish the dose-response relationship between sedentary time and poor health. Study 1 confirmed that office workers are sedentary for a large proportion (80%) of working hours and that work contributed nearly half of total weekly sedentary exposure. It is therefore important to establish a safe acceptable level of daily sedentary exposure, especially occupational sedentary exposure, in order to refine and potentially legislate current sedentary guidelines (Phase 6 of framework).

In addition, further research exploring the relationship between light activity and health outcomes could assist in the development of interventions that modify sedentary behaviour (Phase 5 of framework). While this thesis confirmed the reciprocal relationship between sedentary time and light activity during work hours, it is important to explore whether the introduction of light intensity activity negates the adverse impact of prolonged sedentary behaviour. In Study 4, when examining all participants, following the intervention period it was found that the reduction in sedentary time during work hours (8 less sedentary minutes during work hours) was matched by the increase in light activity during work hours (7 more light intensity minutes during work hours), without any significant change in MVPA. It is not known whether this magnitude of improvement in sedentary time and light activity is sufficient to improve health or to prevent chronic disease, however, recent laboratory studies indicate that small changes in light activity can positively impact health (Dunstan, Kingwell, et al., 2012; Swartz et al., 2011). Future studies could explore the dose-response relationship between light activity and health outcomes such as cardiometabolic indicators, waist girth measures and blood glucose response.

The evidence from studies in this thesis is inconclusive regarding the relationship between sedentary behaviour and musculoskeletal pain. It is important to continue research into this relationship between musculoskeletal pain and activity in order to develop interventions that may improve the occupational health of sedentary workers. Office workers report a high rate of musculoskeletal pain, particularly in the upper quadrant (Harcombe & McBride, 2009; Janwantanakul et al., 2008). Further, work-related musculoskeletal disorders account for 60% of all workers' compensation claims in Australia (Safe Work Australia, 2010) with white-collar workers reporting 14 per 1000 injuries as chronic joint or muscle conditions (Australian Bureau of Statistics, 2011). While there is a trend for a decreasing incidence of work-related musculoskeletal disorders in Australia (Australian Bureau of Statistics, 2011), there is still a significant cost to employers in terms of productivity, absenteeism and workers' compensation (Centers for Disease Control and Prevention, 2013). Reducing occupational sedentary behaviour may assist in improving cardiometabolic health but there may be the added benefit of improving musculoskeletal health. However, as the causality between physical activity, sedentary behaviour and musculoskeletal pain has not been clearly established, a research priority should be to further explore this important relationship.

Future research should use an objective measure of sedentary behaviour and incorporate a comprehensive assessment of musculoskeletal pain. It may be possible to examine the relationship between accelerometer derived sedentary time and musculoskeletal pain using existing large accelerometer data sets such as NHANES, if sufficient musculoskeletal information is available. It is possible that musculoskeletal pain may influence participation in sedentary behaviour (Phase 4 of framework) and further, sedentary behaviour may contribute to the development of musculoskeletal pain. Therefore the presence of musculoskeletal pain may be a confounding factor in sedentary behaviour interventions.

Further research is needed to determine the physiological benefits and distinctions between standing and participation in light intensity activity. This may be achieved by comparing objectively measured sedentary behaviour and light activity of occupational groups that participate in mainly standing or light activity. Alternatively, conducting simulated laboratory studies have the advantage of controlling for activity and standing and may also be able to assess muscle activation intensity and patterns that could assist in the understanding of musculoskeletal symptoms associated with standing and light activity. Further population and laboratory research that explores standing and light activity would contribute to measuring and understanding of variations in sedentary behaviour in different populations (Phases 2 and 3 the framework).

Developing new intervention studies may be assisted by conducting qualitative exploratory studies with employees, managers and practitioners to examine new ways to reduce occupational sedentary behaviour and to introduce light activity into the office environment. For example, collecting qualitative data regarding participation and health benefits from organisations that incorporate "Activity Based Working" may assist in developing new interventions to reduce occupational sedentary behaviour. Further, future workplace sedentary behaviour research should continue to explore novel and practical ways to encourage participation in light activity during work hours. Rating interventions in terms feasibility and practicality may assist in developing tailored interventions to reduce workplace sedentary behaviour (Phase 5 of the framework).

The participants in Study 4 that used the Active Workstation perceived that work productivity was impaired which may be the reason why there was only limited use of the Active Workstation (Tudor-Locke et al., 2013). Further, as Active Workstations are expensive to purchase, future research should consider whether the cost of an Active Workstation is offset by the potential benefits and if work productivity can be maintained in real work situations. Further research that measures work productivity in terms of quality and volume of work is needed in real work, rather than laboratory environments. In addition, future studies should address ways to motivate workers to use an Active Workstation.

Two long-term Active Workstation studies have focused on weight and waist girth reduction in overweight and obese participants (John et al., 2011; Koepp et al., 2013). Weight reduction may be an intrinsic motivator for people to use the Active Workstation. In Study 4, all participants received tailored e-mails throughout the intervention period to assist in motivating the participants in the study. Motivation may be improved in future studies by increasing the frequency of tailored e-mails or by creating a pedometer challenge that encourages activity during work hours.

13.5 Conclusion

Sedentary behaviour research has grown extensively over the last decade with overall sedentary exposure and uninterrupted sedentary behaviour being recognised as potentially independent risk factors for poor health. This thesis contributed to the body of scientific literature regarding the measurement of occupational sedentary behaviour and highlighted that office workers may be particularly vulnerable to the adverse risks associated with prolonged sedentary exposure. Further, this thesis, for the first time examined the important relationship between accelerometer determined sedentary time, light activity and MVPA and self-reported musculoskeletal pain of sedentary workers. In addition, this thesis found that a number of different interventions developed using a participatory approach, could significantly reduce occupational sedentary behaviour of office workers.

Future sedentary behaviour research should focus on the dose-response relationship between sedentary behaviour and poor health in order to develop detailed sedentary exposure guidelines. There is also the need for more comprehensive research that examines the relationship between musculoskeletal pain and sedentary behaviour using objective measures of sedentary behaviour and physical activity and detailed characterisation of pain. Finally, it is also important to bring together the skills and expertise from all health professionals that interact with office workers, to develop tailored interventions with the aim of limiting occupational sedentary exposure.

There is great potential to use new and existing technologies to reduce the risks associated with sedentary exposure of office workers. In the offices of the future, chairs and desks may become redundant with interfaces that incorporate whole body movements, rather than the click of a mouse. It is hoped that health professionals will embrace the opportunities to contribute to sedentary behaviour research and advocate for less sedentary and more active office work.

14.0 References

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APPENDIX A: Study 1 - Participant information and consent form (office workers)

Participant Information Sheet

Title of Project – Physical Activity of Office Workers

Chief Investigator: Sharon Parry, School of Physiotherapy, Curtin University of Technology, Telephone 0414 270 213. Professor Leon Straker, School of Physiotherapy, Curtin University of Technology, Telephone 9266 3634

Thank you for your interest in participating in this important research project. Below you will find information about this research to help you decide whether to participate.

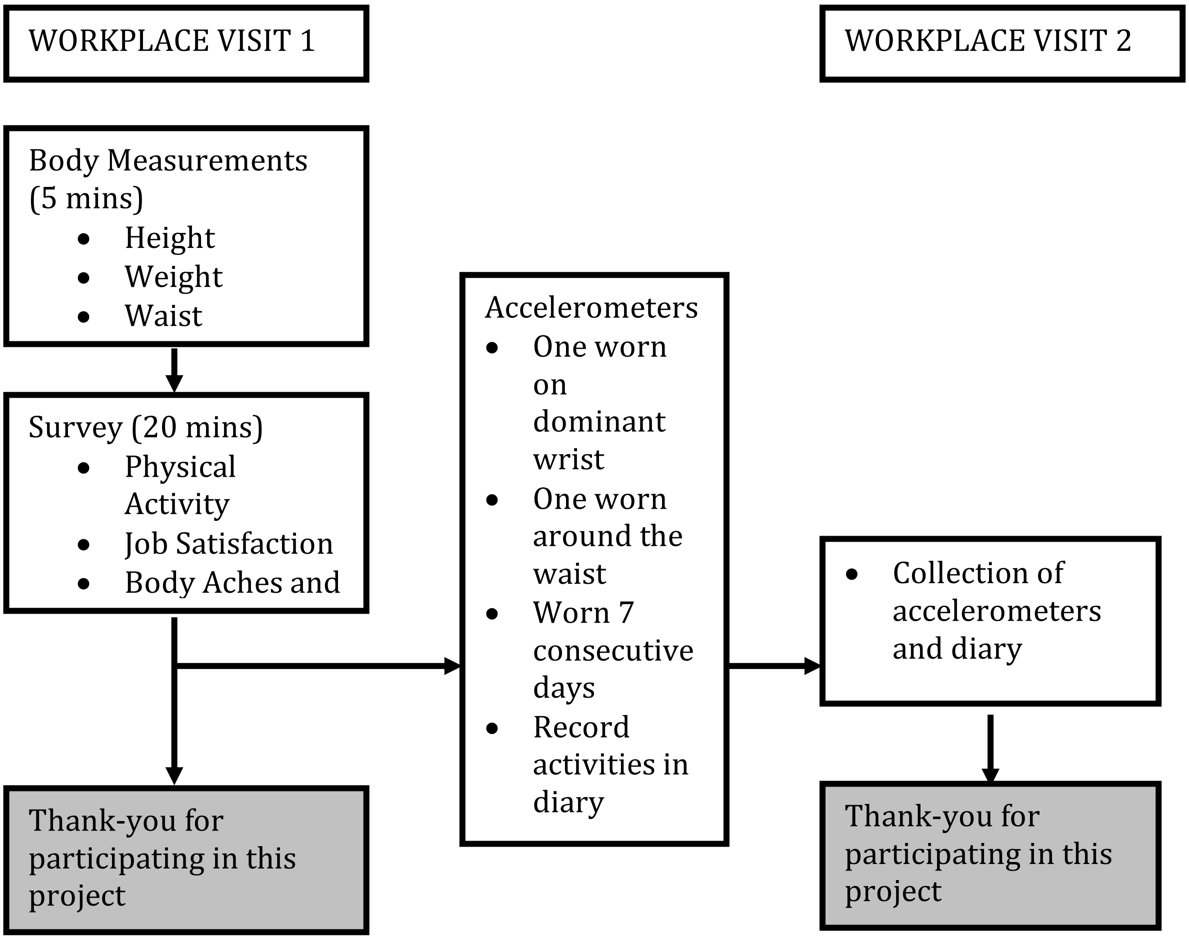
Purpose of the Study
Research from Australia and around the world has confirmed that more people are employed in less active jobs and that people are becoming less physically active. This trend is increasing, which is evident in the alarming rate of obesity and associated diseases in the developed world. We know that office based work is essentially sedentary and that there are an increasing number of people participating in less active jobs. However, there is very little information about the differences in activity levels between activities at work and activities outside of the office. In this study, we hope to find out exactly how active office workers are while they are working and when they are not at work – after work and on the weekends. To provide information comparing activity at work and outside of work we will ask you to complete some questionnaires about your activities at work and at home.

Some of you will also be asked to wear 2 motion sensors, called accelerometers, that record the amount and the intensity of your activity. The information that we gather from the questionnaires and the accelerometers will give us a better understanding about the physical demands of office work and how active office workers are in their spare time. This information will be used to help design work based programmes that promote a more active lifestyle.

Procedures
If you agree to participate, we will visit you at your workplace and take some measurements (height, weight and waist circumference) and ask you to complete a questionnaire about your physical activities at work and at home, your job satisfaction and about any aches and pains that you might be experiencing. This questionnaire will take about 20 minutes to complete. Please refer to Procedure Diagram below.

If you agree to also wear the accelerometers (which are about the size of a wrist watch) we will ask you to wear one on your dominant wrist (on a watch strap) and another at your waist (on an elastic belt). We will ask you to wear these devices for 7 consecutive days during all waking hours and to briefly record your activities in a diary that we will provide.

Procedure Diagram



Discomforts, Risks and Benefits
By agreeing to take part in this study you will help us get a better understanding of the importance of physical activity in the workplace. At the end of the study, you can request to see your individual results and be provided with a "work health report" by contacting the Chief Investigator. This will give you the opportunity to see how much physical activity you participate in at work and outside of work and see how you compare to the current WA guidelines for physical activity.

The findings will be presented at international conferences and published in international scientific journals.

There is no risk to wearing the accelerometers. There may be minor discomfort from the straps attaching the devices, but this is unlikely and similar to wearing a normal watch and belt.

Confidentiality
You will be allocated an identification number so that your name will remain confidential to the Investigators. All the data will be recorded using this identification number. All data, including names and codes, will be stored in a

locked room at the School of Physiotherapy. It will not be possible to identify any individual in any report on this research.

Request for more information
You are encouraged to discuss any concerns regarding the study with the Chief Investigator at any time, and to ask any questions you may have.

Refusal or withdrawal
You may refuse to participate in the study, and if you do agree to participate then you will be free to withdraw from the study at any time without problems. If you do decide to withdraw from the study then please contact the Chief Investigator at the earliest opportunity. If you withdraw, all your data will be destroyed.

Thankyou again for agreeing to participate in this research. Your contribution is very much appreciated.

Queries can be directed to
the Chief Investigator, Sharon Parry Phone 0414 270 213, email
sharon.parry@postgrad.curtin.edu.au
Or the
School of Physiotherapy, Curtin University, Phone 9266 4644
Or the
Secretary of Curtin University Human Research Ethics Committee on 9266 2784

Participant Consent Sheet

Title of Project – Physical Activity of Office Workers

Chief Investigator: Sharon Parry, School of Physiotherapy, Curtin University of Technology, Telephone 0414 270 213.

You are voluntarily making a decision whether or not to participate in this research project. Your signature certifies that you have decided to participate, having read and understood the information presented. Your signature also certifies that you have had an adequate opportunity to discuss the study with the investigator and you have had all your questions answered to your satisfaction.

I,..

of (address) ....

Phone……………………………………

consent to participate and give my permission for any results of this study to be used in any report or research paper, on the understanding that confidentiality will be preserved. I understand that I may withdraw from the study at any time without negative consequence. If so, I undertake to contact the investigators at the earliest opportunity.

Signature..

Date………………………………………

Office Use Only
I have explained the nature of and the procedures involved in the study to which the subject has consented to participate and have answered all questions. In my judgment the subject is voluntarily and knowingly giving informed consent and possesses the capacity to give informed consent to participate in this research study.

Investigator Signature...

Date………………………………………

Queries can be directed to
the Chief Investigator, Sharon Parry, Phone 0414 270 213, email sharon.parry@postgrad.curtin.edu.au
Or the
School of Physiotherapy, Curtin University, Phone 9266 4644
Or the
Secretary of Curtin University Human Research Ethics Committee on 9266 2784

APPENDIX B: Studies 1-4 - International Physical Activity Questionnaire (IPAQ)

International Physical Activity Questionnaire

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives.

The questions are about the time you spend being physically active in the ***last 7 days****. They include questions about activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise and sport.*

Your answers are important.

Please answer each question even if you do not consider yourself to be an active person.

In answering the following questions,

Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal

Moderate activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal

Part 1. Job related physical activity

This section is about work related physical activities. This includes paid jobs, farming, volunteer work, manual work carried out at work, and any other unpaid work that you did outside your home. **Do not** include unpaid work you might do around your home, like housework, yard work, general maintenance and caring for your family. These questions are asked later in part 3. Do not include sports or leisure activities, which are asked in part 4.

	Yes	**No (go to part 2)**
Do you currently have a job or do any unpaid work outside your home?	○	○
If YES how many days per week?	……………………	

The next questions are about all the physical activity you did in the **last 7 days** (the last week) as part of your paid or unpaid work. <u>This does not include travelling to and from work</u>.

	Days / week	**No vigorous job related physical activity**
During the last 7 days, on how many days did you do **vigorous** physical activities like heavy lifting, digging, heavy construction, or climbing up stairs **as part of your work?** Think about *only* those physical activities that you did for at least 10 minutes at a time.	………………	○
	Hours /day	**Minutes/day**
How much time in total did you usually spend on one of those days doing **vigorous** physical activities as part of your work?	………………	……………..

	Days / week	**No moderate job related physical activity**
Again, think about only those physical activities that you did for at least 10 minutes at a time. During **the last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads **as part of your work?** Please do not include walking.	………………	○
	Hours /day	**Minutes/day**
How much time in total did you usually spend on one of those days doing **moderate** physical activities as part of your work?	………………	……………..

	Days / week	**No job related walking**
During the **last 7 days**, on how many days did you walk for at least 10 minutes at a time **as part of your work**? Please do not count any walking you did to travel to and from work.	………………	○
	Hours /day	**Minutes/day**
How much time in total did you usually spend on one of those days walking as part of your work?	………………	……………..

Part 2. Transportation physical activity

These questions are about how you travelled from place to place, including to and from work, stores, movies, doing errands and so on.

	Days / week	No travel in a motor vehicle
During the **last 7 days**, on how many days did you **travel in a motor vehicle** like a train, bus, car, or tram?	……………….	○
	Hours /day	**Minutes/day**
How much time in total did you usually spend on one of those days **travelling** in a train, bus, car, tram, or other kind of motor vehicle?	……………	……………..

Now think only about the <u>bicycling</u> and <u>walking</u> you might have done to travel to and from work, to do errands, or to go from place to place.

	Days / week	No travel on a bicycle
During the **last 7 days**, on how many days did you **bicycle** for at least 10 minutes at a time to go **from place to place**?	……………….	○
	Hours /day	**Minutes/day**
How much time in total did you usually spend on one of those days **bicycling** from place to place?	……………….	……………..

	Days / week	No travel by walking
During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time to go **from place to place**?	………….. …	○
	Hours /day	**Minutes/day**
How much time in total did you usually spend on one of those days **walking** from place to place?	…………… …	……………..

Part 3. Housework, house maintenance and caring for family

This section is about some of the physical activities you might have done in the last 7 days in and around your home, like housework, gardening, yard work, general maintenance work, and caring for your family.

	Days / week	**No vigorous activity in garden or yard**
Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, chopping wood, shovelling, or digging in the garden or yard?	………………	○
	Hours /day	**Minutes/day**
How much time in total did you usually spend on one of those days doing **vigorous** physical activities in the garden or yard?	………………	……………..

	Days / week	**No moderate activity in garden or yard**
Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, sweeping, washing windows, and raking in the garden or yard?	………………	○
	Hours /day	**Minutes/day**
How much time in total did you usually spend on one of those days doing **moderate** physical activities in the garden or yard?	………………	……………..

	Days / week	**No moderate activity inside home**
Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, washing windows, scrubbing floors and sweeping inside your home?	……….	○
	Hours /day	**Minutes/day**
How much time in total did you usually spend on one of those days doing **moderate** physical activities inside your home?	……………	……………..

Part 4. Recreation, sport and leisure-time physical activity

This section is about all the physical activities that you did in the last 7 days solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned in the previous several questions.

	Days / week	No walking for leisure
Not counting any walking you have already mentioned, during the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **in your leisure time**?	....	○
	Hours /day	**Minutes/day**
How much time in total did you usually spend on one of those days **walking** in your leisure time?	....	....

	Days / week	No vigorous activity for leisure
Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like aerobics, running, fast bicycling, or fast swimming **in your leisure time**?	....	○
	Hours /day	**Minutes/day**
How much time in total did you usually spend on one of those days doing **vigorous** physical activities in your leisure time?	....	....

	Days / week	No moderate activity for leisure
Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like bicycling at a regular pace, swimming at a regular pace, and doubles tennis **in your leisure time**?	....	○
	Hours /day	**Minutes/day**
How much time in total did you usually spend on one of those days doing **moderate** physical activities in your leisure time?	....	....

Part 5. Time spent sitting

These questions are about the time you spend sitting while at work, at home, and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting to watch television. Do not include any time spent sitting in a motor vehicle or on a bicycle that you have previously mentioned.

	Hours /day	Minutes/day
During the last 7 days, how much time did you usually spend sitting on a **weekday**?	………………	……………..
During the last 7 days, how much time did you usually spend sitting on a **weekend** day?	………………	……………..

APPENDIX C: Studies 1-4 - Modified Nordic Musculoskeletal Questionnaire

Have you at any time in the past 12 months had trouble (ache, pain, discomfort) in:	Does work contribute to your pain?		Have you had to reduce your activity at work?		Have you had to reduce your leisure activities?		Have you been seen by a Doctor or other Health Professional?		Have you needed to take any medication for this pain?	
	A		B		C		D		E	
Q 1 Neck No ☐ Yes ☐ → If no, go to question 2 If yes, please complete A - E	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐
Q 2 Shoulders No ☐ Yes ☐ → If no, go to question 3 If yes, please complete A - E	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐
Q 3 Elbows/wrists/hands No ☐ Yes ☐ → If no, go to question 4 If yes, please complete A - E	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐
Q 4 Upper Back No ☐ Yes ☐ → If no, go to question 5 If yes, please complete A - E	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐
Q 5 Low Back (small of back) No ☐ Yes ☐ → If no, go to question 6 If yes, please complete A - E	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐
Q 6 One or both hips/thighs No ☐ Yes ☐ → If no, go to question 7 If yes, please complete A - E	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐
Q 7 One or both knees No ☐ Yes ☐ → If no, go to question 8 If yes, please complete A - E	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐
Q 8 One or both ankles/feet No ☐ Yes ☐ → If yes, please complete A - E	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐

APPENDIX D: Studies 1 and 4 - Job Satisfaction Survey

Please describe how satisfied or dissatisfied you feel with each of the features of your present job. Please tick the appropriate box.	extremely dissatisfied	very dissattisfied	moderately dissatisfied	not sure	moderately satisfied	very satisfied	extremely satisfied
Q 1 The physical work conditions	☐	☐	☐	☐	☐	☐	☐
Q 2 The freedom to choose your own method of working	☐	☐	☐	☐	☐	☐	☐
Q 3 Your fellow workers	☐	☐	☐	☐	☐	☐	☐
Q 4 The recognition you get for good work	☐	☐	☐	☐	☐	☐	☐
Q 5 Your immediate boss	☐	☐	☐	☐	☐	☐	☐
Q 6 The amount of responsibility you are given	☐	☐	☐	☐	☐	☐	☐
Q 7 Your rate of pay	☐	☐	☐	☐	☐	☐	☐
Q 8 Your opportunity to use your abilities	☐	☐	☐	☐	☐	☐	☐
Q 9 Industial relations between management and workers from your firm	☐	☐	☐	☐	☐	☐	☐
Q 10 Your chance of promotion	☐	☐	☐	☐	☐	☐	☐
Q 11 The way your firm is managed	☐	☐	☐	☐	☐	☐	☐
Q 12 The attention paid to suggestions you make	☐	☐	☐	☐	☐	☐	☐
Q 13 Your hours of work	☐	☐	☐	☐	☐	☐	☐
Q 14 Your job security	☐	☐	☐	☐	☐	☐	☐
Q 15 Now, taking everything into consideration, how do you feel about your job as a whole?	☐	☐	☐	☐	☐	☐	☐

APPENDIX E: Studies 1 and 4 - Health Performance Questionnaire (HPQ)

Health and Performance Questionnaire

To what extent did health problems in the last month effect:-

(a) the **quality** of your work

O1	O2	O3	O4	O5
To a large extent				Not at all

(b) the **quantity** of tasks accomplished at your work

O1	O2	O3	O4	O5
To a large extent				Not at all

How do you assess your general **productivity** during the last month?

O1	O2	O3	O4	O5	O6	O7	O8	O9	O10
The worst that anybody could do							The absolute best that anybody could perform in my position		

APPENDIX F: Studies 1-4 - Accelerometer and diary instruction sheet

<u>Studies 1-3</u>

ACCELEROMETER INSTRUCTIONS

The hip accelerometer that is attached to the elastic belt should sit on the bony part of your right hip, with arrow always pointing **UPWARDS**

The wrist accelerometer should be worn on your dominant wrist, with the arrow always pointing to the **LITTLE FINGER**

Please wear the accelerometers for the whole week during waking hours. They can be worn in the shower or the bath; anything except for diving.

If you need to remove the accelerometers for any reason, please record this in your activity diary. Please note the time and the activities performed while the accelerometers were removed.

ACTIVITY DIARY INSTRUCTIONS

Please fill in the diaries daily; GREEN sheet for a working day and ORANGE sheet for a non-working day (weekend)
Write down the main activity and tick the box to indicate the **INTENSITY** of the activity

1. **<u>Light activities</u>** include sitting, reading, computer work, any activity where there is little or no physical exertion
2. **<u>Moderate activities</u>** include activities that make you breathe harder than normal such as brisk walking, bicycling or swimming at a regular pace, doubles tennis, carrying light loads, sweeping or washing floors
3. **<u>Hard activities</u>** include activities that make you breathe *much harder* than normal such as aerobics, running, fast bicycling or swimming, heavy household tasks like digging or carrying heavy loads

Study 4

ACCELEROMETER INSTRUCTIONS
The accelerometer that is attached to the elastic belt should sit on the bony part of your right hip, with arrow always pointing **UPWARDS**

Please wear the accelerometers for the whole week during waking hours.

If you need to remove the accelerometer for any reason, please record this in your activity diary. Please note the time and the activities performed while the accelerometers were removed.

ACTIVITY DIARY INSTRUCTIONS

Please fill in the diaries daily; GREEN sheet for a working day and ORANGE sheet for a non-working day (weekend)
Write down the main activity and tick the box to indicate the **INTENSITY** of the activity

4. **Light activities** include sitting, reading, computer work, any activity where there is little or no physical exertion
5. **Moderate activities** include activities that make you breathe harder than normal such as brisk walking, bicycling or swimming at a regular pace, doubles tennis, carrying light loads, sweeping or washing floors
6. **Hard activities** include activities that make you breathe *much harder* than normal such as aerobics, running, fast bicycling or swimming, heavy household tasks like digging or carrying heavy loads

APPENDIX G: Studies 1-4 - Activity diary for work and non-work days

Activity Diary for Working Day

DAY:_______________________________Date:___________________

Waking Time	**am**			
Accelerometers fitted	**am**			
Before Work	**Main activity**	Light	Moderate	Hard
Transportation to work	**car/walk/ public transport/bike**	Light	Moderate	Hard
Office Hours START	**am**			
Morning Office hours	**Main activity**	Light	Moderate	Hard
During lunch break	**Main activity**	Light	Moderate	Hard
Afternoon office hours	**Main activity**	Light	Moderate	Hard
Office Hours FINISH	**pm**			
Transportation from work	**car/walk/ public transport/bike**	Light	Moderate	Hard
After work	**Main activity**	Light	Moderate	Hard
Bed time/ Accelerometers off	**pm**			

PLEASE MAKE NOTE OF ANY TIME THAT THE ACCELEROMETERS WERE TAKEN OFF DURING THE DAY AND WHAT ACTIVITIES WERE DONE WHEN THE ACCELEROMETERS WERE NOT WORN

Activity Diary for Non-Working Day

Day:___________________________________Date:____________________

Waking Time	**am**			
Accelerometers fitted	**am**			
Morning (waking until lunchtime)	**Main activity**	Light	Moderate	Hard
Afternoon (lunchtime until dinnertime)	**Main activity**	Light	Moderate	Hard
Evening (after dinner until bedtime)	**Main activity**	Light	Moderate	Hard
Bed time/ Accelerometers off	**pm**			

PLEASE MAKE NOTE OF ANY TIME THAT THE ACCELEROMETERS WERE TAKEN OFF DURING THE DAY AND WHAT ACTIVITIES WERE DONE WHEN THE ACCELEROMETERS WERE NOT WORN

APPENDIX H: Studies 1-4 - Feedback letter to participants

Studies 1 and 3 Feedback letter

Dear

Thank you for participating in the ***Physical Activity of Office Workers*** research project.

Please find enclosed your personal feedback form from the 7 days that you wore the accelerometers. On the back of this letter is some information to help you understand and interpret your individual graph.

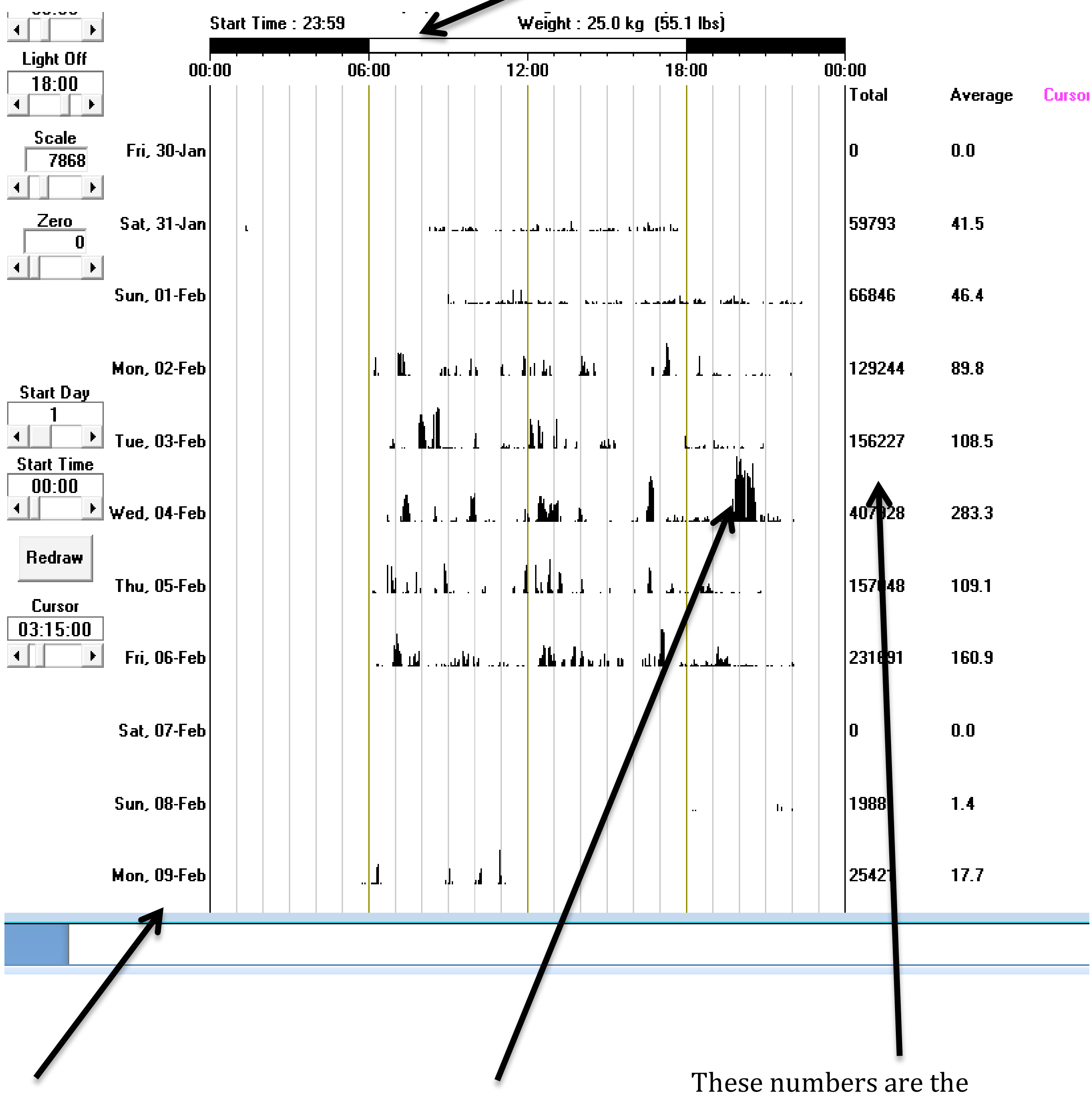
If you have difficulty understanding anything, please feel free to contact me personally and I will be happy to help you review your feedback.

Thanks again,

Sharon Parry

INTERPRETING YOUR ACTIGRAM – ACCELEROMETER READ OUT

Time (in hours)



Days that the accelerometers were worn – if there are no spikes, then the equipment was not worn

The higher and the denser the spikes are, the greater the activity level. Where there are little or no spikes, the activity is sedentary

These numbers are the total daily activity counts – the higher the number, the more activity on that day

> Ignore any height or weight that may be recorded - your personal details are entered at a later time
>
> The scale is the same on each graph for each participant
>
> The graph you receive is from the accelerometer worn on your hip

Study 2 feedback letter

Dear

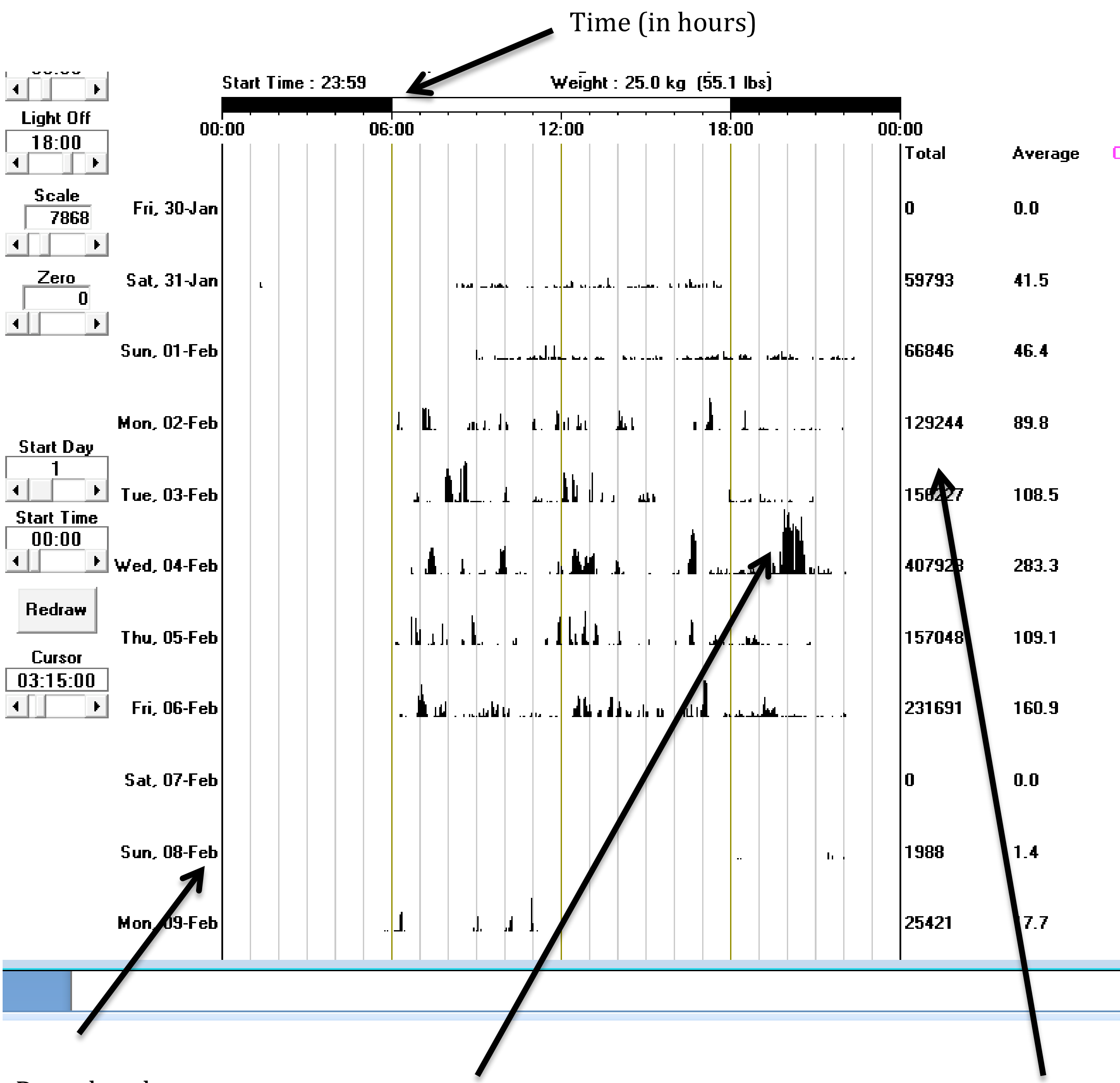
Thank you for participating in the ***Occupational Physical Activity*** research project.

Please find enclosed your personal feedback form from the 7 days that you wore the accelerometers. On the back of this letter is some information to help you understand and interpret your individual graph.

If you have difficulty understanding anything, please feel free to contact me personally and I will be happy to help you review your feedback.

Thanks again,

Sharon Parry
Tel: 0414 270 213
e-mail: parrys@arach.net.au



Days that the accelerometers were worn – if there are no spikes, then the equipment was not worn

The higher and the denser the spikes are, the greater the activity level. Where there are little or no spikes, the activity is sedentary

These numbers are the total daily activity counts – the higher the number, the more activity on that day

- Ignore any height or weight that may be recorded - your personal details are entered at a later time
- The scale is the same on each graph for each participant
- The graph you receive is from the accelerometer worn on your hip

Study 4 feedback letter

Dear

Thank you for participating in the ***Improving Health by Participation in Workplace Programmes*** research project.

Please find enclosed your personal feedback form from the days that you wore your accelerometer. On the back of this letter is some information to help you understand and interpret your individual graph.

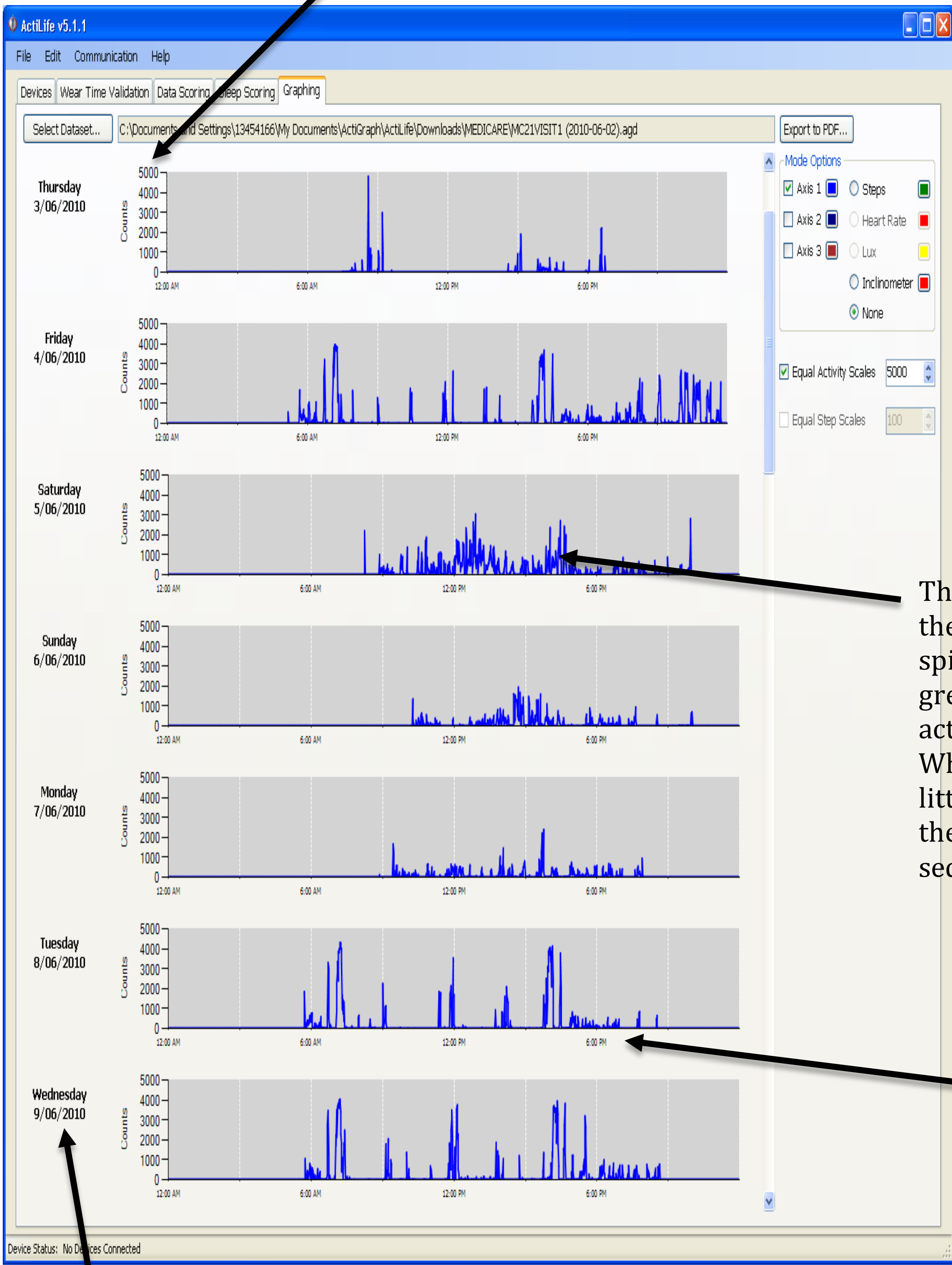
If you have difficulty understanding anything, please feel free to contact me personally and I will be happy to help you review your feedback.

Thanks again,

Sharon Parry
Tel: 0414 270 213
e-mail: parrys@arach.net.au

INTERPRETING YOUR ACCELEROMETRY READOUT

Activity counts



The higher and the denser the spikes are, the greater the activity level. Where there are little or no spikes, the activity is sedentary

Time of day

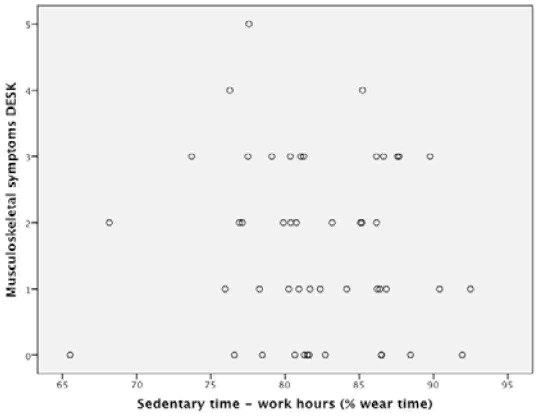
Days that the accelerometers were worn – if there are no spikes, then the equipment was not worn

The graph you receive is your individual readout

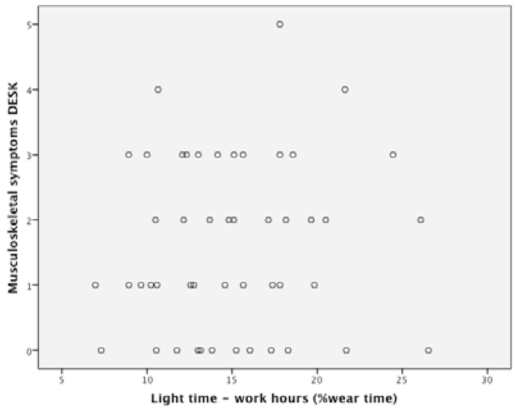
The scale on the left side of each day is the same for each day but may be different to the scale on other peoples' graphs – therefore readouts can vary quite a lot between individuals.

APPENDIX I: Study 1 - Scatter plots illustrating the relationship between desk- and non-desk-related musculoskeletal symptoms and sedentary time/physical activity

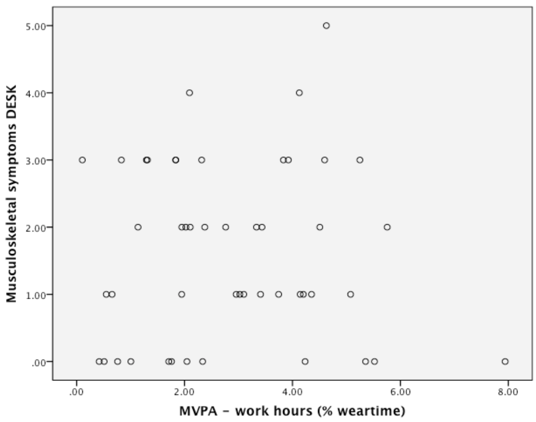
Scatter plots of relationship between desk-related musculoskeletal symptoms and sedentary time (a), light time (b) and MVPA (c) during work hours and non-desk-related musculoskeletal symptoms and sedentary time (d), light time (e) and MVPA (f) during total non-work time. Note – proportional measures used (% wear time) for each variable



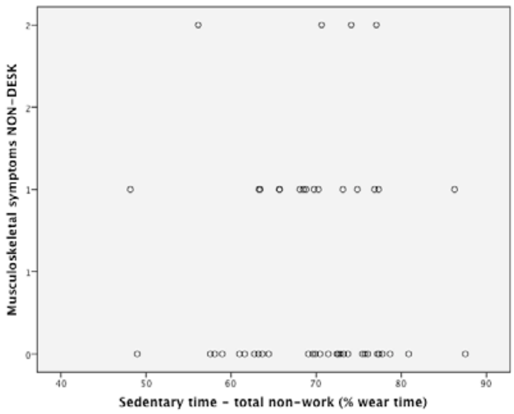
(a) Desk/Sedentary time work hours



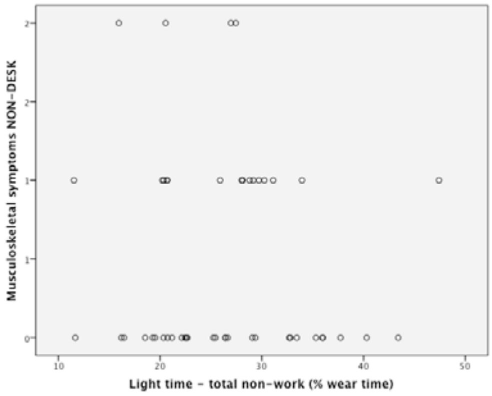
(b) Desk/Light activity work hours



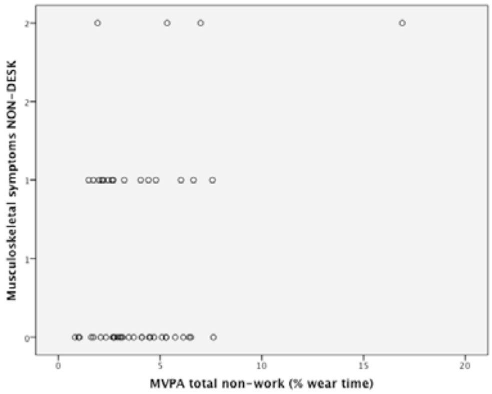
(c) Desk/MVPA work hours



(d) Non-desk/Sedentary time total non-work



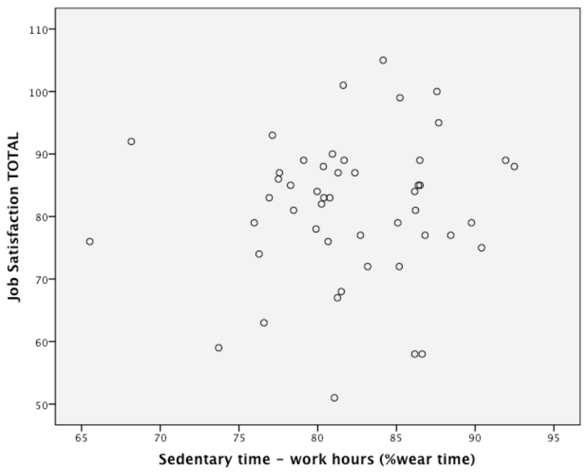
(e) Non-desk/light time total non-work



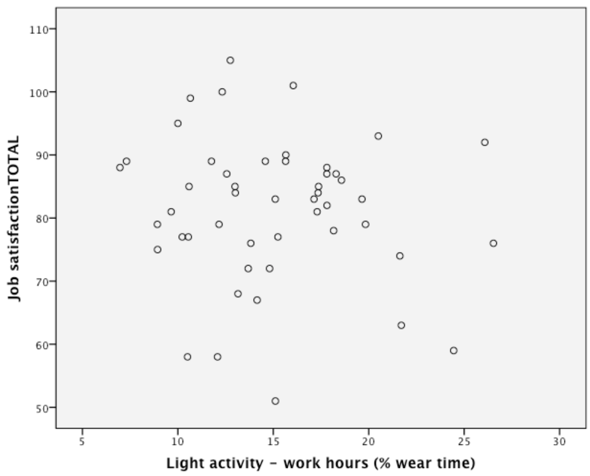
(f) Non-desk/MVPA total non-work

APPENDIX J: Study 1 - Scatter plots illustrating the relationship between job satisfaction and sedentary time/physical activity at work and during total non-work time

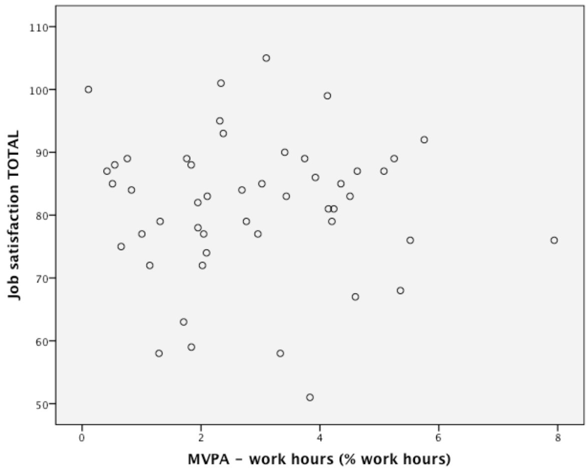
Scatter plots of relationship between job satisfaction and sedentary time (r = 0.097)(a), light activity (r = -0.104) (b) and MVPA (r = -0.030)(c) at work and sedentary time (r = 0.026) (d), light activity (r = -0.094)(e) and MVPA (r = 0.197)(f) during total non-work. Note – proportional measures used (% wear time) for each variable



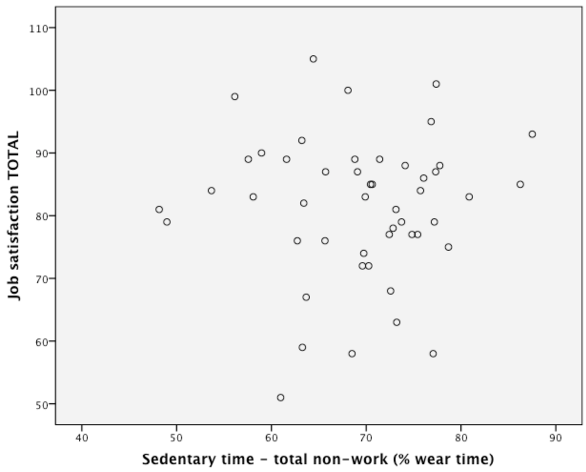
(a) Job satisfaction/sedentary time (work hours)



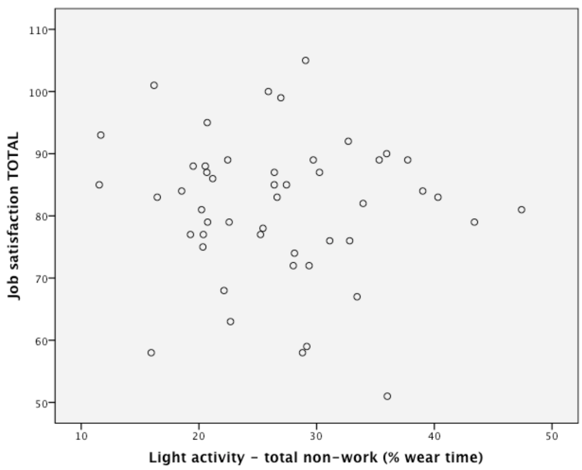
(b) Job satisfaction/light activity (work hours)



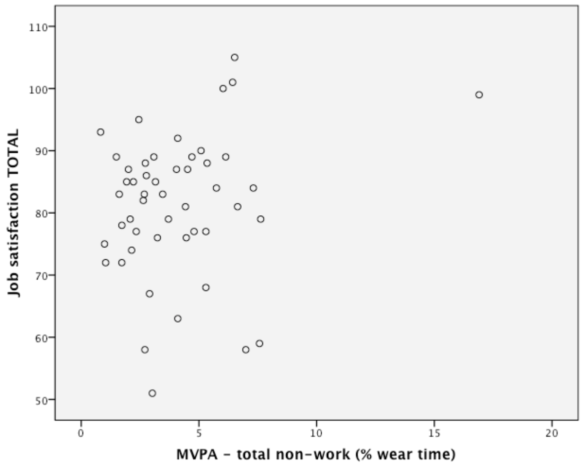
(c) Job satisfaction/MVPA (work hours)



(d) Job satisfaction/sedentary time (total non-work)



(e) Job satisfaction/light activity (total non-work)



(f) Job satisfaction/MVPA (total non-work)

APPENDIX K: Study 2 - Participant information and consent form (teachers)

Participant Information Sheet

Title of Project –Workplace Physical Activity

Chief Investigators: Sharon Parry, School of Physiotherapy, Curtin University of Technology, Telephone 0414 270 213. Professor Leon Straker, School of Physiotherapy, Curtin University of Technology, Telephone 9266 3634

Thank you for your interest in participating in this important research project. Below you will find information about this research to help you decide whether to participate.

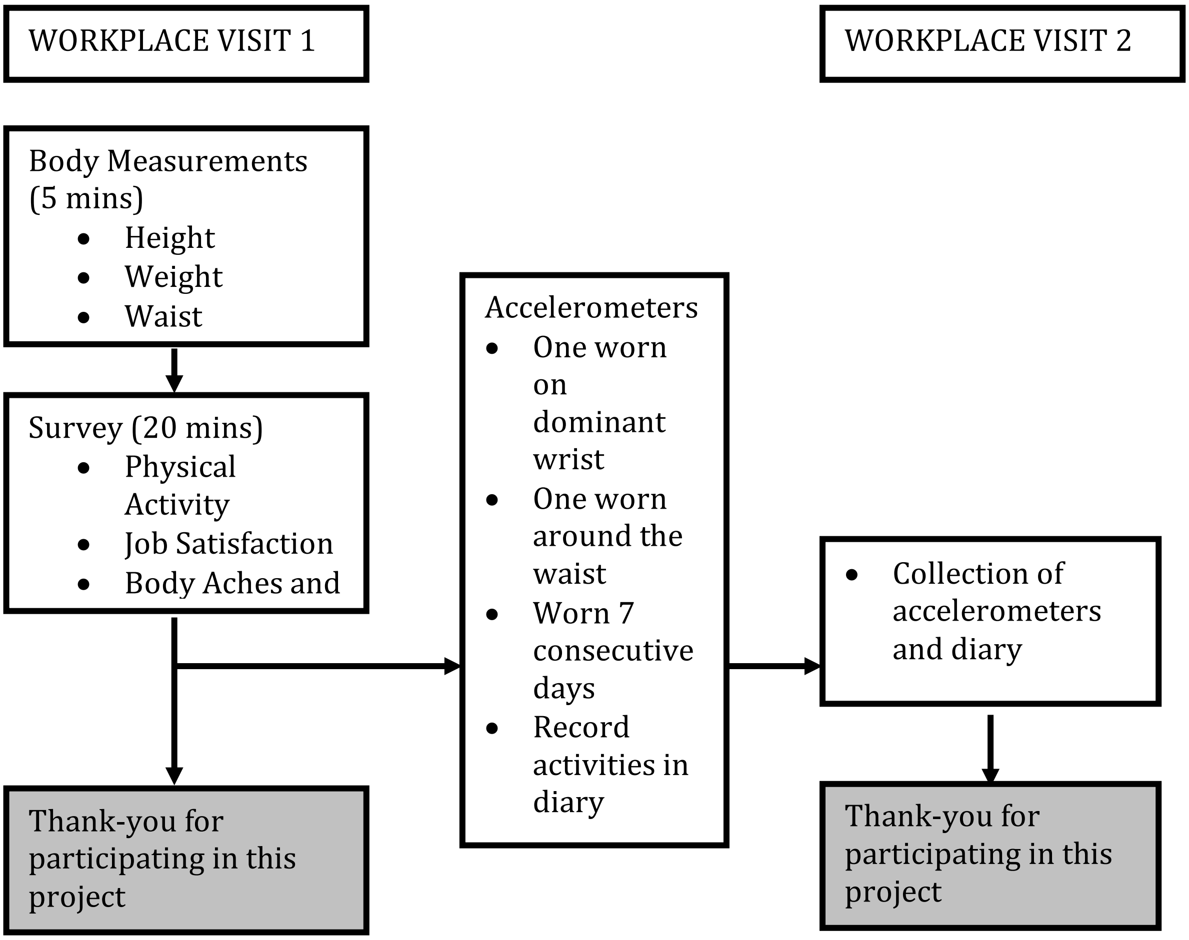
Purpose of the Study
Research from Australia and around the world has confirmed that more people are employed in less active jobs and that people are becoming less physically active. This trend is increasing, which is evident in the alarming rate of obesity and associated diseases in the developed world. We know that teachers have a variety of physical demands in the workplace, from using a computer to running a physical education programme. To date, there is very little information about the physical demands of being a teacher. In this study, which is part of a larger research project examining physical activity of sedentary workers, we hope to find out exactly how active teachers are while they are working and when they are not at work – after work and on the weekends. To provide information comparing activity at work and outside of work we will ask you to complete some questionnaires about your activities at work and at home.

Some of you will also be asked to wear 2 motion sensors, called accelerometers, that record the amount and the intensity of your activity. The information that we gather from the questionnaires and the accelerometers will give us a better understanding about the physical demands of teaching and how active teachers are in their spare time. This information will be used to help design work based programmes that promote a more active lifestyle.

Procedures
If you agree to participate, we will visit you at your school and take some measurements (height, weight and waist circumference) and ask you to complete a questionnaire about your physical activities at work and at home, your job satisfaction and about any aches and pains that you might be experiencing. This questionnaire will take about 20 minutes to complete. Please refer to Procedure Diagram below.

If you agree to also wear the accelerometers (which are about the size of a wrist watch) we will ask you to wear one on your dominant wrist (on a watch strap) and another at your waist (on an elastic belt). We will ask you to wear these devices for 7 consecutive days during all waking hours and to briefly record your activities in a diary that we will provide.

Procedure Diagram



Discomforts, Risks and Benefits
By agreeing to take part in this study you will help us get a better understanding of the importance of physical activity in the workplace. At the end of the study, you can request to see your individual results and be provided with a "work health report" by contacting the Chief Investigator. This will give you the opportunity to see how much physical activity you participate in at work and outside of work and see how you compare to the current WA guidelines for physical activity.

The findings will be presented at international conferences and published in international scientific journals.

There is no risk to wearing the accelerometers. There may be minor discomfort from the straps attaching the devices, but this is unlikely and similar to wearing a normal watch and belt.

Confidentiality
You will be allocated an identification number so that your name will remain confidential to the Investigators. All the data will be recorded using this identification number. All data, including names and codes, will be stored in a locked room at the School of Physiotherapy. It will not be possible to identify any individual in any report on this research.

Request for more information
You are encouraged to discuss any concerns regarding the study with the Chief Investigator at any time, and to ask any questions you may have.

Refusal or withdrawal
You may refuse to participate in the study, and if you do agree to participate then you will be free to withdraw from the study at any time without problems. If you do decide to withdraw from the study then please contact the Chief Investigator at the earliest opportunity. If you withdraw, all your data will be destroyed.

Thankyou again for agreeing to participate in this research. Your contribution is very much appreciated.

Queries can be directed to
the Chief Investigator, Sharon Parry Phone 0414 270 213, email
sharon.parry@postgrad.curtin.edu.au
Or the
School of Physiotherapy, Curtin University, Phone 9266 4644
Or the
Secretary of Curtin University Human Research Ethics Committee on 9266 2784

Participant Consent Sheet

Title of Project – Workplace Physical Activity

Chief Investigator: Sharon Parry, School of Physiotherapy, Curtin University of Technology, Telephone 0414 270 213.

You are voluntarily making a decision whether or not to participate in this research project. Your signature certifies that you have decided to participate, having read and understood the information presented. Your signature also certifies that you have had an adequate opportunity to discuss the study with the investigator and you have had all your questions answered to your satisfaction.

I,...

of (address) ....

Phone..

consent to participate and give my permission for any results of this study to be used in any report or research paper, on the understanding that confidentiality will be preserved. I understand that I may withdraw from the study at any time without negative consequence. If so, I undertake to contact the investigators at the earliest opportunity.

Signature...

Date ....

Office Use Only
I have explained the nature of and the procedures involved in the study to which the subject has consented to participate and have answered all questions. In my judgment the subject is voluntarily and knowingly giving informed consent and possesses the capacity to give informed consent to participate in this research study.

Investigator Signature...

Date ....

Queries can be directed to
the Chief Investigator, Sharon Parry, Phone 0414 270 213, email sharon.parry@postgrad.curtin.edu.au
Or the
School of Physiotherapy, Curtin University, Phone 9266 4644
Or the
Secretary of Curtin University Human Research Ethics Committee on 9266 2784

APPENDIX L: Study 2 – Results and discussion for the comparison between self-reported sitting and accelerometer determined sedentary time for teachers

Results

Self-reported sitting across teachers

12 of the 17 teachers that wore an accelerometer also completed the IPAQ section on sitting. For teachers, self-reported sitting on work days of 3.29 hours/day (197.50 ± 59.26 mins) was significantly less than the 4.75 hours/day reported on non-work days (285.00 ± 138.66 mins, $t = -2.56$, df_{11}, $p = 0.026$) (Table L).

Table L: Self-reported sitting time and accelerometer determined sedentary time on work days and non-work days

	Work day	Non-work day
Self-report: Sitting (mins/day)	197.5 ± 59.3	285.0 ± 138.7º
Accelerometer determined: Sedentary time (mins/day)	572.03 ± 52.38^	554.25 ± 88.71^

º Significant difference between work days and non-work days ($p < 0.05$)

^Significant difference between self-reported sitting time and accelerometer determined sedentary time ($p < 0.001$)

Comparison between self-reported sitting and accelerometer determined sedentary time

For teachers accelerometer determined sedentary time on work days of 9.53 hours/day (572.03 ± 52.38 mins/day) was significantly greater than self-reported sitting time of 3.29 hours/day on work days (197.50 ± 59.26 mins, $t = -14.86$, df_{11}, $p < 0.001$) (Table L). Similarly on non-work days, for teachers accelerometer determined sedentary time of 9.24 hours/day (554.25 ± 88.71 mins/day) was significantly greater than self-reported sitting time of 4.75 hours/day reported on non-work days (285.00 ± 138.66 mins, $t = -7.67$, df_{11}, $p < 0.001$) (Table L).

Discussion

The self-reported sitting time of 198 mins/day on a work day for teachers was greater than the sitting time reported for service workers (51 mins/day) and clerical workers and managers (160-181 mins/day) (Jans et al., 2007). However, work hours on work days were not isolated so that self-reported sitting time for teachers included non-work hours on work days and accelerometer determined sedentary indicated that teachers were most sedentary during this period.

Further, similar to seated office workers, teachers underestimated sedentary time when compared to accelerometer measures. These results are consistent with other research findings (Fitzsimons et al., 2012). Therefore the use of self-report measures of sitting may not accurately reflect the sedentary behaviour of teachers and further objective measures of sedentary time of occupational groups are important in determining the true health risks associated with different professions.

References

Fitzsimons, C., A. Kirk, M. Murphy and N. Mutrie (2012). "Agreement between the IPAQ-long weekday sitting item and the activPAL™ activity monitor in Scottish adults." Journal of Science and Medicine in Sport **15, Supplement 1**(0): S295-S296.

Jans, M. P., K. I. Proper and V. H. Hildebrandt (2007). "Sedentary behaviour in Dutch workers - Differences between occupations and business sectors." American Journal of Preventive Medicine **33**(6): 450-454.

APPENDIX M: Study 4 - Participant information and consent form

Participant Information Sheet

Title of Project – Improving Health by Participation in Workplace Programmes

Chief Investigator: Sharon Parry, School of Physiotherapy, Curtin University of Technology, Telephone 0414 270 213

Thank you for your interest in participating in this important research project. Below you will find information about this research to help you decide whether to participate.

Purpose of the Study
Research from Australia and around the world has confirmed that there are a number of health risks associated with being an office worker such as neck and back pain and reduced activity levels. The information that we gather from this study will give us a better understanding about ways to improve the health of office workers.

The aim of this study is to compare programmes focusing on different aspects of health. In this study, you will be asked to participate in a work-based health programme.

Procedures

The health issue that will be targeted in the programme will be randomly allocated. You will not know about the interventions that other workplaces are doing in order to avoid any influence from other groups.

If you agree to participate we will visit you at your workplace and take some measurements (height, weight and waist circumference) and ask you to complete a questionnaire about your activities at work and at home, your attitude to exercise, about any aches and pains that you might be experiencing and your job satisfaction. The questionnaire will take about 20 minutes to complete. If you agree to participate in the study you will also be asked to wear a small motion sensor called an accelerometer that is attached around your waist on an elastic belt. This device is small and should not interfere with any of your normal activities. We will ask you to wear this device for 7 consecutive days during all waking hours and to briefly record your activities in a diary that we will provide.

You will then be asked to attend 4 meetings of your work team. Each meeting will be approximately 1 hour. The first meeting will be to discuss one aspect of work related health. At the second meeting your work group will develop a programme that aims to improve this aspect of health. At the third and fourth meetings you will have the opportunity to further refine your health programme, discussing the details of the implementation of your programme and any barriers or foreseeable problems associated with your workplace programme. You will then participate in the programme you develop for 3 months.

After 3 months, at the end of the programme, we will measure you again, ask you to repeat the questionnaire and wear the accelerometer and briefly record your activities in a diary for another 7 days. All the measures will be repeated again at 12 months following the programme.

At the end of the study, you can request to see your individual results and be provided with a "work health report" by contacting the Chief Investigator.

A procedure diagram is shown on the next page.

Procedure Diagram

WORKPLACE VISIT 1 (30 minutes)
- Body measurements – height, weight and waist circumference
- Complete surveys
- Accelerometer fitted around the waist and activity diaries distributed

↓

WORKPLACE VISIT 2 -7 days later (5 minutes)
- Collection of accelerometer and diaries

↓

WORKPLACE VISITS 3 – 7 (1 hour meetings)
- Work-related health meetings to discuss and design workplace

↓

INERVENTION PERIOD - 3 months
- **Participation in programme**

↓

WORKPLACE VISIT 8 - 3 months after the programme (30 minutes)
- Repeat body measurements and surveys
- Distribution of accelerometers and diaries for second data collection period

↓

WORKPLACE VISIT 9 -7 days later (5 minutes)
- Collection of accelerometers and diaries

↓

WORKPLACE VISIT 10 -12 months after the intervention (30 minutes)
- Repeat body measurements and surveys
- Distribution of accelerometers and diaries for third data collection period

↓

WORKPLACE VISIT 11 - 7 days later (5 minutes)
- Collection of accelerometers and diaries

Discomforts, Risks and Benefits
By agreeing to take part in this study you will help us get a better understanding about how we can improve the health of office workers at the workplace. You will have the opportunity to see how your health varies over time and how it compares to Western Australian health recommendations.

The findings will be presented at international conferences and published in international scientific journals.

There is no risk to wearing the accelerometers. There may be minor discomfort from the straps attaching the devices, but this is unlikely and similar to wearing a belt.

The interventions could involve changes to the office environment or policies and procedures. Interventions could also involve education or physical activity seminars or modifications to office equipment. Any concerns about the risks and safety of the interventions will be discussed at the planning meetings.

Confidentiality
You will be allocated an identification number so that your name will remain confidential to the Investigators. All the data will be recorded using this identification number. All data, including names and codes, will be stored in a locked room at the School of Physiotherapy. It will not be possible to identify any individual in any report on this research.

Request for more information
You are encouraged to discuss any concerns regarding the study with the Chief Investigator at any time, and to ask any questions you may have.

Refusal or withdrawal
You may refuse to participate in the study, and if you do agree to participate then you will be free to withdraw from the study at any time without problems. If you do decide to withdraw from the study then please contact the Chief Investigator at the earliest opportunity. If you withdraw, all your data will be destroyed.

Thankyou again for agreeing to participate in this research. Your contribution is very much appreciated.

Queries can be directed to
the Chief Investigator, Sharon Parry 0414 270 213, email parrys@arach.net.au
Or the
School of Physiotherapy, Curtin University, Phone 9266 4644
Or the
Secretary of Curtin University Human Research Ethics Committee on 9266 2784

Participant Consent Sheet

Title of Project – Improving Health by Participation in Workplace Programmes

Chief Investigator: Sharon Parry, School of Physiotherapy, Curtin University of Technology, Telephone 0414 270 213.

You are voluntarily making a decision whether or not to participate in this research project. Your signature certifies that you have decided to participate, having read and understood the information presented. Your signature also certifies that you have had an adequate opportunity to discuss the study with the investigator and you have had all your questions answered to your satisfaction.

I,……………………………of (address)..

Phone..

consent to participate and give my permission for any results of this study to be used in any report or research paper, on the understanding that confidentiality will be preserved. I understand that I may withdraw from the study at any time without prejudice. If so, I undertake to contact the investigators at the earliest opportunity.

Signature..

Date ....

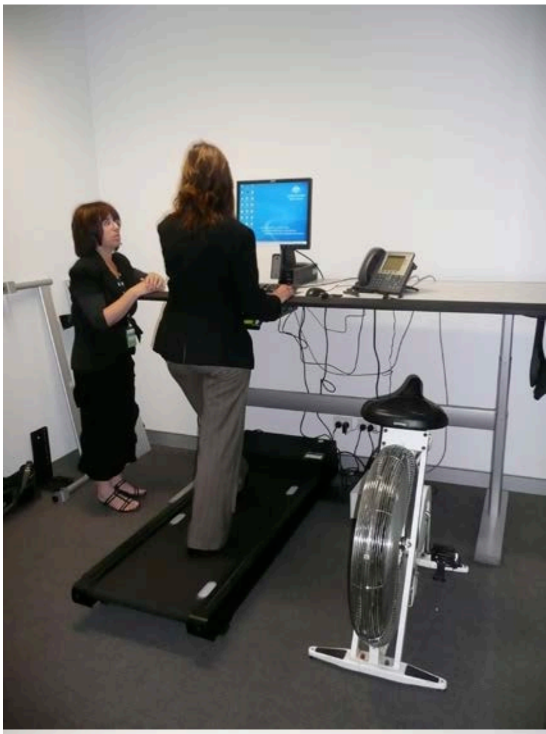
Office Use Only
I have explained the nature of and the procedures involved in the study to which the subject has consented to participate and have answered all questions. In my judgement the subject is voluntarily and knowingly giving informed consent and possesses the capacity to give informed consent to participate in this research study.

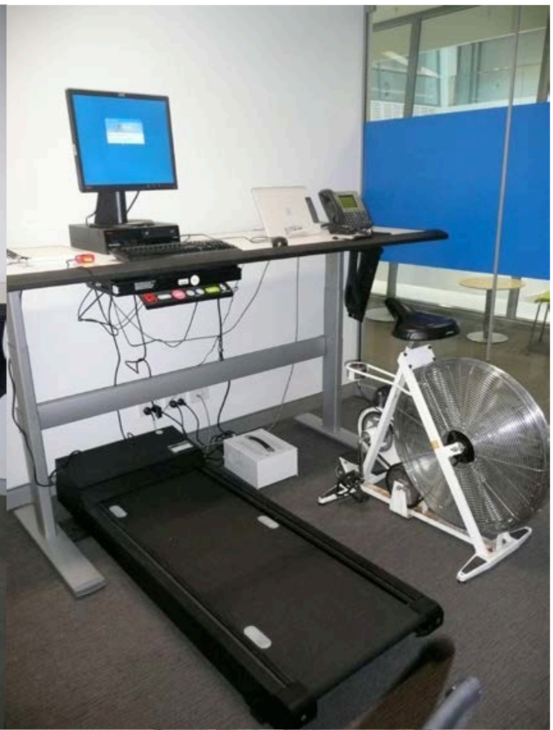
Investigator Signature...

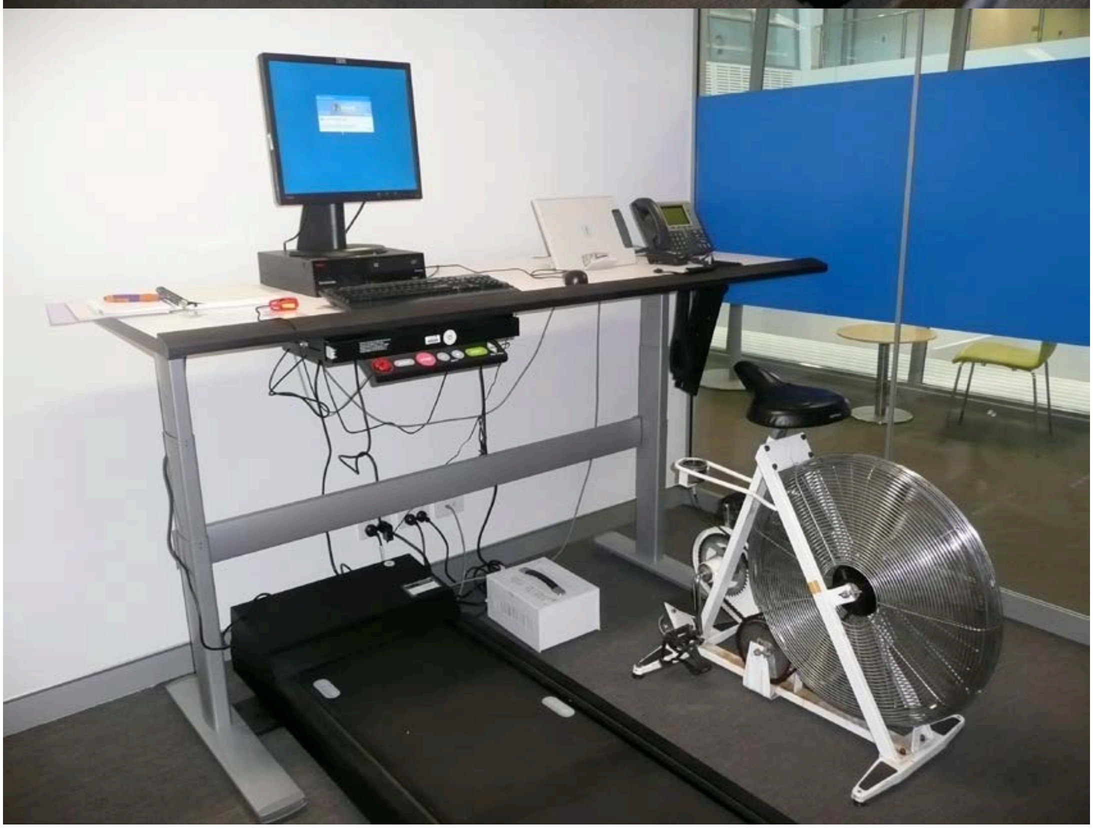
Date ....

Queries can be directed to
the Chief Investigator, Sharon Parry 0414 270 213, email parrys@arach.net.au
Or the
School of Physiotherapy, Curtin University, Phone 9266 4644
Or the
Secretary of Curtin University Human Research Ethics Committee on 9266 2784

APPENDIX N: Study 4 - Active Workstation photographs







APPENDIX O: Study 4 - 'Homework' sheet for participants in Intervention A ('Active office')

Ideas for Increasing Workplace Physical Activity

TIME FRAME	WORKPLACE CHANGES
SHORT TERM Within 2 weeks	e.g change default printers to another floor
MEDIUM TERM Within 2 months	e.g walk and talk meetings
LONG TERM Greater than 2 months	e.g active workstation

APPENDIX P: Study 4 - Feedback sheet for participants

Example - Organisaton 2, Intervention A

Dear

Over the last few months, your group has been trying to implement a number of changes the group proposed. We are interested in how each of these things worked for you.

How frequently did you participate in different aspects?

Aspect	More than an hour each day	Less than an hour each day	2-3 times a week	Occasionally	Never
Increase use of stairs					
ACTIVE WORK STATION					
Standing between calls					
Increase activity around workplace – take longer routes to printer etc					

What were the best aspects of the project?

____

____

____

____

What were the worst aspects of the project?

____

____

____

____

What would you recommend for other work groups?

____

____

APPENDIX Q: Study 4 – Results and discussion for the comparison between self-reported sitting and accelerometer determined sedentary time across all participants in Study 4

Results

Self-reported sitting across all participants

Of the 62 participants that completed the study, 48 participants also had complete IPAQ questionnaires. There was a significant reduction in self-reported sitting time on work days (-66 mins/day, t = 2.56, df_{47}, p = 0.014). The estimated increase in self-reported sitting of 14 mins/day on weekend days, was not significant (14 mins/day, t = -0.54, df_{47}, p = 0.591) (Table Q.1, Figure Q.1)

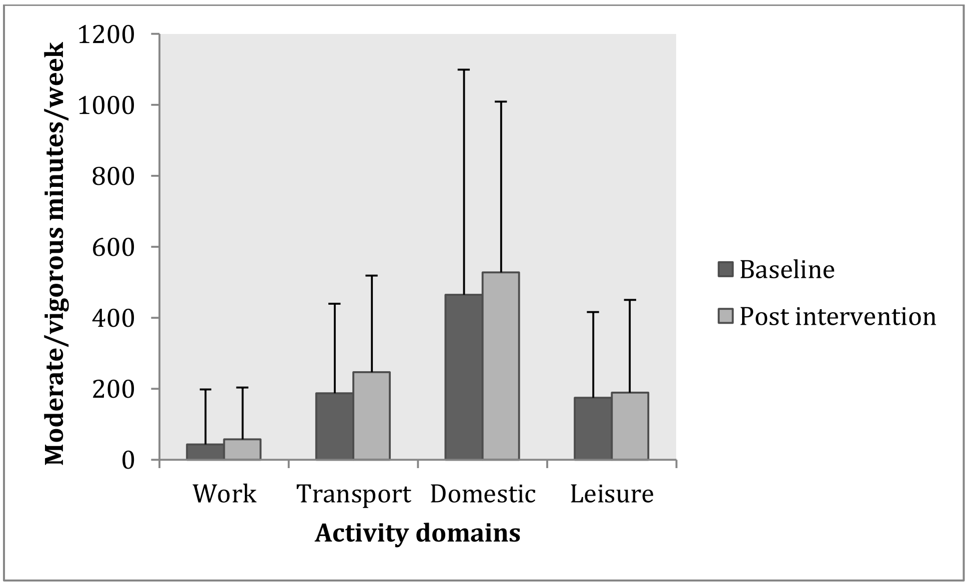
Table Q.1: Self-reported sedentary time (sitting) on work days and weekend days, MVPA over a whole week (bouts>10 mins) for work, transport, domestic and leisure time for all participants before and after intervention

Outcome measures	Baseline (mean mins/day ± SD)	Post-intervention (mean mins/day ± SD)	Mean Change	95% CI	*P*
Sitting time (n=48)					
Work day	581.25 ± 139.02	515.31 ± 149.86	-65.94	-14.07, -117.80	0.014
Weekend day	290.94 ± 143.40	305.31 ± 160.77	14.38	67.81, -39.06	0.591
MVPA (n=48)					
Work	42.29 ± 156.40	58.13 ± 145.06	15.83	65.64, -33.97	0.526
Transport	188.02 ± 251.61	247.40 ± 272.43	59.38	145.01, -26.26	0.170
Domestic	456.83 ± 633.77	527.71 ± 482.50	61.88	241.65, -117.90	0.492
Leisure	174.69 ± 241.70	189.90 ± 261.07	15.21	114.82, -84.40	0.760

Figure Q.1: Self-reported sitting time (mean mins/days ± SD) at baseline and following the intervention period

As illustrated in Figure Q.2, there appeared to be an increase in MVPA across all domains of work, transport, domestic and leisure following the intervention period, however these changes were not significant ($t > -1.40$, $p > 0.170$) (Table 11.4).

Figure Q.2: Self-reported MVPA for whole week in bouts >10 mins during work, active transport, domestic duties and leisure time (mean minutes/week ± SD)



Discussion

Self-reported sitting time (IPAQ) reduced following the intervention by an estimated 66 minutes on work days, which was significantly greater than the accelerometer determined 14 minute reduction in sedentary time. Participants in this study significantly over-estimated the reduction in sitting time. It is possible that the participants perceived that there was much less sitting and hence reported the greater reduction. This finding highlight the discrepancies between self-reported and objective measures of sitting time and underlies that care should be taken when interpreting the results of studies that use self-reported measures of sitting or sedentary time as the sole outcome measure. Importantly IPAQ was never developed as an outcome measure, it was designed as a monitoring instrument for large population research, and therefore it is not an ideal instrument to assess changes in sitting time (Craig et al., 2003; Healy, Clark, et al., 2011; D. E. Rosenberg et al., 2008). Even though IPAQ has been used to assess sitting time (Bauman et al., 2011; Yates et al., 2012), it may be best used in intervention studies in conjunction with other objective measures of sedentary behaviour to provide contextual information about whether sitting occurs predominately on week days or weekends and whether transport sitting contributes to overall sitting time.

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APPENDIX R: - Study 4 - distribution of musculoskeletal pain at baseline and following the intervention period for the 3 organisations and 3 interventions

Table R.1: Distribution of self-reported musculoskeletal pain at baseline and following the intervention for the 3 Organisations

	Organisation 1 (n=15)		Organisation 2 (n=19)		Organisation 3 (n=13)	
Body regions	**Baseline**	**Post-intervention**	**Baseline**	**Post-intervention**	**Baseline**	**Post-intervention**
Neck	73.3 (11)	73.3 (11)	52.6 (10)	26.8 (7)	53.8 (7)	61.5 (8)
Shoulder	53.3 (8)	53.3 (8)	52.6 (10)	42.1 (8)	38.5 (5)	53.8 (7)
Elb/wrist/hand	40.0 (6)	33.3 (5)	47.4 (9)	26.3 (5)	46.2 (6)	53.8 (7)
Upper back	33.3 (5)	26.7 (4)	21.1 (4)	15.8 (3)	30.8 (4)	28.5 (5)
Lower back	60.0 (9)	60.0 (9)	52.6 (10)	52.6 (10)	38.5 (5)	46.2 (6)
Hip	13.3 (2)	20.0(3)	0 (0)	5.3 (1)	30.8 (4)	30.8 (4)
Knee	13.3 (2)	13.3 (2)	10.5 (2)	21.1 (4)	46.2 (6)	38.5 (5)
Ankle	26.7 (4)	26.7 (4)	5.3 (1)	10.5 (2)	7.7 (1)	7.7 (1)

Table R.2: Distribution of self-reported musculoskeletal pain at baseline and following the intervention for the 3 Interventions

	Intervention A (n=14)		Intervention B (n=12)		Intervention C (n=21)	
Body regions	**Baseline**	**Post-intervention**	**Baseline**	**Post-intervention**	**Baseline**	**Post-intervention**
Neck	71.4 (10)	71.4 (10)	58.3 (7)	58.3 (7)	52.4 (11)	42.9 (9)
Shoulder	42.9 (6)	57.1 (8)	66.7 (8)	41.7 (5)	42.9 (9)	47.6 (10)
Elb/wrist/hand	21.4 (3)	21.4 (3)	41.7 (5)	33.3 (4)	61.9 (13)	47.6 (10)
Upper back	14.3 (2)	28.6 (4)	50.0 (6)	33.3 (4)	23.8 (5)	19.0 (4)
Lower back	50.0 (7)	50.0 (7)	50.0 (6)	66.7 (8)	52.4 (11)	47.6 (10)
Hip	0 (0)	7.1 (1)	8.3 (1)	25.0 (3)	23.8 (5)	19.0 (4)
Knee	21.4 (3)	21.4 (3)	16.7 (2)	16.7 (2)	23.8 (5)	28.6 (6)
Ankle	14.3 (2)	14.3 (2)	25.0 (3)	25.0 (3)	4.8 (1)	9.5 (2)

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Parry, S. and Straker, L. (2013). "Office work contributes significantly to sedentary behaviour associated risk." BMC Public Health **13**: 296.

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Parry, S., Straker, L., Gilson, N. D. and Smith, A. J. (2013). "Participatory workplace interventions can reduce sedentary time for office workers - a randomised controlled trial." PLoS ONE **8**(11): e78957

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