ABSTRACT

Objective: To describe the change in objectively measured sitting, standing and stepping time for office-based workers as they transitioned from a conventional to an activity-permissive workplace physical environment.

Methods: This pre-post study observed 17 office-based working adults [mean age 33 (SD 7) years] from an academic research centre as they transitioned from a conventional to a purpose-built, innovative activity-permissive workplace physical environment with flexible layouts, workspaces, and working conditions. Participants wore an activity monitor (activPAL3, PAL Technologies Limited, Glasgow, UK) for seven consecutive days at both the conventional and innovative workplaces to determine time spent sitting, standing, stepping, the number of sit to stand transitions and the length and number of sitting bouts ≥ 30 minutes. They also completed a self-reported log of workplace time and monitor wear time. Participants’ height, weight, descriptive characteristics, body composition (measured by DXA) and moderate-to-vigorous physical activity (measured by ActiGraph GT3X+; LLC, Fort Walton Beach, FL) were recorded. I standardized results to an 8-hour workday and compared outcomes between the conventional and innovative workplaces using Hodges-Lehmann median point estimate (90% CI).

Results: The transition to the innovative workplace resulted in a non-significant decrease in workplace sitting time (-24 minutes/ 8-hour workday; 90% CI = -55 to 9 minutes/ 8-hour workday) and a corresponding increase in workplace standing (12 minutes/ 8- hour workday; 90% CI = -42 to 61 minutes/ 8-hour workday). There were no differences in the number of sit to stand transitions or sitting bouts ≥ 30 minutes in the workplace. Participants spent more time sitting in bouts ≥ 30 minutes at the innovative workplace (increase of 16 minutes/ 8-hour workday; 90% CI = -7 to 44 minutes/ 8-hour workday). None of these changes were statistically significant.
Conclusions: This group of office workers did not significantly change their total workplace sitting time or how it was accumulated with the transition to the innovative workplace physical environment. The results of this preliminary investigation suggest that interventions include a multifaceted approach to complement physical environment changes in order to reduce prolonged sitting time.
PREFACE

Statement of co-authorship:

I was involved in all aspects of this thesis project including generation of the study design, data collection, data analysis and interpretation and the preparation of the thesis. This was done with direction and input from Dr. Maureen Ashe, Dr. David Dunstan, Dr. Genevieve Healy, Dr. Ken Madden and Dr. Heather McKay. Dr. Elisabeth Winkler was also involved in the preparation and analysis of the activPAL3 activity monitor data.

Abstracts:

This work was accepted as an abstract at the Canadian Association for Research on Work and Health Conference 2012. The abstract is based on data presented in Chapter 5.

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Research ethics approval:

The study was approved by the UBC Clinical Research Ethics Board (H10-02045) and Vancouver Coastal Health Research Institute (#V10-02045)
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<thead>
<tr>
<th>Term</th>
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<tr>
<td>Active</td>
<td>Meeting physical activity guidelines, defined by Canadian Society for Exercise Physiologists as 150 minutes of moderate to Vigorous Physical Activity per week accumulated in bouts of 10 minutes or greater.</td>
</tr>
<tr>
<td>ActiGraph GT3X+</td>
<td>An activity monitor worn at the waist to determine time spent in different activity intensities (LLC, Fort Walton Beach).</td>
</tr>
<tr>
<td>Activity-permissive workplace</td>
<td>Workplace physical environment designed to increase opportunities for physical activity and limit prolonged sitting.</td>
</tr>
<tr>
<td>Activity Monitor</td>
<td>Device used to record activity patterns (activity intensity or posture).</td>
</tr>
<tr>
<td>activPAL</td>
<td>An activity monitor worn on the thigh to determine time spent sitting, standing and stepping and sit to stand transitions (PAL Technologies Limited, Glasgow, UK).</td>
</tr>
<tr>
<td>CHHM</td>
<td>Centre for Hip Health and Mobility</td>
</tr>
<tr>
<td>Conventional workplace</td>
<td>A traditional workplace physical environment not designed to increase opportunities for physical activity or limit prolonged sitting.</td>
</tr>
<tr>
<td>CSEP</td>
<td>Canadian Society for Exercise Physiologists</td>
</tr>
<tr>
<td>Dual Energy X-ray Absorptiometry (DXA)</td>
<td>Used to assess body composition (percent fat mass and percent lean mass).</td>
</tr>
<tr>
<td>Inactive</td>
<td>Not meeting physical activity guidelines.</td>
</tr>
<tr>
<td>Metabolic Equivalent of Task (MET)</td>
<td>The relative value of energy expenditure to which all other activities are compared.</td>
</tr>
<tr>
<td>Moderate to Vigorous Physical Activity (MVPA)</td>
<td>Activities that expend greater than 3 METs.</td>
</tr>
<tr>
<td>Non-exercise Activity Thermogenesis (NEAT)</td>
<td>Energy expenditure from activities not including eating, sleeping and purposeful exercise.</td>
</tr>
<tr>
<td>Sedentary time</td>
<td>Time spent in sedentary behaviours, those that are low in energy expenditure, only slightly above resting (1 - 1.5 METs), and are undertaken in a sitting or lying posture.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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<tr>
<td>UBC</td>
<td>University of British Columbia</td>
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<td>VCHRI</td>
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CHAPTER 1: INTRODUCTION

Rapid advances in technology, and the automation of many of our daily activities, have resulted in high levels of sedentary behaviour – or too much sitting. Cross-sectional and prospective studies have demonstrated that time spent in sedentary behaviours is adversely associated with several health outcomes, including cardiovascular disease and premature mortality (1, 2). Importantly, these associations occurred even in adults who meet the public health guidelines for physical activity. Therefore, it is important to better understand the impact of sedentary time on adverse health outcomes and to identify novel opportunities to evaluate how strategies to decrease sedentary behaviour might improve health.

Adults spend a large proportion of their waking hours at the workplace and for many office-based occupations, the majority of these hours are spent sitting (3-5). The potential negative implications of prolonged sitting have spurred an emerging area of research that seeks to explore strategies to reduce sedentary time in the workplace. The workplace is recognised as a potentially ideal setting in which to intervene; the many hours people spend at work provide an opportunity to adapt structured work environments in order to change workplace behaviours. A shift toward a more physically active workplace environment could potentially play an important role in enhancing physical activity and reducing sedentary time (6). Features such as stairwells and floor plans, contribute to how an employee works and moves in their workplace. However, no previous studies characterized in detail the influence of an activity-permissive workplace, defined as a workplace designed specifically to provide opportunities to increase physical activity and reduce prolonged sitting, on workers’ sedentary time.
In 2011, the Vancouver Centre for Hip Health and Mobility (CHHM) moved from a conventional workplace to a workplace designed specifically to be more activity-permissive. This provided the unique opportunity to prospectively examine the impact of a change in physical work environment on workplace sedentary time. CHHM faculty, staff and trainees who anticipated moving to the new building were recruited to participate in a pre-post observational study monitoring workplace activity patterns before and after the move. This thesis specifically examines their workplace sedentary time before and after the transition to the activity-permissive workplace physical environment.

There are seven chapters in this thesis. Following this introductory chapter, Chapter 2 defines sedentary time and provides evidence for the relationship between increased sedentary time and adverse health outcomes. In addition, the specific importance of workplace sedentary time and strategies to reduce it are discussed. This chapter also focuses on the potential role of the workplace physical environment on workplace sedentary time. The research question and hypothesis are outlined in Chapter 3. Chapter 4 provides the methods used to complete the study including information on the study sample and outcome measures. The results of the study, relevant for this thesis, are presented in Chapter 5. Chapter 6 discusses the results in relation to previous research and provides the limitations, strength and implications of the study. Chapter 7 provides a summary and conclusion of this thesis.
CHAPTER 2: LITERATURE REVIEW

In the following section, I provide an overview of the literature related to workplace sedentary time and its association with health. I also review studies that describe interventions designed to reduce prolonged uninterrupted sedentary time in the workplace, with a particular focus on the workplace physical environment.

2.1 Sedentary Behaviour

2.1.1 Defining Physical Activity and Sedentary Behaviour

Physical activity is defined as any bodily movement that results in energy expenditure above the resting metabolic rate (7). Physical activities can be classified by intensity based on their energy expenditure. Energy expenditure at rest is defined as 1 MET (metabolic equivalent of task) and this is the relative value to which all other activities are compared. The spectrum of activity intensity ranges from resting to maximal physical activity. Conventionally, physical activity categories have been divided into light (1.6 – 2.9 METs), moderate (3 – 5.9 METs) or vigorous intensity (≥ 6 METs) (8, 9). In contrast, sedentary behaviours are those that are low in energy expenditure, only slightly above resting (1 - 1.5 METs), and are undertaken in a sitting or lying posture (10, 11). Sedentary behaviours are entrenched across many domains including sitting during leisure, sitting in the household, sitting during travel and sitting in the workplace (12). Throughout this thesis, I use the term sedentary time to describe time spent in various sedentary behaviours and operationalize as sitting time when this behaviour is measured.
2.1.2 Sedentary Time as Distinct from Physical Inactivity

Canadian physical activity guidelines, from the Canadian Society for Exercise Physiologists (CSEP), recommend adults accumulate 150 minutes of moderate or vigorous physical activity (MVPA) per week, accumulated in bouts of 10 minutes or more, for health benefits (13). Those who meet these guidelines are considered “physically active”, or “active” and those who do not mean these guidelines are considered “inactive”. I use the terms (active and inactive) throughout my thesis to reflect meeting these guidelines, as defined by CSEP. Importantly, sedentary time, refers to time spent in specific sedentary behaviours as described above, and is distinct from the concepts of active and inactive. To illustrate, an individual can be active but also acquire large amounts of sedentary time. Conversely, an individual could be inactive, but acquire small amounts of sedentary time. Moreover, the determinants of active, inactive and sedentary behaviours differ (11) and likely also have different physiological consequences (14).

2.2 Measuring Sedentary Time

To investigate the independent influence of sedentary time on health outcomes it is essential to accurately measure time spent in sedentary behaviours. Sedentary time can be measured using self-reported (15-17) and/or objective measures (18, 19). Most published studies used self-reported measures but objective measures (20), such as inclinometers and accelerometers, are becoming more affordable and are increasingly being utilized (1). Nonetheless, published reviews that evaluated the measurement of sedentary time recommended that both self-reported and objective instruments were important to provide an accurate description of time spent in sedentary behaviours (2, 20). These methods are described in detail in the next section.
2.2.1 Self-reported Measures of Sedentary Time

Self-report questionnaires for sedentary time can capture behaviour-specific (e.g. television viewing time), domain-specific (e.g. workplace), and/or overall sitting time. Questions regarding sedentary time can be included as part of a general physical activity questionnaire, for example the widely used International Physical Activity Questionnaire (IPAQ) includes a question on sitting time (15), or asked separately. Healy and colleagues, in their review, recommend that self-reported measures be specific and focus on domains rather than relying upon overall estimates of sitting time (20). The advantages of using self-reported measures are: (i) they are relatively inexpensive and therefore feasible for larger studies and, (ii) they classify specific sedentary behaviours and can provide the context in which the behaviour occurs. However, sedentary behaviours are not discrete, memorable events and instead are typically accumulated in a sporadic and varied manner, which often makes recall difficult (2). Thus, limitations of self-reported questionnaires include (i) participant recall bias; and (ii) participant interpretation.

2.2.2 Objective Measures of Sedentary Time

Methods for the objective measurement of sedentary time include direct observation and the use of activity monitoring devices. Direct observation is not feasible for large studies and long time periods as it is intrusive and expensive. Activity monitors allow sedentary time to be assessed objectively, based on estimates of activity intensity and/or body posture. Two commonly used types of activity monitors that measure sedentary time are the ActiGraph (LLC, Fort Walton Beach, FL) and the activPAL (PAL Technologies Limited, Glasgow, UK). Both monitors are small devices worn on the body to provide information on activity patterns. The tri-axis ActiGraph GTX3+ monitor processes raw acceleration into activity counts to determine activity intensity over time (21). Sedentary time is not directly measured, but derived from time in low activity counts (typically <100 counts/minute on the vertical axis) (22). To compare,
the activPAL3 monitor directly measures time spent in three postures: sitting/lying (sedentary), standing, and stepping.

Activity monitors have many benefits as they do not rely on self-report and thus eliminate recall bias. Monitors generate time and date stamped information over multiple days enabling investigators to quantify total sedentary time and describe patterns of sedentary time (2). However, there are limitations. These include adherence to the monitor wearing protocol and assumptions made in data analysis. For example, algorithms provided by the manufacturers may not be ideal for determining all behaviours (23) and there are challenges as some monitors are unable to distinguish non-wear time from sedentary time (20). Monitors also do not describe the activity and its context (2). For example, without corresponding diary information, monitors are unable to differentiate between sedentary time related to travel, leisure, household or work purposes. Commonly used activity monitors are also unable to distinguish upper extremity activity or capture activities like swimming or cycling. Therefore, wherever possible, it is essential to utilize both objective measures (to accurately quantify sedentary time) and self-reported measures (to provide information regarding context and activities that are not necessarily captured by the monitors).

2.2.3 Summary

Given the limitations of subjective measures of sedentary time, there is a well-established need for objective measures of sedentary time to complement more traditional self-reported measures.
2.3 Sedentary Time and Health

Over the past decade, many investigations have reported on the detrimental health effects of sedentary time (1, 24). A Canadian population-based study, using objective measures, reported that in 2007-2009, Canadian adults spent 69% of waking hours in sedentary time (25). In comparison, American adults spent between 50 to 60% of their waking hours in sedentary time in 2003-2004 (22). Clearly, sedentary time represents a large proportion of adults’ waking hours and it behoves us to better understand its impact on health.

A systematic review by Thorp and colleagues (1) summarized longitudinal studies that investigated sedentary time and its association with selected health outcomes. Although the association of sedentary time with mortality was consistent across studies, evidence to support the associations of sedentary time with weight gain/obesity, disease incidence or markers of cardio-metabolic health, was limited (1). Limitations of some of the studies reviewed included the inconsistent measurement of sedentary time while others did not account for physical activity levels. Most cross-sectional and prospective studies that investigated sedentary time and health outcomes used self-reported measures of sedentary time (total sitting time, TV viewing time, etc.); very few used objectively measured sedentary time (26-34). Further, Thorp and colleagues’ review (1) reported the findings for prospective studies using objectively measured sedentary time separately. They found that obesity related outcomes predicted sedentary time (30) and mixed results for the association between insulin resistance and sedentary time (31, 32).

A substantial contribution to the evidence base for the adverse health implications of increased sedentary time comes from a population-based study of Australian adults: the Australian Diabetes, Obesity and Lifestyle study (AusDiab). AusDiab provided both cross-sectional and prospective evidence linking high
levels of TV viewing time with markers of cardio-metabolic health (35-39), the incidence of metabolic syndrome (40), and mortality (41). Detrimental associations of objectively-assessed (ActiGraph accelerometer) sedentary time with cardio-metabolic biomarkers were also observed in a sub-sample of the 2004-2005 AusDiab participants (26, 27). In addition, publications from the AusDiab study are among the few that reported associations between cardio-metabolic risk factors and increased sedentary time measured by general self-reported sitting time (39) and objective accelerometry data (26).

In Canada, a population-based prospective study of 17,013 adults, over 12 years, on average, reported that overall sitting time was significantly associated with all-cause mortality and cardiovascular disease mortality independent of physical activity level (42). Despite growing evidence that supports detrimental health implications of increased sedentary time, there are currently no published Canadian recommendations for limiting sedentary time. However, in Canada CSEP recommends that children limit their screen time to less than two hours a day (43). In Australia, the Heart Foundation provides general guidance along similar lines for adults but not explicit recommendations (44).

2.3.1 Sedentary Time Accrual

The relationship between sedentary time with adverse health outcomes depends not only upon the total amount of sedentary time, but the pattern in which it is accumulated (33, 34, 45). For the same total amount of time spent sitting, it is advantageous to interrupt sedentary time with bouts of activity, rather than continuously sitting for prolonged periods. A subsample of the AusDiab study (n=168, mean age 53.4 years, 61% women) was the first to report that the number of interruptions, or breaks in sedentary time was associated with cardio-metabolic health outcomes independent of total sedentary time and MVPA (45). Study participants wore ActiGraph accelerometers during waking hours for seven days and investigators
defined breaks in sedentary time by the number of occasions the accelerometer counts met or exceeded 100 counts/minute. In this study, participants with increased number of breaks in sedentary time had a lower average waist circumference, body mass index, triglycerides level and two-hour fasting blood glucose compared to those who accumulated less breaks in sedentary time (45). The importance of breaks in sedentary time was further confirmed using a U.S. population-based dataset (National Health and Nutrition Examination Survey; NHANES). Healy and colleagues used NHANES accelerometer data from 4757 adults (≥ 20 years old) in 2003/2004 and 2005/2006, which was collected and analyzed using the same accelerometer and definition of sedentary breaks stated above, to assess the association with cardio-metabolic biomarkers. They showed that increased frequency of sedentary breaks were beneficially associated with waist circumference and C-reactive protein, after adjusting for total sedentary time and MVPA (34). The differences in waist circumference between the highest and lowest quartiles of sedentary breaks in both the AusDiab (45) and NHANES study (34) (6.0 cm and 4.1 cm respectively) were noted to be clinically significant. Tudor-Locke and colleagues investigated the 2005/2006 NHANES dataset separately (n=3453, ≥ 20 years old) and observed only small differences (approximately 1-2 breaks) in the number of sedentary breaks across BMI categories (normal, overweight and obese) and this difference was only statistically significant in men (33). The evidence for the beneficial health impact of breaks in sedentary time is currently based on cross-sectional studies and large prospective studies and/or intervention studies are needed to strengthen the evidence base.

While the number of breaks in time spent in sedentary behaviours appears to be important, researchers have also begun to investigate the independent influence of long continuous bouts of sedentary time: both their prevalence, and their impact on health outcomes. Ryan and colleagues investigated prolonged bouts of continuous sitting in the workplace of more than 20, 30 or 55 minutes in duration (46). These durations
were chosen based on little or no evidence and relied on previously published recommendations or expert opinion from the Chartered Society for Physiotherapy in the UK, Atlas and colleagues (47) and Owen and colleagues (48). The Chartered Society for Physiotherapy in the UK recommended no more than 20 minutes of continuous sitting. However, they more recently recommended that adults, “try to take a break for a few minutes at least hourly” (49). A maximum of 30 minutes sitting was recommend for people with back pain (47). A review of the adverse impact of sitting time, on the other hand, recommended individuals take at least a five minute break from sitting every hour (48). In addition, to the recommendations identified by Ryan and colleagues (46) the general consumer advice provided by the Australian Heart Foundation suggests standing and taking breaks from the computer every 30 minutes as a strategy to reduce sitting time at work (44). Owen and colleagues also suggest standing up and moving after 30 minutes of continuous sitting (12) and derived this based on previous reviews (1, 11) and studies in animals (50). Dunstan and colleagues were the first to investigate acute physiological consequences of breaks in prolonged sitting bouts (51). They compared uninterrupted sitting to bouts of 20 minutes of sitting interrupted by either light activity or MVPA in 19 overweight/obese adults (aged 45 to 64, 42% women) and found that interrupted sitting was beneficial for postprandial glucose and insulin levels. Further research that investigates the impact of the number and length of prolonged bouts of sitting on health is needed to make evidence-supported recommendations regarding prolonged sitting bouts. Within this thesis, prolonged sitting is defined as continuous sitting of 30 minutes or more.

2.3.2 Physiology of Sedentary Time

Mechanisms that explain the association of increased sedentary time with adverse health outcomes are not well established. Hamilton and colleagues proposed that the physiology related to time spent in sedentary behaviours, and its mechanisms that influence health are different from the pathways that explain health
related changes associated with MVPA (14). Studies of bed rest, immobilization, space travel, spinal cord injury and animal models provide limited knowledge regarding the physiology of sedentary time related to metabolism, bone mineral content and cardiovascular health (2). Further investigation is needed to determine the specific mechanisms that underpin potential adverse effects of sedentary time and health. In this section, I provide a brief overview of the proposed mechanisms of sedentary time related to cardio-metabolic health.

Differences in skeletal muscle activation during sitting versus standing might play a role in cardio-metabolic health. Although there is little difference in energy expenditure between these postures, 1.0 MET expended during quiet sitting compared to 1.2 METs for quiet standing (8), standing constantly demands that large lower limb skeletal muscles contract; muscles that are inactive during sitting (14). Further, skeletal muscle fiber groups activated during standing are again different than those recruited while performing MVPA. Recruitment of postural muscles during standing may influence glucose uptake and the action of lipoprotein lipase, an enzyme involved in lipid metabolism (uptake of triglycerides and free fatty acids by skeletal muscles and high-density lipoprotein production) (14). Animal studies have found that lipoprotein lipase activity was suppressed when animals were sedentary (through hind limb unloading to prevent standing and ambulatory activity of the animal); this was not observed when the animals were engaged in light activities such as standing or walking (14, 50, 52). In humans, Dunstan and colleagues observed differences in postprandial glucose and insulin levels between uninterrupted sitting and sitting bouts of 20 minutes (with either an interruption of light activity or MVPA) (51). Thus sedentary behaviours may impair acute metabolic processes, which in turn might contribute to poor cardio-metabolic health and related diseases.
The low energy expenditure of sedentary time may have important health implications as it displaces the opportunity to engage in light intensity or incidental activities that increase energy expenditure. Using data from the 2003-2006 US NHANES study, the objectively measured amount of time spent in light and sedentary activities were inversely proportional (34). Time spent in non-exercise activity thermogenesis (NEAT) activities, referring to activities that exclude planned exercise, explains the largest amount of variance in daily energy expenditure (53). As most people do not engage in regular exercise, only 1-2% of the variance in daily energy expenditure is due to exercise (53). Therefore, light/incidental activities are important to maintain energy balance and healthy body weight. Replacing time spent in sedentary behaviours with light activities (e.g. short walking breaks, etc.) can increase energy expenditure. Levine and colleagues found, in a pilot study (n=20, 50% women), that obese individuals sat for 2 hours longer a day than lean individuals and suggest that if these obese individuals replaced this extra sitting time with NEAT ambulatory activities they could expend an extra 320 kcals/day, which over a year would results in a loss of approximately 15 kg in body weight (54).

2.3.3 Summary

Although adverse health outcomes from increased sedentary time have been described, clear evidence from randomized controlled trials to support the effect of sedentary time on a spectrum of health indicators is lacking. Furthermore, the possible physiological mechanisms underlying these health effects remain undefined.
2.4 Workplace Sedentary Time

At the turn of the century there was a dramatic shift from a labour force comprised mostly of those performing manual labour to mostly white collar and service workers (55). The number of professional and technical employees increased more than fourfold from 1910 until 2000. This trend has accelerated over the last 30 years. For example, the number of physically demanding agricultural and manufacturing jobs have decreased and employees in the service sector have increased 13% (from 70 to 83% over the last 30 years) (55). Over the past five decades, an increase in occupations such as those that involve computer based work performed while seated generally has resulted in a lower energy expenditure (56, 57). In 2000, over half of employed Canadians used computers at work and this has continued to increased (58). A myriad of advances in computing and other technologies coupled with more sedentary business practices, have influenced workplace culture. For example, it is common for office-based employees to use email to communicate with co-workers therefore negating the opportunity to interrupt their sitting. This trend away from workplace physical activity toward a more sedentary workday needs to be reversed. To do so requires strategies that encourage activity at the workplace, increase the physical workloads in work related tasks, or both (57, 59).

Working adults spend a considerably large volume of their waking hours at work; a typical workday in Canada is more than eight hours (60) which is half of a 16 hour waking day. Working adults in the Netherlands (3) and Australia (4, 5) spend one-third to one-half of every working day sitting down. In office-based occupations such as managerial/professional or administrative positions, these figures balloon to three-quarters of a workday spent in sedentary tasks (5). Not surprisingly, for jobs where employees spent more time sitting (≥ 75% of their time sitting) individuals were less physically active. A study in Canada by Chan and colleagues reported that workers in the healthcare sector who reported spending ≥ 75% of their
time sitting recorded only 6500 steps/day by pedometer compared with 10 500 steps/day for those who had more active jobs (<25% of time spent sitting) (61). Alarming, employees who spend a substantial amount of time in sedentary tasks at work likely do not compensate for their sedentary occupations with more physical activity or less time in sedentary behaviours during leisure time (3, 62, 63). Thus, the workplace represents an ideal setting to intervene to reduce prolonged sedentary time and encourage healthier behaviours.

Most of the evidence related to workplace sedentary time to date has relied on self-reported sitting time measures. However, a few smaller studies objectively measured sedentary time in the workplace (46, 62, 64-66). McCardy and colleagues measured workplace sedentary time in 21 adults (mean age 38 years, 48% women) with sedentary occupations using a customized physical activity monitoring system that consisted of two accelerometers and four inclinometers (62). Workers sat more and stood/walked less on working days compared with leisure days [597 (122) vs. 484 (83) minutes/day, respectively; $P<0.0001$] (62). Sitting time was objectively measured, using an activPAL activity monitor in university employed office workers in Scotland (46). Participants (n= 83, mean age 40 years, 75% women) spent 66% of their workday seated, based on a standard 9:00-17:00 workday. They also reported prolonged bouts of sitting time greater than 20, 30 and 55 minutes. Most sitting time was accumulated over long uninterrupted periods -- only 8% of workers took a break from sitting every 55 minutes on workdays measured. In Scotland, Tigbe and colleagues used the activPAL monitor to determine the workplace sedentary time of administrative postal workers (64). They found that during 8-hour work-shifts the office-based workers spent 51% of their time sitting and 17.6 hours sitting/lying across an entire 24 hour period on a workday. An Australian study of office-based employees (n=104) used ActiGraph accelerometers to specifically measure sedentary time at work (66). The average time spent in sedentary behaviours during working hours was
76% for office workers, 73% for customer service workers and 82% for call centre workers. Furthermore, Ruiz-Tendero and colleagues characterised the sedentary time of Spanish university workers (administrators, researchers and cleaning staff) using the ActiGraph accelerometer (n=47, mean age 36 years, 64% women) (65). Administrators and researchers spent significantly more working time in sedentary tasks than cleaning staff (63%, 61% respectively vs. 22%; \( P<0.01 \)). An important limitation is that not all studies reported the actual work time of individual participants; two studies reported sedentary time for participants specific working hours (65, 66), one study used whole day values of workdays (62), others used general employer office hours (46) or work shifts (64).

### 2.4.1 Workplace Sedentary Time and Health

In the 1950s, Morris and colleagues first identified the potential relevance of workplace physical activity for health outcomes (67). Their original study of British civil servants reported health benefits for those with more physically active jobs. Although the focus of this research was on the benefits of physically active jobs, it was actually one of the first studies to investigate the health impacts of occupational sedentary time. Sixty years later, there is now renewed focus on the deleterious impact of sedentary time as occupations become increasingly more sedentary (68).

A systematic review conducted in 2010 by van Uffelen and colleagues (69) focused on studies that specifically investigated workplace sedentary time and adverse health outcomes. This review found mixed evidence in regard to the association of workplace sedentary time with health risk. Prospective studies typically reported occupational sedentary time to be associated with an increased risk of type 2 diabetes and mortality, but were not associated with increased body mass index (BMI) or risk for cancer, despite these links observed for cross-sectional and case-control studies. However, the methodological quality of
the included studies limits the findings of this review. All of the studies in the review used self-reported measures of occupational sitting time and less than half of the studies adjusted for physical activity.

Research examining the relationship between workplace sitting and health outcomes has traditionally focused on musculoskeletal outcomes. Sustained and restricted postures are known to contribute to occupational injuries (70-72). The ergonomic literature suggests that constrained postures such as prolonged sitting can result in musculoskeletal disorders through repetitive overuse and recommended that workers vary their posture throughout the workday for their musculoskeletal health (57, 73). Those with sedentary occupations (such as data entry operators or computer workers) have a high prevalence of musculoskeletal disorders (74, 75). Furthermore, occupational related musculoskeletal disorders result in a high economic burden (76).
2.4.2  Determinants of Sedentary Time in the Workplace

As working adults spend a substantial portion of their day at their workplace, the workplace is an ideal setting to intervene to decrease and/or break up sedentary time with activity. However, in order to change behaviour, it is important to understand the determinants of sitting in the workplace. The Social Ecological Model, as proposed by Sallis and colleagues (77), provides an ideal framework to investigate the interaction between health and the workplace, in particular, workplace sedentary time (12). The framework identifies individual, social/organizational and environmental factors that interact to influence behaviour (6, 12, 77) (see Figure 2.1). Key determinants of workplace behaviour include both the individual’s beliefs and values and the organizational workplace culture (78-80). Further, the organization’s values with respect to their employees’ health and productivity, and the perceived norms and expectations by the employees are also important factors influencing workplace behaviour (81). The social ecological approach also identifies the importance of the workplace physical environment, which is discussed in detail later in this chapter.
Limited knowledge is available in regards to the interaction between the person, organization and physical environment to limit sedentary time in the workplace setting and only a few studies have begun to investigate this area (80, 82). Bennie and colleagues provided insight into the acceptability of short physical activity breaks in the workplace through a survey of 801 Australian desk-based employees aged 18 to 70 years (66% women) (80). They found that men required support from management to incorporate short activity breaks in order to overcome their perceived lack of time, and women required more information on the benefits of breaks. Focus groups performed with office-based government employees in Australia (n=22, 91% women), separately for managerial and non-managerial positions, highlighted the need for shared responsibility of the individual, managers and organization to successfully implement strategies to

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**Figure 2.1** Social Ecological Model for the determinants of workplace sedentary time. Reproduced based on Zimring et al.(6) and Owen et al. (12).
reduce and/or interrupt workplace sedentary time (82). The focus groups also identified the adaption of strategies to specific occupational roles and the consideration of the impact that these strategies may have on productivity as important factors for successful implementation (82). These studies provide evidence for the personal and organizational influence on workplace sedentary time. This is similar to approaches used in general workplace health promotion that require a combination of improving the work organization and the working environment, to promote active participation and encouraging personal development (83).

2.4.3 Summary

Many occupations require workers to spend most of their workday in sedentary pursuits. There are multiple contributing factors leading to increased workplace sitting and the potential detrimental health effects. Similar to the evidence surrounding overall sitting time and health, there is a lack of clear evidence from randomized control trials to support the deleterious effect of workplace sedentary time on a wide range of health outcomes.

2.5 Interventions at the Workplace

The workplace is a key setting for health promotion (84). Many organizations adopt policies and programs to promote all aspects of health (nutrition, physical activity, mental health, etc.) with the aim to reduce health costs, increase morale and productivity and reduce absenteeism. Traditionally, workplace health promotion programs center on interventions to increase physical activity through walking programs, onsite fitness facilities, and education to encourage physical activity outside of the workplace (85-88). However, despite the high prevalence of sedentary time that occurs during work hours very few programs specifically address this behaviour. In this section, I provide an overview and update of interventions that measured
workplace sedentary time. I then discuss additional strategies to reduce and/or interrupt workplace sedentary time.

2.5.1 **Interventions to Reduce Workplace Sedentary Time**

There are few workplace interventions that specifically measure occupational sedentary time. In 2010, Chau and colleagues (89) reviewed the literature for interventions in the workplace that measured workplace sedentary time. I updated their search strategy; and my search keywords included *workplace setting and sitting* in the following databases, PubMed, PsychINFO, Cochrane Register of Controlled Trials, CINAHL, EMBASE, PEDro from April 2009 to March 2012. I also performed a forward search of included articles and checked the reference lists. My updated search identified six additional relevant studies (90-96). A summary of all the interventions to reduce sitting time based on Chau and colleagues review (89) and my updated search is provided in **Table 2.1**, with the findings discussed below.

Chau and colleagues (89) identified six relevant studies; five were randomized control trials (97-101) and one was a pre-post observational study (102). All of the studies used self-reported measures of sitting time, only one study specifically assessed sitting during the workplace (101), and none had a primary aim to decrease sitting time. The interventions identified included individualized physical activity plans, motivational materials, pedometers, and/or provision of local walking routes. None of these interventions showed a statistically significant decrease in workplace sitting compared with a control or second intervention group. However, four studies (97-100) demonstrated statistically significant within-participant decreases in sitting time with their respective interventions. In particular, Opedenacker and Boen found decreases in overall self-reported sitting in university employees (n=71) who received a three month in-person coaching (147 minutes per week reduction) or telephone coaching (429 minutes per week
Marshall and colleagues found a statistically significant decrease in weekday sitting of 105 MET minutes per week (time spent in activity weighted by MET intensity) for university employees (n=655) who received an eight week web-based intervention, the web-based intervention was not significantly different from the print based intervention (97). In Canada, a 12-week email based multisite workplace intervention (n=2121) resulted in a statistically significant decrease in sedentary work status from baseline but not compared to a control group (99). Aittasalo and colleagues investigated a 12 month goal-oriented counselling intervention with or without fitness testing for employees (n=155) in workplaces serviced by occupational health care units and found a statistically significant reduction in workday sitting time, however, these results were not significantly different from the control group (98). This review highlighted a dearth of research on workplace interventions to reduce sitting time (89).

Of the six studies (90-96) identified from the updated search, three aimed to specifically reduce workplace sedentary time (92, 94, 96) and four objectively captured sedentary time in the workplace (93-96). The interventions included pedometers (90, 91), workstations (92-94), informational material (96) and a comprehensive physical activity program (95). Four studies (90, 93, 95, 96) showed statistically significant decreases in sitting with their respective interventions and two (91, 92) did not. Freak-Poli and colleagues observed a statistically significant decrease in workday sitting time (measured by self-reported questionnaire) of approximately 36 minutes/day with a pedometer-based 4 month pre-post intervention that had employees (n=762) target 10 000 steps/day with supplemental web-based educational materials (90). Furthermore, the intervention resulted in changes in cardio-metabolic health and body composition. Specifically, they found a statistically significant decrease in waist circumference and blood pressure but an increase in triglycerides and total cholesterol. The investigators also found that a reduction in weekday sitting was not a statistically significant predictor of waist circumference improvement post-intervention (91).
For the three small studies that specifically investigated the impact of modifying the workstation environment on sedentary time (92-94), only one found a statistically significant difference (93). Carr and colleagues investigated the effect of a pedal bike active workstation intervention to reduce workplace sitting in office workers (n=18) (92). The intervention did not result in a statistically significant decrease in workplace sitting (measured by self-reported questionnaire), however, participants did report that their perceived sedentary time at work decreased as a result of using the machine. John and colleagues investigated the effect of a treadmill workstation in obese and overweight office workers (n=12) on sitting time measured by the activPAL activity monitor (93). They observed a significant decrease in workday sitting time (not specific to work hours), 20.6 hours/day to 19.2 hours/day after nine months. Gilson and colleagues did not observe a change in workplace sedentary time with the addition of height-adjustable workstations for employees (n=11) to share in an open plan office as measured by the Sensewear armband activity monitor (Body Media Inc., Pittsburgh, USA) (94). Height-adjustable workstations were also included as part of a comprehensive physical activity promotion program that was provided to German office workers (n=25), where Ellegast and colleagues measured sitting time in this group with self-completed activity logs and a CUELA Activity System objective activity monitor consisting of multiple sensors (95). The intervention group significantly reduced self-reported total daily sitting time by 58.3 (SD 19.3) minutes compared to control group and significantly reduced objectively measured sitting during work. Lastly, Kozey-Keadle and colleagues used objective measures to determine sedentary time in office workers (n=14) before and after a seven day information based intervention to reduce sedentary time (96). The participants were provided strategies to reduce their sedentary time across all domains (home, work, transportation and recreation). Workplace strategies included standing to answer the phone, taking 5-minute breaks each hour, taking the stairs, going to talk to colleagues instead of emailing, not eating lunch at their desk and using the washroom on a different floor. After the seven day intervention, participants significantly reduced their workday sedentary time from 70% to 65% (a 37 minute reduction per 16-hour
waking day) as measured by the activPAL and there was no difference in the number of weekday breaks in sedentary time per day. Participants also wore an ActiGraph accelerometer and provided self-reported sitting time, however, no statistically significant differences in sedentary time before and after the intervention were observed with these measures. This study illustrates that sedentary time derived from different objective and self-reported measures is not necessarily comparable.

Overall, there are few interventions specifically aimed to reduce workplace sedentary time. None of these interventions investigated the workplace physical environment beyond the workstation and most used self-reported measures of sitting time, not always specific to time spent at the workplace. The studies identified provide evidence that it is possible to intervene to reduce sedentary time at the workplace. In their review, Chau and colleagues recommend that future interventions to reduce sedentary time should focus on increasing light activities, standing and slow walking (89). Moving forward to extend this work, it is also important that studies objectively measure workplace sedentary time.
Table 2.1 The impact of interventions on workplace sedentary time. Reproduced in part from Chau et al. (89).

<table>
<thead>
<tr>
<th>Study</th>
<th>Study Design</th>
<th>n</th>
<th>Sample [Mean (SD) age]</th>
<th>Intervention</th>
<th>Aim to Reduce Sedentary Time</th>
<th>Sedentary Time Measure</th>
<th>Results</th>
</tr>
</thead>
</table>
| Ellegast (95) 2012 Germany | 12 week RCT   | 25         | Office workers          | 1. Control; 2. Physical activity promoting package (height-adjustable workstations, motivation and incentive with pedometers) | Self-reported activity logs of daily sitting time and CUELA Activity System (multiple sensors) | Activity Logs: Intervention group reduced total sitting time by 58.3 (19.3) minutes compared to control group (P≤0.001).  
CUELA Activity System: Significant reduction in sitting for intervention group during work (P≤0.001). |
<p>| Gilson (94) 2012 Australia | 1 week pre-post study | 11 (Women = 7; Men = 4) | Office workers 46.9 (9.8) years | Shared height-adjustable workstations in an open plan office. | Yes | Sensewear armband accelerometer | No significant change in mean percentage of sedentary time at work. (75.8 % (10.30) to 75.7% (8.4)). |
| Kozey-Keadle (96) 2012 USA | 7 day pre-post study | 14         | Overweight, non-exercising office workers | Information and strategies to reduce sedentary time at home, work, transportation, and in recreation. | Yes | activPAL monitor; ActiGraph monitor and self-reported questionnaire | Significant reduction in weekday sedentary time (34 minutes/ 16-hour day) as measured by the activPAL monitor (P&lt;0.05). |
| John (93) 2011 USA | 9 month pre-post study | 12 (Women = 7; Men = 5) | University employees 46.2 (9.2) years | Treadmill workstations | | activPAL monitor | Significant decrease in median daily sitting/lying 1238 (128) min/day at baseline, 1056 (233) min/day at 3 months and 1150 (87) min/day at 9 months. |
| Carr (92) 2011 USA | 4 week pre-post study | 18 (Women = 16; Men = 2) | Full time employees in sedentary jobs 40 (11) years | Provided pedal exercise machine to use at workstation. | Yes | Self-reported questionnaire | No significant differences in sitting time. |
| Freak-Poli (90, 91) 2011 Australia | 4 month pre-post study | 762 (Women = 457; Men = 305) | Corporate workplaces 40 (10) years | Pedometer-based walking program with website support | | Self-reported questionnaire of weekday sitting | Significant reduction in sitting time [-0.6 (-0.9 to -0.3) hours/day]. Reduced weekday sitting was a not significant predictor in change in waist circumference. |</p>
<table>
<thead>
<tr>
<th>Study</th>
<th>Study Design</th>
<th>n</th>
<th>Sample [Mean (SD) age]</th>
<th>Intervention</th>
<th>Aim to Reduce Sedentary Time</th>
<th>Sedentary Time Measure</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gilson (101) 2009 Australia, Spain, UK</td>
<td>10 week RCT</td>
<td>179 (Women = 140; Men = 39)</td>
<td>University employees 41 (10) years</td>
<td>1. Control; 2. Route-based walking; 3. Incidental walking</td>
<td>Self-reported log of sitting minutes during the workday</td>
<td>No significant differences in sitting time.</td>
<td></td>
</tr>
<tr>
<td>Opdenacker &amp; Boen (100) 2008 Belgium</td>
<td>3 month RCT</td>
<td>66 (Women = 140; Men = 39)</td>
<td>University employees; Group 1=39 (11); Group 2=40 (10) years</td>
<td>1. In-person coaching; 2. Telephone-based coaching</td>
<td>Self-reported questionnaire; sitting minutes per weekday in last week</td>
<td>Both groups significantly decreased sitting time (F=6.51; P&lt;0.05). (Group 1 = 147 min/week, Group 2 = 429 min/week). No significant between-group differences.</td>
<td></td>
</tr>
<tr>
<td>Østerås &amp; Hammer (102) 2006 Norway</td>
<td>6 month pre-post study</td>
<td>131 (Women = 51; Men = 80)</td>
<td>Healthy working adults 41 (9) years</td>
<td>Individualized physical activity plan</td>
<td>Self-reported questionnaire; sitting minutes per day in last week</td>
<td>No significant differences in sitting time.</td>
<td></td>
</tr>
<tr>
<td>Plotnikoff (99) 2005 Canada</td>
<td>12 week RCT</td>
<td>2121 (Women = 1558; Men = 553; Not reported = 10)</td>
<td>Large private and public workplaces 45 (6) years</td>
<td>1. Email-based intervention on physical activity and nutrition; 2. Control</td>
<td>Self-reported workplace activity status questionnaire</td>
<td>Both groups significantly reduced their sedentary work activity status (P&lt;0.001). No significant between-group differences.</td>
<td></td>
</tr>
<tr>
<td>Aittasalo (98) 2004 Finland</td>
<td>12 month RCT</td>
<td>155 (Women = 87; Men = 68)</td>
<td>Workplaces serviced by occupational health care units; 44 (9) years</td>
<td>1. Counselling; 2. Counselling and fitness testing; 3. Control</td>
<td>Self-reported questionnaire; sitting minutes per workday in last week</td>
<td>Workday sitting time significantly decreased for all groups (P = 0.023). No significant between-group differences.</td>
<td></td>
</tr>
<tr>
<td>Marshall (97) 2003 Australia</td>
<td>8 week RCT</td>
<td>655 (Women = 337; Men = 318)</td>
<td>University employees; 43 (10) years</td>
<td>1. Print based intervention; 2. Web-based intervention</td>
<td>Self-reported questionnaire; sitting minutes per weekday in last week</td>
<td>Group 2 significantly reduced weekday sitting time on a by 105 MET min/week (P=0.03). No significant differences between groups</td>
<td></td>
</tr>
</tbody>
</table>
2.5.2 Strategies to Interrupt Workplace Sedentary Time

Although there is a lack of empirical evidence on their effectiveness, many strategies have been proposed on how to interrupt prolonged periods of sitting and to introduce breaks into the workday. Studies in the ergonomic literature recommend short micro breaks to help alleviate musculoskeletal complaints and eye strain without negative effects on productivity (103-106). These breaks allow for postural changes and/or to incorporate physical activity with short bouts of walking. Focus groups performed with office-based government employees in Australia (n=22, 91% women) identified strategies to interrupt and/or reduce workplace sitting (82). These strategies included: purposeful group breaks, increasing incidental activity (such as taking the stairs or changing the location of key workplace destinations) and workload planning (such as planning to complete tasks in a way that permits breaking up sitting time).

Taylor and colleagues (107) proposed the concept of “booster breaks” to interrupt sedentary time at the workplace with physical activity. “Booster breaks” incorporate activity into work breaks already provided by employers. These work breaks are typically 10 to 15 minutes long and are generally spent in sedentary tasks. In a six-month pilot study (n=8), the implementation of “booster breaks” in a small workplace resulted in positive health outcomes and a non-statistically significant decrease in sitting time of 205 minutes/workday (108). Additional studies successfully implemented activity breaks during the workday (109-111), however, these studies did not report the impact of these breaks on workplace sedentary time.

2.5.3 Summary

There is limited evidence on workplace interventions aimed specifically to reduce workplace sedentary time.
2.6 Workplace Physical Environment

The physical environment can promote or restrict physical activity (6, 12). Traditionally, architects design buildings “toward human energy conservation” (112) and yet for health benefits the physical workload in workplace should be increased (57). In this section, I discuss specific aspects of the workplace physical environment to limit workplace sedentary time and encourage physical activity. In particular, I compare features common to a conventional workplace physical environment to those designed to encourage physical activity and reduce sedentary time (activity-permissive). In this thesis, I define conventional workplace as a workplace that was not specifically designed to be activity-permissive.

Owen and colleagues identified several important features of the workplace environment relevant to sedentary time (12). They include: the furniture design for sitting; neighbourhood walkability; availability of parking, transit and bike facilities; building design; and stair design. Zimring and colleagues reviewed the influence of the building on physical activity and also highlighted the value of the building design and building element design (6). The building design characteristics identified as important for encouraging physical activity within the building include the building circulation system and the inclusion of appealing activity permissible spaces and amenities. Key features of the design of specific building elements (such as stairs) identified were the accessibility, appeal, safety and comfort of elements. Literature in this area is limited as changes to the physical environment can be expensive. However, studies that investigate smaller scale changes to the environment such as stair appeal and workstation redesign provide the impetus for further research in this field.
2.6.1.1 Building Level Features

The staircase provides an important opportunity to increase workplace physical activity. Staircases in conventional buildings are often not accessible or appealing. Their design is based only on their use as emergency exits with elevators promoted as the main circulation routes within the building. Increased stair use is the most cost effective intervention to increase energy expenditure (113) and there have been many programs aimed to increase stair use through point of decisions prompts and by enhancing staircase appeal. The US Centre for Disease Control developed a tool kit to increase stair use that included motivation signs and music/artwork (114, 115). Nicoll and colleagues investigated the effect of an innovative office building design where the elevator was programmed to stop at only every third floor (116). They found that compared to a traditional building set-up, the intervention increased stair use. Nicoll also proposed a theoretical model for stair use that focused on physical environmental factors and highlighted the importance of stair appeal, comfort, convenience, legibility (refers to being able to see the stairs and recognize their use) and safety (117). They tested this model by measuring stair use in buildings in two university campuses (n=10 buildings) and found that variables that increased legibility and convenience were most important for increased stair use.

The layout of elements within the building is also a key determinant of workplace physical activity as workers tend to take faster and more attractive routes to destinations (6). In a conventional workplace, the layout of the office is designed for convenience and functionality. Consequently, groups of coworkers who frequently work together are put in close proximity to each other and commonly used items are placed within easy reach (i.e. printer at the desk). Vertical integration, where key destinations are spread out throughout different floors of a building, may increase physical activity. This is because an employee will have to walk a bit further and possibly use stairs to interact with their colleagues in-person or to go to a key
destination within the building, such as the lunch room. There is no evidence regarding the influence of workplace vertical integration on workplace sedentary time. However, placing key destinations in the workplace further away from an employee’s workstation provides an opportunity to break up prolonged sitting and increase activity.

2.6.1.2 Workstation Level Features

Conventional workplaces encourage employees to work in a seated position for most tasks. Height-adjustable workstations allow employees to adjust their individual workstation to choose whether to work in the traditional sitting posture or standing. The popularity of these workstations is increasing but their benefits have not been rigorously examined. Energy expenditure from standing workstations has been compared to conventional sitting, therapy balls and active workstations (workstations that allow workers to be physically active through a cycle ergometer or treadmill) (118-120). Two of the studies showed an increased energy expenditure for work performed while standing (118, 120) and one did not (119). There is also inconclusive evidence on the influence of height-adjustable workstations and their impact on musculoskeletal complaints (121, 122). In addition, Wilks and colleagues studied perceptions of the standing workstations and suggested that education is needed to increase their use (123). Two studies (94) (95) examined the use of height-adjustable workstations in workplace interventions with mixed results. Gilson and colleagues (94) showed no change in workplace sedentary time (as measured by the Sensewear armband accelerometer) with the introduction of a shared height-adjustable workstations in an open plan office. Ellegast and colleagues (95) found a statistically significant decrease in objectively measured workplace sitting with height-adjustable workstations included as part of a multifaceted physical activity program. Further evidence is needed to determine the effectiveness of these workstations for decreasing sedentary time and improving health. Additionally, the impact of other standing options within...
the workplace, such as standing level tables in lunch rooms or in meeting rooms, has not been investigated and could also provide an opportunity to decrease workplace sedentary time.

2.7 Summary of Rationale

Adverse health outcomes associated with sedentary behaviour highlight the need to limit sedentary time in our daily lives. The workplace provides an ideal opportunity to intervene as office-based working adults spend a large portion of their waking hours sitting at work. One possible approach to increase opportunities for activity and decrease sedentary time is to adapt the physical environment. Changes to the workplace physical environment, and their influence on objectively measured sedentary time, have not been investigated. There is a need to determine if a workplace specifically designed to be activity-permissive will result in less prolonged periods of workplace sitting.
CHAPTER 3: RESEARCH OBJECTIVES AND HYPOTHESES

In the following section I provide the rationale, objectives and hypothesis for this thesis.

3.1 Rationale

Increased sedentary time is associated with adverse health outcomes. This is particularly relevant to working adults as they spend a large portion of their workday in sedentary pursuits. The physical environment can promote or restrict activity in a workplace and presents a novel opportunity to intervene. This prospective study observed office-based workers as they transitioned from a conventional workplace to an activity-permissive workplace physical environment designed to increase physical activity and reduce sedentary time. I used activPAL3 activity monitors to objectively measure sitting, standing and stepping time before and after the workplace transition.

3.2 Research Objectives

3.2.1 Primary Research Objectives

The primary objectives I will address are related to time spent at the workplace and include:

1. To describe the change in objectively measured workplace sitting, standing and stepping time (minutes/day) for office-based workers as they transition from a conventional to an activity-permissive workplace physical environment.

2. To describe the change in the number of objectively measured workplace sit to stand transitions (change in posture between sitting and standing; transitions/day) for office-based workers as they transition from a conventional to an activity-permissive workplace physical environment.

3. To describe the change in the number and length of objectively measured prolonged bouts of sitting ≥ 30 minutes (number of bouts/day, minutes/day) at the workplace for office-based workers.
as they transition from a conventional workplace physical environment to a activity-permissive workplace physical environment.

3.2.2 Secondary Research Objectives

The secondary objectives I will address are related to the overall time (including time at the workplace and outside of the workplace) and body composition. They include:

1. To describe the changes in objectively measured overall sitting, standing and stepping time (minutes/day), sit to stand transitions (transitions/day), the number and length of prolonged bouts of sitting ≥ 30 minutes (number of bouts/day, minutes/day) and overall MVPA (minutes/day) for office-based workers as they transition from a conventional workplace to an activity-permissive workplace physical environment.

2. To describe the change in body composition (percent fat mass, percent lean mass) before and after the transition from a conventional workplace to an activity-permissive workplace physical environment.

3.3 Hypotheses

3.3.1 Primary Hypotheses

My hypotheses are included below.

1. There will be a statistically significant decrease in workplace sitting time and an increase in standing and stepping time after the transition to the activity-permissive workplace physical environment.

2. There will be a statistically significant increase in the number of workplace sit to stand transitions after the transition to the activity-permissive workplace physical environment.
3. There will be a statistically significant decrease in the number and length of prolonged sitting bouts $\geq 30$ minutes at the workplace after the transition to the activity-permissive workplace physical environment.

3.3.2 Secondary Hypotheses

1. There will be a statistically significant decrease in overall sitting time and in the number and length of sitting prolonged bouts $\geq 30$, an increase in standing and stepping time, and an increase in the number of sit to stand transitions and no change in total MVPA after the transition to the activity-permissive workplace physical environment.

2. There will be a statistically significant decrease in percent body fat mass and corresponding increase in percent body lean mass after the transition to the activity-permissive workplace physical environment.
CHAPTER 4: METHODS

This section describes the methods used in this thesis project. I followed the STROBE (Strengthening the Reporting of Observational studies in Epidemiology) (124) guidelines for reporting observational studies that include the following items: study design, setting, participants, variables, data sources/management, bias, study size, and statistical methods.

4.1 Study Design

This study was a natural experiment of office-based workers as they transitioned from a conventional office environment to an intentionally designed movement-oriented workplace. The study used a pre-post design at a single workplace, with participants acting as their own control, to investigate the effect of the change in workplace physical environment on sitting, standing and stepping time and the number of sit to stand transitions. The study was approved by the Vancouver Coastal Health Research Institute (VCHRI) and the University of British Columbia (UBC) Clinical Research Ethics Board. Assessments were conducted at two locations; baseline was conducted at the Willow Chest Centre, Vancouver General Hospital (VGH) and at the Clinical Research Unit, in the Gordon and Leslie Diamond Centre, VGH. The follow-up assessments were conducted at the Robert H. N. Ho Research Centre, VGH and at the Clinical Research Unit, in the Gordon and Leslie Diamond Centre, VGH.

4.1.1 Timeline

Participant recruitment occurred on a continual basis from February 11, 2011 until June 22, 2011 with baseline measurement occurring from February 28, 2011 to June 30, 2011. The move to the new workplace occurred in three waves starting on June 20, 2011 and continuing to July 13, 2011.
subsequent follow-up data collection period (post-move) occurred three to six months after participants transitioned to the new workplace (from October 27, 2011 to December 1, 2011).

4.1.2 Setting

The Centre for Hip Health and Mobility (CHHM) is a research and clinical facility affiliated with UBC and VCHRI. The CHHM moved from the original workplace (Workplace A) to the new workplace (Workplace B) and this transition and the corresponding activity patterns of the staff, faculty and trainees are the focus of my thesis. Figure 4.1 shows the exteriors of Workplace A and B. A general overview of the physical characteristics of the workplaces are described below and characterized in greater detail in the Results section. Workplace A consisted of one floor (3rd floor) in the Willow Chest Centre (Building 1) and three floors (Floors 1, 2, and 5) in the Research Pavilion (Building 2). These buildings are retrofitted hospital buildings that have been converted into office and laboratory space. The Willow Chest Centre is a four story building with two stairwells and one passenger elevator cart of which the CHHM occupied approximately 1800 ft². It is connected to the Research Pavilion, a seven-story building with two stairwells and two passenger elevator carts of which the CHHM occupied approximately 11 000 ft². The Research Pavilion is a restricted access building, but the Willow Chest Centre is only restricted access after business hours; both buildings are shared with other UBC and VCHRI research groups. Individual and shared offices are present in both buildings.

The new workplace (Workplace B) is on four floors (Floors 4-7) in the newly built Robert H. N. Ho Research Centre. Building features include an office layout that promotes vertical integration, a staircase as a main design feature, height-adjustable workstations, standing options in common areas for meeting and eating, centralized supplies/printing, etc. Vertical integration refers to key destinations spread out throughout
different floors of the building and in the new building the kitchen, eating area and equipment were located on a different floors from most workers. Height-adjustable workstations (Haworth Inc., Holland, MI, USA) were installed in single occupancy offices mostly located on the 7th floor. These workstations were electronically operated and allow workers to choose the height of the desk (either for standing or sitting).

The building is seven stories tall and is physically connected to an adjacent VCHRI affiliated building. The CHHM occupies approximately 40 000 ft² of space within this building. It features two stairwells and one passenger elevator cart and has restricted access.
Figure 4.1 Exterior of Workplace A and Workplace B buildings: (i) is the exterior of Workplace A Building 1; (ii) is the exterior of Workplace A Building 2 and; (iii) is the exterior of Workplace B.

All buildings are located on the Vancouver General Hospital Campus (VGH), within 2 blocks of each other, in central Vancouver, British Columbia (please see map in Figure 4.2). The surrounding neighbourhood is rated as 90 out of 100 for walkability score (125).
4.1.3 Participants

The population of interest was office-based workers. The source of the population was CHHM affiliated faculty, staff and graduate trainees who transitioned workplaces to the Robert H. N. Ho Research Centre (Workplace B). Most individuals originally worked at VGH in the Research Pavilion or the Willow Chest Centre office buildings prior to the move to the Robert H. N. Ho Research Centre. Trainee positions included those at the Master’s level, PhD level and post-doctoral fellows. Staff positions included research and lab technicians, research coordinators, operations staff and administration. The majority of faculty, staff and trainees performed desk-based computer work for most of their workday. Other daily tasks varied from
administrative tasks, report writing, computer analysis, equipment-based analysis, meetings and email and telephone correspondence.

4.2  Study Sample

4.2.1  Recruitment

Recruitment of participants was achieved through information sessions, advertisements posted in the workplace and emailed targeted distribution lists. CHHM administration forwarded, via group email lists, recruitment material to potentially eligible CHHM members. Interested participants contacted the research coordinator, who provided information and determined eligibility. All participants provided written, informed consent prior to participating in the study.

4.2.2  Inclusion Criteria

Eligible participants were adults (aged 18-65 years) who were able to walk and expected to be working at least 0.8 FTE (full-time equivalent) at the new workplace.

4.2.3  Exclusion Criteria

Participants were excluded if they were pregnant, had known contraindications that would preclude periods of standing, had a planned absence from work of greater than three months (between the first and second data collection points) and/or a planned relocation to another worksite during the transition period.
4.2.4 Sample Size

The sample size was a convenience sample based on all eligible CHHM members (including staff, trainees and faculty) who were planning to move to the new building (n=79 CHHM members moved into the building during the assessment period).

4.3 Data Collection

Data collection occurred at baseline (pre-move) and follow-up (three to six months post move). At each time point participants attended two measurement sessions eight days apart and a workplace physical environment assessment was completed (see Figure 4.3). Data collection was staggered based on participant interest and facility availability. Trained study research staff conducted all assessments and the assessments lasted approximately 45 minutes.

At the first assessment session eligibility was confirmed and informed consent obtained prior to measurement. During the assessment, participants completed a questionnaire regarding demographic characteristics and had their height and weight measured. Participants were then fitted with the two activity monitors (activPAL3, ActiGraph GT3X+) and instructed on their use and how to complete the activity log. The second assessment occurred eight days after the first assessment session. At this assessment participants returned the two activity monitors and the completed activity log. They then underwent a whole-body dual energy X-ray absorptiometry (DXA) scan and completed an interview-administered questionnaire regarding their activity patterns. At the final assessment they also completed a self-reported questionnaire regarding the acceptability of the new workplace.
4.4 Outcome Measures

In this section, the outcome measures used in this study are outlined. It provides a description of the measures, the variables assessed, the reliability and validity of measurement tools, and any pilot work completed. The primary outcomes consisted of workplace sitting, standing and stepping time, the number of sit to stand transitions in the workplace and the number and length of prolonged sitting bouts ≥ 30 minutes in the workplace. All primary outcomes were determined from the activPAL3 activity monitor, before and after the transition to the new workplace. Daily values for the activPAL3 activity monitor outcomes and MVPA (measured by the ActiGraph GT3X+ activity monitor) were determined for all waking time, not just the time spent at the workplace. In addition, information on (i) individual characteristics of participants and (ii) their workplace environment were collected. Specifically, descriptive outcomes for participants are provided including: body composition (height, weight, and percent lean and fat mass by

Figure 4.3 Study data collection flow chart for the baseline and final assessments.
DXA) and demographic information (age, gender, education, and job characteristics). An audit of the physical environment of the original workplace and the new workplace was conducted to provide the following description: the building specifications, staircase and elevator appeal and accessibility.

4.4.1 Primary Outcome

4.4.1.1 ActivPAL Activity Monitor

Description

The activPAL3 (PAL Technologies Limited, Glasgow, UK) is a small tri-axial accelerometer that provides time and date stamped information on body posture and activity. Its dimensions are 53 x 35 x 7 mm, it weighs 15 g and it has a 4 MB memory capacity. The monitor uses a proprietary algorithm to determine time spent sitting/lying (referred to as sitting in this thesis), standing and stepping, as well as the number of postural transitions between sitting/lying and standing. It is not able to detect the difference between sitting and lying. The activPAL3 has a sampling frequency of 10Hz and therefore, records information on posture and movement in intervals of 0.1s.

The monitor was worn medially on the anterior thigh. Waterproof attachment of the monitor was performed according to manufacturer instructions. The monitors were placed in a nitrile pouch (North by Honeywell, Canada) and wrapped in an adhesive dressing (Tegaderm, 3M Health Care, St. Paul, USA or Opsite Flexifix, Smith & Nephew, Hull, England). A layer of Hypafix (BSN Medical, Hamburg, Germany), a dressing retention sheet, was placed on the skin between the monitor and the skin to prevent irritation, then a layer of adhesive dressing was used to secure the monitor to the skin. All materials were hypoallergenic. Participants were instructed to wear the monitor continuously for seven days and to record any non-wear
time in the activity log (detailed below). The activity log contained written instruction of the wear protocol and instructed participants to change the adhesive dressing for the activPAL3 after two to three days of wearing and to contact the research staff if any skin irritation occurred. A total of nine participants reported skin irritation; one stopped wearing the monitor during the assessment period.

Reliability and Validity

Literature using the activPAL3 activity monitor is limited. The earlier generation of the activPAL, single axis accelerometer, is a valid and reliable method for detecting various postures and postural transitions in healthy adults and the newer model uses the same algorithm for detecting posture. Previous researchers investigated the monitor accuracy compared to direct observation and other activity monitors in both laboratory settings and in free-living conditions (18, 127-130). The monitors were found to be 100% accurate at detecting sitting/lying, standing and stepping time at various treadmill speeds, self-selected outdoor walking and during activities of daily living (129, 130). Godfrey and colleagues found the activPAL to be 98% accurate in measuring static (sitting/lying and standing) and dynamic (walking) activities in young adults in free-living conditions (128). Furthermore, the activPAL was found to be more precise and more sensitive to changes in sitting time than the ActiGraph accelerometer, the most commonly used activity monitor, when compared to direct observation ($r^2 = 0.94$ vs. $r^2 = 0.39$) (18).

Preliminary Testing

All units were tested according to manufacturer instructions (131). They were charged and set to collect data; one hour lying flat on a horizontal surface followed by one hour in a vertical position. The data output
was then reviewed to ensure all units recorded the appropriate times in the horizontal and vertical positions during data collection. All units recorded data that was deemed acceptable.

The monitor protocol outlined above was piloted on three volunteers prior to the study. The volunteers wore the activPAL3 monitors using the waterproof attachment protocol for a minimum of four days and kept a log of their wear time. The data was reviewed to ensure the monitors were recording data and that the data collected were within expected values for the participants. Participants were also asked to provide feedback on the wear protocol. All data was within expected ranges and participant feedback was incorporated into a revised wear protocol.

4.4.1.2 Activity Log

Description

Participants completed daily activity logs (Appendix 1) during the seven days that they wore the two activity monitors. The log required participants to record sleep time (time woke up and time went to sleep), work time (defined as time spent in the workplace), wear time (time monitor was removed for greater than 10 minutes) and travel time. Further, participants were asked to record if they left their workplace for greater than 45 minutes during the workday. This log is a modified version of an activity log that has previously been used in studies at The University of Queensland.
4.4.2 Secondary Outcome Measures

4.4.2.1 ActiGraph Activity Monitor

Description

The ActiGraph GT3X+ (LLC, Fort Walton Beach, FL) is a tri-axial accelerometer that uses piezoelectric sensors to detect acceleration in three planes (vertical, antero-posterior, and medio-lateral). The monitor has dimensions of 46 x 33 x 15 mm, weighs 19 g and has a memory capacity of 512 MB. The ActiGraph GT3X+ can characterize daily activity patterns by using specific thresholds or cut-points to define sedentary behaviour, light activity and MVPA. The total amount of time spent in certain activity intensities as well as time and date stamped bouts of activity are calculated.

Participants were instructed to wear the monitor on the right side of the waist (attached via an elastic belt) for seven consecutive days. The monitors were set to collect data at a 30 Hz frequency rate. The device stores the raw acceleration data that can be processed and converted into counts per unit of time. The ActiGraph GT3X+ was only worn during waking hours (not worn during the night or in water) and participants recorded when the monitor was removed in the activity log. Written instructions were also provided in the activity log.

Reliability and Validity

ActiGraph is one of the most commonly used activity monitors in the literature. According to the manufacturer, the ActiGraph GT3X+ is comparable to earlier generations of ActiGraph accelerometers (132). The activity monitor has been tested for reliability and validity in the laboratory and in free-living conditions. Researchers have showed high intra-instrument reliability in the laboratory (133-135) and
sufficient inter-instrument reliability in free-living conditions (136, 137). In addition, Welk and colleagues found the monitor to be reliable for detecting treadmill walking (ICC ≥ 0.80) (138) and Patterson and colleagues concluded that the test-retest reliability of the accelerometer to detect different physical activities and sedentary activities was very high (r = 0.98) (139).

The validity of the ActiGraph accelerometer has been determined by comparing the accelerometer output to indirect calorimetry. A review by Plasqui and colleagues (140) reported reasonable correlations (r=0.30 to 0.96) between the doubly labelled water-derived energy expenditure and the ActiGraph accelerometer. Validation studies have also been conducted comparing the ActiGraph output to oxygen consumption during walking/running on treadmill and threshold values for various energy expenditures were developed by determining appropriate regression equations (141). A linear relationship for the accelerometry output and oxygen consumption has been shown with respect to walking but not for running (137). The monitors were only moderately correlated with energy expenditure during lifestyle activities (r = 0.55 to 0.59) (23, 142, 143). Therefore, the intensity and type of the physical activity may influence the accuracy of the accelerometer.

4.4.2.2 Perceptions of Workplace Sitting

Description

Participants completed an interviewer-administered questionnaire to determine their perceptions of workplace sitting (Appendix 2). This was part of a larger questionnaire of self-reported activity patterns in and outside of the workplace (results not reported) (16). The questionnaire has five items that captured the percentage of time participants spent sitting at the workplace; how much they would like to spend sitting at
the workplace and the percentage of time that they perceive their coworkers spend sitting at the workplace as well as their personal control of workplace sitting time by answering questions using on a Likert scale (with one representing strongly disagree and five representing strongly agree).

**Preliminary Testing**

The questionnaire was pilot tested to determine the feasibility of its administration. The assessor conducted three pilot interviews prior to the study and appropriate modifications were made to the questionnaire based on feedback. No changes were made to the questions regarding perceptions of workplace sitting.

**4.4.2.3 Workplace Acceptability**

**Description**

Participants completed a self-administered questionnaire regarding their perceptions of their new workplace at the follow-up assessment (Appendix 3). The questionnaire has six items that captured the following domains: enjoyment, productivity, if they would want to return to their original workplace, sitting time at the workplace and sitting and standing time outside the workplace. Participants were asked to rate their agreement with statements using a one to five Likert scale where one represents strongly disagree and five represents strongly agree. This questionnaire is a modified version of a questionnaire that has previously been used in studies at The University of Queensland to determine workplace acceptability.
4.4.3 Descriptive Information

4.4.3.1 Demographic
Participants’ age, gender, education, job characteristics and health history (144) were collected via self-administered questionnaire at the baseline assessment.

4.4.3.2 Body Composition
Description

Dual energy X-ray absorptiometry (DXA; Hologic QDR 4500W, Hologic Inc., Bedford, MA) was used to measure body composition, and followed standard manufacturer recommended protocols (145). Participants underwent a whole-body DXA scan performed by a trained DXA technician. Participants were screened prior to the scan to ensure they did not have any contraindications (pacemaker, pregnancy or exposure to radiation from medical imaging in the previous three months) and removed any metal prior to the scan (if this was not possible it was recorded). For the duration of the whole-body scans, the participants lay supine on the padded measurement table and were requested to remain still during the scan (approximately six minutes). The effective dose equivalent of one whole-body DXA scan is, on average, three microSv for the total scan, which is equivalent the approximately the background radiation one would receive in one day (145). Analysis was completed with manufacturer provided evaluation software (Hologic Inc., Bedford, MA (145)) and provides participants percent fat mass, total fat mass, percent lean mass and total lean mass.

Height was measured twice to the nearest 1 mm using a stadiometer (Seca Inc, Hanover, MD) and body weight was measured twice to the nearest 0.1 kg with a self-calibrating scale (Seca Inc, Hanover, MD). The
average values for both measurements were used for analysis. Body mass index was calculated as weight (kg)/ height (m²).

Reliability and Validity

The DXA (Hologic QDR 4500W) has been shown to have great precision and to be a reliable methodology for determining body composition (146, 147). However, consistency in data collection and analysis are important to maintain the accuracy of the measurements thus the same detailed protocol was used for all scans. Quality assurance scans were performed daily during assessments and the precision of the Hologic QDR 4500W for repeated measures of body composition results is less than 2%.

4.4.4 Workplace Physical Environment Assessment

I performed environmental audits of the Workplace A (Building 1 and 2) and of the Workplace B. The audit (see Appendix 4) was based on relevant fields from the Checklist of Health Promotion Environments at Worksites (CHEW) (148) and Nicoll’s stair specific measures (117). The audit focused on aspects of the physical environment that promote or inhibit movement within the workplace, such as the stairs, elevators and standing options. A second trained assessor also independently completed the assessments. After the assessment was complete we compared scores, and decided by consensus on any discrepancies; this occurred for a total of 9 out of 100 items.

From the CHEW questions a stair score was determined based on a number of factors present that are thought to promote stair use divided by the total number of staircases (see Appendix 4). In addition, other staircase features based on Nicoll (117) were rated based on if the feature is present (yes/no) or a score
where higher values represent qualities that are thought to contribute to increased stair use (see Appendix 4). Stair Appeal refers to the forms and finishes of the staircase and was rated as one for basic (emergency exit), two for enhanced (has minimal forms and finishes to increase the appeal of the staircase), and three for articulated (upgraded finished or stair form to increase the appeal of the staircase). Setting appeal assessed the view from the staircase (from zero to three) on the top floor of the workplace occupied by CHHM staff. Zero was used to represent a staircase with no view and three was for a people-oriented or landscape view. The accessibility of the staircase was also rated using a one to three scale with one representing staircases that had no or limited access, two for restricted key card access and three for unrestricted. Maintenance was scored based on a scale (zero to three) with zero used for staircases that were nonoperational and three for staircases that were in excellent condition. Legibility was determined based if the staircase under observation was the main staircase for circulation within the building or not (yes/no answer). Lastly, the maximum number of risers between landings and the stair width were also recorded.

Reliability and Validity

Previous studies have used modified versions of the CHEW to investigate health promotion in the workplace (149-160). Oldenburg and colleagues reported acceptable reliability for most attributes measured in the CHEW (ICC 0.47-1.0) (148)

The stair specific measures were adopted from Nicoll (117) and based on a social ecological model for stair use. They were correlated with stair use in academic buildings on a university campus. In this regression
analysis, stair width \( r = 0.148 \) and accessibility of each staircase \( r = 0.127 \) were significantly correlated to stair use.

**Preliminary Testing**

The two assessors reviewed the audit tool prior to the assessment. The assessors performed a pilot test for the stair and elevator assessment. The pilot test occurred at an independent workplace on the VGH campus and allowed the assessors to clarify the definitions of elements measured and the scales used.

**4.5 Data Entry and Management**

All information collected from participants was reviewed and entered by an independent research assistant. Participant’s confidentiality was maintained through the use of a unique numeric study code for each participant and all information was securely stored in a locked filing cabinet or password protected electronic files. A standardized protocol was followed to ensure data entry, cleaning and analysis were completed with rigor for the self-reported measures, activity monitor data, and DXA data, as described below.

**4.5.1 Self-reported and Measured Outcome Data Entry, Cleaning and Analysis**

All questionnaires were reviewed by study staff to ensure completeness at the assessments. Data entry was performed by an independent research assistant and reviewed. I checked all data for entry errors and if there were discrepancies found then further data screening was done (161). Each questionnaire was analyzed according to publisher’s recommendations and the data was checked for in accuracies and
4.5.2 Activity Monitor Data Entry, Cleaning and Analysis

All monitors were operated using the same computer and same assessor. The monitor numbers were also recorded and cross-checked when participants returned them. The data were downloaded immediately after the assessments and checked for accuracy using manufacturer provided software.

The activPAL3 monitors were initialized, downloaded and data was preliminarily analyzed using manufacturer software (Version 6.0) to determine sitting, standing and stepping time and the number of transitions. The resulting spreadsheet was further analyzed using SAS 9.2 (SAS Institute Inc., Cary, North Carolina USA) to incorporate the information from the activity log (wear time, waking time and time at the workplace). The amount of sitting, standing and stepping time, the number of sit to stand transitions and the number and length of prolonged bouts of sitting $\geq 30$ minutes were calculated for each day both for time at the workplace and for overall waking time. The daily average values for each outcome were then determined separately across all workplace time and all waking time. The monitor wear time was estimated from self-reported sleep times participants provided in their log accounting for any reported removal time of periods of $\geq 10$ minutes. If sleep times were not recorded they were estimated from the ActiGraph GT3X+ recorded wear time and the ActiGraph GT3X+ data itself, as participants were instructed to only wear this activity monitor during waking hours. The self-reported sleeping times were matched to events of sitting, standing and stepping in the activPAL3 data to ensure their accuracy (i.e. sleeping time would match a long event of sitting/lying time). The files were visually inspected to check for errors due to data entry, self-report inaccuracies or processing and were corrected. Workplace time was determined from self-reported log extreme values using Stat Software Version 11 (StatCorp, Texas, USA).
values accounting for reported removal time of periods of ≥10 minutes. If workplace times were not recorded the day was not included as a workday.

Monitor wear compliance during workplace time was determined based on self-reported monitor wear time and workplace time. Acceptable compliance was considered as 90% wear time during working hours. There were no restrictions for the amount of workplace time or days required and all activPAL3 monitored workplace time was considered in the analysis. To account for variation in working time, each workplace outcome was standardized to an eight-hour workday by multiplying by \([480 \text{ minutes} / \text{observed workplace time}]\). To account for the influence of change in sitting time the number of transitions were reported as the number of transitions observed per workplace sitting hour.

Overall monitor wear compliance was determined based on self-reported monitor wear time and waking time. Acceptable compliance was considered as 90% wear time during waking hours. To be included in the overall analysis participants were required to have at least one monitored non-working day. There were no limits placed on the amount of wear time or days required. As the amount of wear time varies across participants, and across assessment periods, the activPAL3 overall outcomes were standardized to a 16-hour day by multiplying their values by \([960 \text{ minutes} / \text{observed waking time}]\).

The ActiGraph GT3X+ accelerometers were initialized and downloaded using manufacturer software. The raw ActiGraph GT3X+ files were converted to a 15 second epoch of the uniaxial data for analysis. The accelerometry data was further analyzed using MeterPlus (Santech, La Jolla, CA) to remove non-wear time and to classify activity into intensity using counts. The cut-point of \(≥1952 \text{ counts/minute}\) was used to
determine MVPA (141). Both total amount of MVPA and MVPA accumulated in bouts of at least 10 minutes were reported. Non-wear time was determined as 60 minute of continuous zeros and all valid days (≥ 10 hours wear time) were considered in the analysis (162). The ActiGraph GT3X+ outcomes were standardized to a 16-hour day (outcomes were multiplied by [960 minutes/ observed waking time]).

4.5.3 DXA Analysis

A trained research technician analyzed all DXA scans using manufacturer provided evaluation software (Hologic Inc., Bedford, MA) (145). The percent fat mass, total fat mass, percent lean mass and total lean mass (excluding the head region) were determined. Analysis of the baseline and follow-up scans were completed at the same time.

4.6 Statistical Analysis

I described participant characteristics using means and standard deviations, or medians and interquartile range if the data was skewed. Descriptive analyses were used to examine the daily average time spent sitting, standing and stepping and the number of transitions between postures. The average daily number of bouts and total time sitting ≥ 30 minutes were also determined. All values were provided for time spent in the workplace and overall (workplace and non-workplace time). The variance for each participant’s workplace daily averages was examined by plotting the standard deviation of the mean daily values for each participant at baseline and follow-up. The change scores (baseline values subtracted from follow-up values) for time spent in sitting, standing and stepping, the number of transitions and the number of bouts of and total time sitting ≥ 30 minutes were also reported for workplace time and all waking time. The change scores were analysed using a t-test for normally distributed outcomes or the Hodges-Lehmann point estimate of the median for non-normally distributed outcomes. The mean change/ point estimate of
median change and 90% confidence interval are reported. All analyses were completed using Stata Software Version 11 (StatCorp, Texas, USA). All p-values reported are two-sided with a significance level of p<0.05.
CHAPTER 5: RESULTS

The results from the study are presented in this chapter. First I state the characteristics of the sample, then describe the physical workplace environment before and after the transition (the intervention) followed by the description of workplace sitting, standing and stepping time before and after the transition. Overall daily sitting time and physical activity for participants at baseline and follow-up is also described. A description of participants' body composition at baseline and follow-up is provided. Lastly, participants' perceptions of their workplace sitting and the acceptability of their workplace are described.

5.1 Characteristics of Sample

5.1.1 Participant Enrollment

Figure 5.1 shows the enrolment of participants through the study. Over the period of February 28, 2011 to June 30, 2011, 27 of the 79 adults who moved into the innovative building completed baseline assessments. The follow-up assessments occurred at a mean time of four months (range three to six months) after the move to the new building. Three participants left employment at CHHM before the follow-up data collection; 17 of the remaining 24 participants provided complete data at both time points.
Figure 5.1 Flow chart of participant recruitment and study participation.
5.1.2 Participant Characteristics at Baseline

Table 5.1 highlights the baseline descriptive characteristics of participants. Participants with complete valid data (n=17) had similar baseline characteristics compared with those who completed the baseline and follow-up assessments (n=24); and with participants who completed only the baseline assessment (n=27).

For all potential participants (n=79) only information on employment type was available; this group consisted of 18% faculty, 43% trainees, 39% staff. Those with complete valid data (n=17) had a lower proportion of participants who were staff (18%) compared to those originally enrolled in the study (37%) and all potential participants (39%). The majority of participants were women with a similar mean age of approximately 34 years across all samples. Overall, most participants with complete valid data (n=17) were also employed full time (82%) and had at least a Master's level education (76%). This was consistent with the sample of participants who had completed the baseline and follow-up assessments and with participants who completed only the baseline assessment. However, those with complete valid data (n=17) had a lower proportion of participants who had been employed for longer than 3 years (18%) compared with the sample of participants who had completed the baseline and follow-up assessments (29%) and with participants who completed only the baseline assessment (26%).
Table 5.1 Baseline descriptive characteristics of study participants: (i) with complete data (n=17); (ii) with baseline and follow-up assessments (n=24); and (iii) who completed the baseline assessment (n=27).

<table>
<thead>
<tr>
<th>Measure</th>
<th>Participants with complete data (n=17)</th>
<th>Participants who completed both assessments (n=24)</th>
<th>Participants who completed the baseline assessment (n=27)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>33.1 (7.0)</td>
<td>34.5 (8.3)</td>
<td>33.6 (8.2)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td>82% (14)</td>
<td>75% (18)</td>
<td>78% (21)</td>
</tr>
<tr>
<td>Men</td>
<td>18% (3)</td>
<td>25% (6)</td>
<td>22% (6)</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bachelor degree or technical/trade certificate</td>
<td>24% (4)</td>
<td>25% (6)</td>
<td>33% (9)</td>
</tr>
<tr>
<td>Master’s degree</td>
<td>41% (7)</td>
<td>42% (10)</td>
<td>37% (10)</td>
</tr>
<tr>
<td>Doctorate</td>
<td>35% (6)</td>
<td>33% (8)</td>
<td>30% (8)</td>
</tr>
<tr>
<td>Length of time at workplace</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 1 year</td>
<td>53% (9)</td>
<td>42% (10)</td>
<td>48% (13)</td>
</tr>
<tr>
<td>Between 1 and 3 years</td>
<td>29% (5)</td>
<td>29% (7)</td>
<td>26% (7)</td>
</tr>
<tr>
<td>&gt; 3 years</td>
<td>18% (3)</td>
<td>29% (7)</td>
<td>26% (7)</td>
</tr>
<tr>
<td>Employment type</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Faculty</td>
<td>18% (3)</td>
<td>17% (4)</td>
<td>15% (4)</td>
</tr>
<tr>
<td>Staff</td>
<td>18% (3)</td>
<td>29% (7)</td>
<td>37% (10)</td>
</tr>
<tr>
<td>Trainee</td>
<td>65% (11)</td>
<td>54% (13)</td>
<td>48% (13)</td>
</tr>
<tr>
<td>Full time Equivalent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>82% (14)</td>
<td>83% (20)</td>
<td>85% (23)</td>
</tr>
<tr>
<td>0.8</td>
<td>18% (3)</td>
<td>17% (4)</td>
<td>15% (4)</td>
</tr>
</tbody>
</table>

Data are Mean (SD) or % (n)
SD, standard deviation
5.2 Physical Environmental Characteristics of the Buildings

The original building complex (Workplace A) consisted of two connected buildings: the Research Pavilion (Building 1) and the Willow Chest Centre (Building 2). All but one of the participants (n=26) had Workplace A as their main workplace prior to the move to the Robert H. N. Ho Research Centre (Workplace B), this participant was located at a different worksite. Key physical environment characteristics of the two workplaces including the available standing options, the staircases and elevators are described in Table 5.2 and Table 5.3.

Table 5.2 Environmental characteristics of the Workplace A (baseline) and Workplace B (follow-up).

<table>
<thead>
<tr>
<th>Measure</th>
<th>Workplace A Building 1</th>
<th>Workplace A Building 2</th>
<th>Workplace B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing Options</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of height-adjustable workstations</td>
<td>0</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>Number of standing meeting rooms</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Number of eating areas with standing options</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Elevator</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of carts</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Stairs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of staircases</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>CHEW Score</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

CHEW, Checklist of Health Promotion Environments at Worksites  
a Score based on the CHEW

Workplace A had mostly closed office rooms, although several were shared office spaces (≥ 3 people). It did not contain any standing options for workstations or common areas. The layout in Workplace B was an open concept with the majority of cubicle workstations. The new workplace has more available standing options, with 16 offices containing height-adjustable workstations (all single occupancy offices), a multipurpose room with standing height tables, and one meeting room with a standing height table (see Figure 5.2).
Figure 5.2 Standing options in Workplace B: (i) shows the standing height table in the meeting room; (ii) shows the standing height tables in the multipurpose room.

Workplace A had three working passenger elevator carts, while Workplace B has only one elevator. There were also three staircases in the buildings in Workplace A and two in Workplace B (see Figure 5.3). The staircases in Workplace B had a higher CHEW stair score than the previous buildings. Table 5.3 describes the features of the staircases in Workplace A (baseline) and Workplace B (follow-up). The staircases in Workplace A and one of the staircases in Workplace B were traditional U-shaped stair wells (with each landing providing a 180 degree change in direction). Workplace B had one staircase that is an articulated design feature and was visible from outside the stairwell as it was enclosed in glass. This main staircase was L-shaped (with each landing providing a 90 degree change in direction). The L-shaped design allowed for fewer risers between landings (6 compared to 11 to 14 in the other staircases) and two landings between each floor. In both workplaces the main staircase had a larger stair width than the other staircases present. All the staircases were well lit with natural light. With respect to access to the staircases, Workplace A Building 2 had unrestricted access while all the other staircases (from both workplaces)
required keys to access most floors from the staircase. There were only minor maintenance issues present in Workplace A; no issues were present in Workplace B.

Table 5.3 Features of the staircases in Workplace A (baseline) and Workplace B (follow-up).

<table>
<thead>
<tr>
<th>Feature</th>
<th>Workplace A</th>
<th>Workplace B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Building 1</td>
<td>Building 2</td>
</tr>
<tr>
<td>Stair Appeal</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Setting Appeal</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Accessibility</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Legibility</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Maintenance</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Number of risers between landings</td>
<td>14</td>
<td>11</td>
</tr>
<tr>
<td>Stair width, cm</td>
<td>117</td>
<td>97</td>
</tr>
</tbody>
</table>

*a Score of 1 to 3 with higher values representing a better staircase for increased stair use  
*b Score of 0 to 3 with higher values representing a better staircase for increased stair use  
*b Legibility score, 1 for main staircase and 0 for other
Figure 5.3 Staircases in Workplace A and Workplace B: (i) Workplace A Building 1 staircase; (ii) Workplace A Building 2 staircase 1; (iii) Workplace A Building 2 staircase 2; (iv) Workplace B staircase 1; (v) Workplace B staircase 2.
5.3 Activity Monitor Wear Compliance

Adherence to wearing both the activPAL3 and ActiGraph GT3X+ activity monitors are described in Table 5.4. Seventeen participants provided valid activPAL3 data at both baseline and follow-up. Seven participants had technical issues with their baseline data and were excluded from the analysis. One participant at baseline and two participants at follow-up experienced technical issues and data were not recorded. These three participants agreed to wear the monitor again and their data is included in the analysis. In addition, several participants (n=9) reported skin irritation from wearing the activPAL3 monitors. These participants were given alternative attachment and waterproofing methods and instructed to change the adhesive dressing more frequently. The overall observed wear time was similar between the baseline and follow-up assessments for the activPAL3 monitors. Here, the 17 participants wore monitors for a mean of seven days with 934 (44) minutes/ day of monitored awake time at baseline and 923 (54) minutes/ day at follow-up. For workdays, the mean monitored number of workdays was four for both the baseline and follow-up assessments. However, at the follow-up assessments participants reported approximately 40 minutes more monitor wear time at work compared with baseline assessment.

The majority of participants had 100% reported monitor wear compliance during reported time at the workplace, with only one non-compliant day observed at both the baseline assessment (out of 72 workdays) and at the final assessment (out of 73 workdays). For participants with at least one non-workday, they contributed 94 valid days observed at baseline, of which 14 of the days were non-compliant with less than 90% compliance with reported activPAL3 monitors wear during waking time. At the follow-up assessment, 7 out of 95 valid days observed were considered non-compliant.
Participants wore the ActiGraphGT3X+ monitors for a mean of 6.8 (0.7) valid days (≥ 10 hours of wear time per day) at baseline, with a mean wear time of 867 (72) minutes/ day. They were worn for a similar amount of days at follow-up [6.7 (0.6) valid days] with greater mean daily wear time [914 (57) minutes/ day]. One day at baseline and three days at follow-up were excluded.

Table 5.4 Activity monitor compliance at baseline and follow-up (n=17).

<table>
<thead>
<tr>
<th>Measure</th>
<th>activPAL3</th>
<th>ActiGraph GT3X+</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline mean (SD)</td>
<td>Follow-up mean (SD)</td>
</tr>
<tr>
<td>Workday (n=17)</td>
<td>Valid days</td>
<td>N/A</td>
</tr>
<tr>
<td>n</td>
<td>4.2 (1.1)</td>
<td>4.2 (1.0)</td>
</tr>
<tr>
<td>Observed wear time</td>
<td>397 (87)</td>
<td>436 (78)</td>
</tr>
<tr>
<td>Self-reported work time</td>
<td>405 (95)</td>
<td>443 (73)</td>
</tr>
<tr>
<td>Self-reported wear time at work</td>
<td>402 (97)</td>
<td>440 (73)</td>
</tr>
<tr>
<td>Overall (n=14)</td>
<td>Valid days</td>
<td>N/A</td>
</tr>
<tr>
<td>n</td>
<td>7.0 (0.4)</td>
<td>6.7 (0.6)</td>
</tr>
<tr>
<td>Observed wear time</td>
<td>934 (44)</td>
<td>923 (54)</td>
</tr>
<tr>
<td>Self-reported awake time</td>
<td>971 (59)</td>
<td>964 (46)</td>
</tr>
<tr>
<td>Self-reported wear time</td>
<td>951 (60)</td>
<td>923 (54)</td>
</tr>
</tbody>
</table>

SD, standard deviation; N/A, not applicable

5.4 Description of Workplace Sitting, Standing and Stepping at Baseline and Follow-up

A description of mean daily workplace sitting, standing and stepping (standardized for an 8-hour workday) at baseline and follow-up is provided in Table 5.5. The transition to the new workplace reduced workplace sitting time by 24 minutes per 8-hour workday (90%CI = -55 to 9 minutes), with a corresponding increase in workplace standing time (12 minutes/8-hour workday; 90%CI = -42 to 61), these differences were not
statistically significant. Daily workplace stepping time did not change from baseline to follow-up (-1 minutes/8-hour workday; 90%CI = -9 to 11). There was also a small, non-significant increase in sitting time spent in bouts ≥ 30 minutes (16 minutes/8-hour workday; 90%CI = -7 to 44) although there was no change in the number of sitting bouts ≥ 30 minutes (0 bouts; 90%CI = -1 to 1). The number of workplace sit to stand transitions/hour of workplace sitting observed did not change from baseline to follow-up (0 bouts; 90%CI = -1 to 1).

Table 5.5 Daily workplace sitting, standing and stepping at baseline and follow-up (n=17).

<table>
<thead>
<tr>
<th>Measure</th>
<th>Baseline median (IQR)</th>
<th>Follow-up median (IQR)</th>
<th>Change (^{c}) (90% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting time</td>
<td>364 (330 to 384)</td>
<td>339 (300 to 367)</td>
<td>-24 (-55 to 9)</td>
</tr>
<tr>
<td>Standing time</td>
<td>79 (54 to 94)</td>
<td>94 (68 to 147)</td>
<td>12 (-42 to 61)</td>
</tr>
<tr>
<td>Stepping time</td>
<td>47 (26 to 57)</td>
<td>41 (32 to 51)</td>
<td>-1 (-9 to 11)</td>
</tr>
<tr>
<td>Sitting time accumulated in ≥ 30 minute bouts</td>
<td>177 (102 to 247)</td>
<td>185 (142 to 291)</td>
<td>16 (-7 to 44)</td>
</tr>
<tr>
<td>Sit to stand transitions (^{b})</td>
<td>5 (3 to 6)</td>
<td>4 (3 to 6)</td>
<td>0 (1 to 1)</td>
</tr>
<tr>
<td>Sitting bouts ≥ 30 minutes (^{a})</td>
<td>3 (3 to 5)</td>
<td>3 (3 to 4)</td>
<td>0 (-1 to 1)</td>
</tr>
</tbody>
</table>

IQR, interquartile range; CI, confidence interval
\(^{a}\) All outcomes adjusted for 8-hour workday
\(^{b}\) Adjusted per hour of workplace sitting time
\(^{c}\) Hodges-Lehmann point estimate of median change

The variation in these outcomes across days for each individual at baseline and follow-up is shown in Figures 5.4 to 5.6. For workplace sitting, standing and stepping time there was generally more variation for the mean daily values at baseline compared to follow-up (a less than 10% difference in the standard deviation). The number of transitions/workplace sitting hour had a higher variation at baseline compared to follow-up values (approximate 20% difference in the standard deviation). With respect to workplace bouts
of sitting ≥ 30 minutes, both the number of bouts and the total amount accumulated in bouts ≥ 30 minutes had higher individual standard deviations at baseline (over 20% difference in standard deviation).
Figure 5.4 Standard deviation for daily mean minutes of workplace (i) sitting, (ii) standing and (iii) stepping time standardized for an 8-hour workday for individuals at baseline and follow-up (n=17).
Figure 5.5 Standard deviation for daily mean number of sit to stand transitions per hour of workplace sitting time for individuals at baseline and follow-up (n=17).

Figure 5.6 Standard deviation for daily mean (i) number of workplace bouts of sitting ≥ 30 minutes and (ii) workplace time spent sitting ≥ 30 minutes standardized for an 8-hour workday for individuals at baseline and follow-up (n=17).
5.5 Overall Sitting, Standing, Stepping and Physical Activity at Baseline and Follow-up

A description of the total daily sitting, standing, stepping and MVPA time (standardized for a 16-hour day) is provided in Table 5.6. The overall sitting, standing and stepping did not change significantly from baseline to follow-up. They recorded a small increase in sitting time (16 minutes/16-hour day; 90% CI = -31 to 85) and small decreases in standing (-15 minutes/16-hour day; 90% CI = -67 to 32) and stepping time (-7 minutes/16-hour day; 90% CI = -30 to 18). The number of sitting bouts ≥ 30 minutes did not change (0 bouts/16-hour day; 90% CI = 0 to 1), however, there was a small non-statistically significant increase in the amount of time spent sitting in bouts ≥ 30 minutes (16 minutes/16-hour day; 90% CI = -63 to 60).

Furthermore, there was no change in the number of sit to stand transitions per hour of sitting time (0 bouts; 90% CI = -1 to 1).

The amount of MVPA was measured by the ActiGraph GT3X+ activity monitor non-significantly increased from baseline to follow-up. The change from baseline to follow-up for total daily MVPA was 5 minutes/16-hour day (90% CI = -6 to 14) and 1 minute/16-hour day (90% CI = -5 to 5) for MVPA accumulated in bouts ≥ 10 minutes.
Table 5.6 Overall daily sitting, standing, stepping and moderate to vigorous physical activity at baseline and follow-up (n=14).

<table>
<thead>
<tr>
<th>Measure</th>
<th>Baseline median (IQR)</th>
<th>Follow-up median (IQR)</th>
<th>Change $^d$ (90% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting time</td>
<td>555 (497 to 596)</td>
<td>553 (525 to 626)</td>
<td>16 (-31 to 85)</td>
</tr>
<tr>
<td>Standing time</td>
<td>244 (225 to 306)</td>
<td>244 (208 to 296)</td>
<td>-15 (-67 to 32)</td>
</tr>
<tr>
<td>Stepping time</td>
<td>153 (115 to 176)</td>
<td>151 (125 to 167)</td>
<td>-7 (-30 to 18)</td>
</tr>
<tr>
<td>Sitting time accumulated in ≥ 30 minute bouts</td>
<td>271 (239 to 322)</td>
<td>292 (226 to 315)</td>
<td>16 (-36 to 60)</td>
</tr>
<tr>
<td>MVPA $^b$</td>
<td>61 (54 to 67)</td>
<td>67 (51 to 70)</td>
<td>5 (-6 to 14)</td>
</tr>
<tr>
<td>MVPA (bouts ≥ 10 minutes) $^b$</td>
<td>17 (11 to 23)</td>
<td>17 (14 to 22)</td>
<td>1 (-5 to 5)</td>
</tr>
<tr>
<td>Sit to stand transitions $^c$</td>
<td>6 (5 to 8)</td>
<td>6 (4 to 7)</td>
<td>0 (-1 to 1)</td>
</tr>
<tr>
<td>Sitting bouts ≥ 30 minutes</td>
<td>5 (5 to 7)</td>
<td>5 (4 to 6)</td>
<td>0 (0 to 1)</td>
</tr>
</tbody>
</table>

IQR, interquartile range; MVPA, moderate to vigorous physical activity; CI, confidence interval

$^a$ All outcomes adjusted for 16-hour day

$^b$ Assessed by the ActiGraph GT3X+ Accelerometer

$^c$ Adjusted for 1 hour of sitting time

$^d$ Hodges-Lehmann point estimate of median change
5.6 Body Composition

Body composition was determined by BMI and DXA at the baseline and follow-up assessments and is presented in Table 5.7. Participants’ BMI did not change at the follow-up assessment (0 kg/m²; 90% CI = -0.3 to 0.3). There was also no change in body composition as measured by DXA. Percent body fat was similar at baseline and follow-up (0%; 90% CI = -1.0 to 1.1) as was percent lean mass (0%; 90% CI = -1.1 to 1.0).

Table 5.7 Body composition of study participants at baseline and follow-up (n=17).

<table>
<thead>
<tr>
<th>Measure</th>
<th>Baseline Mean (SD)</th>
<th>Follow-up Mean (SD)</th>
<th>Change* (90% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height, cm</td>
<td>167.4 (10.0)</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Weight, kg</td>
<td>65.7 (10.8)</td>
<td>65.6 (10.6)</td>
<td>0 (-0.3 to 0.3)</td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>23.4 (2.9)</td>
<td>23.4 (3.0)</td>
<td>0 (-0.3 to 0.3)</td>
</tr>
<tr>
<td>DXA outcomes (n=14)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat mass, kg</td>
<td>16.2 (4.6)</td>
<td>16.3 (5.4)</td>
<td></td>
</tr>
<tr>
<td>% Fat</td>
<td>27.9 (7.5)</td>
<td>27.9 (8.4)</td>
<td>0 (-1.0 to 1.1)</td>
</tr>
<tr>
<td>Lean mass, kg</td>
<td>43.1 (10.3)</td>
<td>43.1 (10.1)</td>
<td></td>
</tr>
<tr>
<td>% Lean</td>
<td>72.1 (7.5)</td>
<td>72.1 (8.4)</td>
<td>0 (-1.1 to 1.0)</td>
</tr>
</tbody>
</table>

SD, standard deviation; N/A, not applicable; CI, confidence interval; DXA: dual energy X-ray absorptiometry

*Mean change
5.7 Perception of Workplace Sitting

A description of participants’ perceptions of workplace sitting at baseline and follow-up is provided in Table 5.8. Participants reported that they spent less time sitting at the new workplace [83.8% (7.0) vs. 79.4% (13.3)]. They also reported that people at their workplace generally spent less time sitting at follow-up [87.1% (4.7) vs. 82.5% (8.0)]. However, they did not change their opinion on how much time they would like to spend sitting at their workplace. At both time points participants preferred to spend approximately 60% of their workplace time sitting. Their perceptions of their control of workplace standing changed; at baseline most did not think it was up to them whether they sat or stood at work and at the final assessment they neither disagreed nor agreed with this statement. Lastly, at baseline and follow-up participants agreed that if they have to sit a lot at the workplace, they “feel like exercising in my own time”.

Table 5.8 Perceptions of workplace sitting at the baseline and follow-up assessments baseline (n=17).

<table>
<thead>
<tr>
<th>Question</th>
<th>Baseline</th>
<th>Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>While at your workplace, about how much of your time do you think you usually spend sitting? (n=17)</td>
<td>83.8 (7.0)</td>
<td>79.4 (13.3)</td>
</tr>
<tr>
<td>While at your workplace, about how much of your time would you like to spend sitting, if it was up to you? (n=16)</td>
<td>60.9 (13.2)</td>
<td>60.3 (15.4)</td>
</tr>
<tr>
<td>How much time do people in your workplace usually spend sitting? (n=14)</td>
<td>87.1 (4.7)</td>
<td>82.5 (8.0)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Baseline</th>
<th>Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is up to me whether I sit or stand while working. a (n=17)</td>
<td>2 (2 to 3)</td>
<td>3 (2 to 4)</td>
</tr>
<tr>
<td>If I have to sit a lot at my workplace, I feel like exercising in my own time. a (n=17)</td>
<td>4 (4 to 5)</td>
<td>4 (3 to 5)</td>
</tr>
</tbody>
</table>

SD, standard deviation; IQR, interquartile range

a Likert scale where 1 represents strongly disagree and 5 represents strongly agree
5.8 Acceptability of Activity-permissive Workplace

Table 5.9 presents participants’ rated perceived acceptability of their new workplace. Participants generally enjoyed the new workplace [median 5 (IQR = 4 to 5)] and did not want to return to the original workplace [median 1 (IQR = 1 to 2)]. They also agreed that the new workplace had improved their productivity [median 4 (IQR = 3 to 5)]. They were neutral regarding if the workplace had decreased their time sitting at the workplace [median 3 (IQR = 2 to 4)] or outside of the workplace [median 3 (IQR = 2 to 3)] and did not think that their standing while outside the workplace had decreased [median 2 (IQR = 2 to 3)] with the move to the new workplace.

Table 5.9 Acceptability of the workplace at follow-up assessment based on a Likert scale where 1 represents strongly disagree and 5 represents strongly agree (n=17).

<table>
<thead>
<tr>
<th>Question</th>
<th>Follow-up median (IQR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall, I enjoy the new workplace.</td>
<td>5 (4 to 5)</td>
</tr>
<tr>
<td>The move to the new workplace has improved my productivity.</td>
<td>4 (3 to 5)</td>
</tr>
<tr>
<td>I would rather return to my original workplace set-up.</td>
<td>1 (1 to 2)</td>
</tr>
<tr>
<td>The new workplace has decreased the amount of time I sit while at work.</td>
<td>3 (2 to 4)</td>
</tr>
<tr>
<td>My sitting outside of the workplace has decreased.</td>
<td>3 (2 to 3)</td>
</tr>
<tr>
<td>My standing outside of the workplace has decreased.</td>
<td>2 (2 to 3)</td>
</tr>
</tbody>
</table>

IQR, interquartile range
CHAPTER 6: DISCUSSION

In this section, I discuss the findings of the thesis using the following subsections: i) effect of the move to the innovative workplace; ii) specific activity-permissive building characteristics in relation to the study findings; iii) workplace sedentary time in context of the socio-ecological framework; iv) overall sedentary time and body composition; v) methodological limitations; vi) novel aspects and strengths of the study; and vii) future directions.

Despite the known adverse health outcomes associated with increased sedentary time (1, 24, 69), adults continue to spend many waking hours sitting at work (3-5). Importantly, there is a knowledge gap for effective recommendations and strategies to limit sedentary time in the workplace (89). The physical environment, one key factor in the social ecological framework for behaviour change (77), can promote or restrict activity in a workplace (6, 12) and its influence on objectively measured sitting time has not been investigated. Thus, I observed office-based workers as they transitioned from a conventional to an activity-permissive workplace physical environment designed to increase physical activity and reduce prolonged sitting time.

6.1 Effect of the Move to an Activity-permissive Workplace

To my knowledge, this is the first study to investigate the transition to an innovative activity-permissive workplace physical environment on workplace sitting, standing and stepping. There were no statistically significant differences in workplace sitting or how it was accrued before and after the transition to the new workplace. Although not statistically significant, there was a decrease in workplace sitting time of 24 minutes/ 8-hour workday and a corresponding increase in workplace standing time in the innovative building. Workplace sitting time accumulated in prolonged bouts (≥ 30 minutes) non-significantly increased
by 16 minutes/8-hour workday. Therefore, the trend observed was for participants to sit less in the activity-permissive workplace, but accrue more of their sitting time in a prolonged manner.

When sitting time is reduced it must be replaced by either standing or stepping time. In this study, the intervention did not result in a change to workplace stepping time but did result in a non-statistically significant increase in standing time. Therefore, the decrease (albeit non-significant) in workplace sitting time could be partly attributed to use of standing options available in the innovative workplace (height adjustable workstations and standing height tables for eating lunch and for meetings). Nonetheless, there were no changes in the number of sit to stand transitions or the number of prolonged bouts of sitting ≥ 30 minutes observed at baseline and follow-up. That is, in the new activity-permissive building, participants did not interrupt their sitting more often, which has been reported to be important for health independent of the total sedentary time (33, 34, 45).

Despite the absence of statistically significant changes, there were some interesting findings from this exploratory study that help to explain the workplace sitting time observed. First, participants reported a non-statistically significant increase in work time spent in the innovative building (approximately 40 minutes/workday). Although all results were standardized (to an 8-hour workday to compare across assessments and individuals), the increase in work time may be attributable to the design of the new workplace. Feedback regarding the acceptability of the activity-permissive workplace was overwhelmingly positive. Participants enjoyed the new building and this may have led them to choose to work on-site over other available options (home or other workplaces). The positive feelings toward the building also seemed to result in an increase in participants perceived workplace productivity. Second, there was less variation in each individual’s daily workplace sitting, standing and stepping outcomes at the follow-up assessment. This
could speak to the availability of all staff and equipment located within one building. As a result, daily routines may be more set in the innovative workplace and activity patterns may not vary as much based on task performed. Last, although not significant, participants spent more time sitting in prolonged bouts \( \geq 30 \) minutes and this may be influenced by the comfort of the building and may contribute to the reported increased productivity.

No previous studies have investigated a large scale change to the workplace physical environment on workplace sedentary time and only a few studies (92, 94, 96) have intervened in the workplace to reduce sedentary time. Similar to the current intervention, two pilot studies (92, 94) found no statistically significant differences in self-reported workplace sitting with the addition of cycle ergometer workstations (92) or objectively measured workplace sedentary time (Sensewear armband activity monitor) with the availability of shared height-adjustable workstations in an open plan office (94). Further, Kozey-Keadle and colleagues (96) intervened to decrease sedentary time but across all domains (work, leisure and travel) in non-exercising office workers. They provided specific strategies for the workplace but only observed sedentary time on weekdays not specific to work time. They observed a significant reduction in weekday sitting, objectively measured with the activPAL activity monitor, from 70% to 66% which is equal to an approximate 4% change (34 minute decrease over a 16-hour day). This magnitude of change is similar to that observed in this study, however the studies are not directly comparable as Kozey-Keadle and colleagues measured sitting time for the whole day on workdays and this study measured sitting time at the workplace. Although not their primary aim, other workplace intervention studies have measured changes in sedentary time. Most of these studies did not observe statistically significant changes in sedentary time compared to a control group; two did not observe a statistically significant decrease in sedentary time (101, 102), four observed significant decreases in sedentary time but not between groups (97-100), and three observed a significant
decrease in a pre-post workplace intervention (90, 93, 95). With the exception of two studies (93, 95), all
used self-reported measures of sitting with many investigating workday sitting (not time specifically at the
workplace), and none investigated the influence of the workplace physical environment beyond the
workstation. Overall, this area of research is evolving and the current study extends this limited knowledge
base. However, more evidence from studies using objective measures, over long periods and with strong
methodology is necessary.

This study confirms that office-based workers spend the majority of their time sitting while at work and this
time is accumulated in a prolonged manner. Participants spent over 70% of their time in the workplace
sitting (median of 6.1 hours at baseline and 5.7 hours at follow-up per 8-hour workday). Of the remaining
proportion of the workday, approximately 20% was spent standing and 10% stepping. Very few studies
have reported objectively measured sitting time during working hours. Gilson and colleagues observed
office-based employees with Sensewear armband activity monitors and found them to be sedentary 76% of
working hours (94), similar to that reported in this thesis. The ActiGraph accelerometer was used to
objectively characterize sedentary time in Australian office workers (66) and Spanish university workers
(65). The Australian workers recorded similar sedentary time during work hours to that observed in the
current study; 76% for office wokers (66). The sedentary time of the Spanish university workers was less;
63% for administrators and 61% for researches and 23% for cleaning staff. The activPAL3 activity monitor
used in this current study was also used in Scotland to objectively describe the workplace sitting of
university employed office workers (46) and office-based postal workers (64). Ryan and colleagues
reported a similar percent of workday sitting (66%) in university employed office workers to that observed in
this study; although they based workdays on a standard 9:00-17:00 workday not actual reported work times
(46). In comparison, an examination of Scottish office-based postal workers found that they spent 51% of
their workplace time sitting (64). These lower levels of sitting reported may be due to the specific tasks required during office work in a post office.

The pattern of accumulation of sitting time is important for health - independent of total sitting time (33, 34, 45). In this study approximately three hours of sitting or roughly half of total workplace sitting time was accumulated in prolonged periods (≥ 30 minutes), in approximately three events across an 8-hour workday. In Ryan and colleagues study of Scottish university employees (46) they also investigated prolonged workday sitting bouts and found very similar results. Here, they observed a mean of three sitting events greater than 30 minutes per workday and that 52% of sitting during the workday was accumulated in bouts longer than 30 minutes.

6.2 Specific Activity-permissive Building Characteristics

The focus of this study was the workplace physical environment, in particular characteristics that may limit prolonged sitting and increase opportunities for physical activity. As mentioned earlier, the non-statistically significant change in workplace sitting time corresponded with a slight increase in workplace standing time that might be attributable to the use of standing options available in the activity-permissive workplace. However, this change was not substantial or statistically significant and there was no indication that participants interrupted their workplace sitting, as the number of prolonged bouts of sitting and number of sit to stand transitions did not change. The lack of statistically significant results in this study could be related to the characteristics of the original workplace and/or specific individual behaviours of participants within the workplace.
It is possible that the original workplace did not restrict activity. The original workplace in this study (baseline) consisted of retrofitted hospital buildings and although not designed to be activity-permissive, they were not necessarily purpose built for convenience and efficiency as most traditional office spaces are. Another potential reason for the lack of statistically significant change observed may be that the impact of an activity-permissive environment is only evident if utilized. The new workplace physical environment may indeed allow for increased physical activity and provide opportunities to break up prolonged sitting but this may only be evident if workers purposefully attempt to interrupt and decrease their prolonged sitting.

The social ecological framework identifies the important role of the individual and social or organizational factors, in addition to the environment, to determine behaviour (77) and it may be the case that providing the ideal environment is not enough to produce substantial change. Education and behaviour change strategies may be required to realize the benefits of the activity-permissive environment. Further, participants could have chosen to remain sedentary at the workplace and developed strategies to do so. For example, they could choose to email or call a co-worker instead of visiting in-person and send all printing jobs at once in order to only make a single trip to the printer to negate the effect of key destinations being centralized or placed further away. Also, the standing options allowed workers to choose to sit or stand; high tables in the multipurpose room and meeting room were accompanied by high chairs and the height adjustable workstations were electronically adaptable to user specified heights. In this study, I did not directly measure if and how often participants used the innovative features (standing options, stairs, etc.). The staircases in the new workplace were rated higher for items that are suggested to increase their use than the original workplace; therefore participants may have used them more often. Nicoll and colleagues investigated a change to the workplace physical environment by comparing stair use in a high rise office building with elevator access restricted to every third floor, with a conventional office building (116). Their intervention mandated stair use through the restriction of elevator access and they observed
increased stair use with this approach. The current study did not mandate changes upon those who occupied the building but rather provided options that workers could choose to utilize.

6.3 Framing Workplace Sitting Time in the Socio-ecological Theory

The socio-ecological theory, the framework for this investigation, identifies the interaction of the physical environment, individual factors, and social /organizational factors that contribute to behaviour (12, 77). The intervention focused on a change to the workplace physical environment but this does not occur in isolation as there is an interaction between this and individual and social /organizational factors that in turn, influence workplace sitting time (see Figure 2.1).

The study design permitted controlling for many individual factors, however, participants motivation and preferences were not fully considered. The participants were all physically active, accumulating more than 60 minutes of MVPA per 16-hour day. As they were exceeding physical activity guidelines (13) perhaps they may not consider a change to workplace behaviours as a priority. Furthermore, there was no educational/training component to this intervention. Participants were not given any additional information to complement the move to the innovative workplace: they were not told the benefits of reducing prolonged workplace sitting and/or how the new building could help them achieve this. Of note, over the course of the intervention participants’ opinion on how much time they would like to spend sitting at their workplace did not change. In addition, they did not have an opinion on if the new workplace had influenced their workplace sitting time. Bennie and colleagues identified providing information as important, particularly for women, to incorporate short physical activity breaks into the workplace (80). Education may be essential to maximize the potential of the activity-permissive building.
Social/organizational factors contribute to a person’s behaviour in the workplace (78-81). Workplace norms and expectations are important contributors to workplace behaviour. For example, Owen and colleagues provide the example of the social norm of sitting in a meeting (12), and Gilson suggests that prolonged sitting and productivity are often perceived as one and the same even though this may not be the case (82). Although my study did not measure social/organizational factors, a certain level of organizational support can be assumed from the contracting for the design of an activity-permissive building. Previous research with office-based government employees identified the need for cooperation among individuals, managers and organization to effectively introduce strategies to reduce and/or interrupt workplace sedentary time (82). Support from management was also identified as important, particularly for men, to incorporate short activity breaks in order to overcome their perceived lack of time in a survey of Australian workers (80). Similar to lack of time, productivity was identified by focus groups as an important concern in implementing interventions for reducing prolonged workplace sitting (82). It is encouraging that participants perceived that the new innovative activity-permissive workplace increased their productivity.

Another factor influencing workplace sitting is occupational requirements; that is, different tasks necessitate various amounts of sitting and strategies need to be adapted to specific occupational roles (82). While the participants in the study were all office-based workers, it is likely their responsibilities at the workplace varied and could have differed during the baseline and follow-up assessments. Ultimately, reducing sitting is about behaviour change and it is essential to address the several contributors that could impact on the amount of time people spend sitting at work. Future studies require a multifaceted approach to address the complex nature of workplace behaviour and, in particular, to examine if an additive effect can be achieved.
through an activity-permissive physical environment in combination with a targeted behavioural intervention.

6.4 Overall Sitting Time and Body Composition

There were no statistically significant changes in overall sitting or physical activity outcomes (including workplace and non-workplace time) and in body composition before and after the transition. Furthermore, there was a non-statistically significant increase in overall sitting time, for participants who wore the monitor during at least one non-workday. This is an interesting observation, since the non-statistically significant decrease in workplace sitting time was not observed in the overall data. However, fewer participants contributed to the overall data. In the ideal scenario, workplace interventions will be expected to see their effects translate to a person’s overall activity patterns. However, there are many factors that contribute to overall sitting time such as household, travel and leisure activities, which are beyond the scope of this thesis as the intervention focused on the workplace. Working adults spend a substantial amount of their time at work (60), but it is also important to consider the time both in and outside the workplace and how it may even be influenced by workplace time. Sitting time is generally higher on non-workdays (62) and literature suggests that activity patterns outside of the workplace are not influenced by occupational activity (3, 62-64). Initial studies indicate that workers do not compensate for sedentary occupations by engaging in more physical activity or spending less time in sedentary behaviours during their leisure time (3, 62, 63). Tigbe and colleagues investigated the influence of a physically active occupation and reported that postal workers did not accumulate less physical activity or more sitting outside of work compared to their office-based counterparts (64). Interestingly, participants’ overall MVPA increased by five minutes at the follow-up assessment, albeit not statistically significant. Seasonal differences may also contribute to the differences observed between the two assessments, most of the baseline assessments occurred in spring while the
follow-up assessments occurred in late fall. This study did not detect changes in body composition at the follow-up assessment, which is consistent with the others study findings of no statically significant changes in activity patterns. Further investigation is required to determine if the overall trends observed are in part influenced by the workplace intervention. The small sample size of the current study limits the generalizations that can be made and any interpretation of the study results must be treated with caution.

6.5 Methodological Limitations

I note several limitations in this study. First, the study design was a pre-post observational investigation without a control group for comparison. It was not feasible to have a control group as none of the workers remained at the original worksite. However, the natural experiment allowed for the observation of the same participants in different workplace physical environments and reflects real life conditions. Second, the study was exploratory in nature, with a small sample size and a short follow-up period that limits the generalizability of results. Despite the convenience sample, it represents a 34% recruitment rate of all CHHM members who transitioned to the new workplace; it is not known if all CHHM members met the inclusion criteria and were eligible to participate in the study. Follow-up assessments were performed on average four months after the move; and this time frame may have been too short to observe changes in body composition but did allow participants enough time to adjust to their new workplace. A third limitation may be the diverse type of work participants engaged in, as the study included faculty, staff and trainees with varying work schedules and responsibilities. Although all participants were required to be 0.8 FTE to be included in the study, many worked different schedules. For example, some participants had other work spaces available for them or could chose to work from home which resulted in a range of attendance at the workplace from only a few hours at a time to the standard eight hours a day for five days a week. This reflects the real life conditions of the workplace under investigation. There were also a number of technical
issues with the activPAL3 data at baseline (n=7). Data was retrieved from these monitors, however, the available software is currently unable to analyze the files and they were excluded from this analysis. Nonetheless, the ActivPAL3 data that were used were rigorously checked and of high quality.

Another limitation of the study was the possibility that other factors co-existed that may account for the results observed. The intervention observed in this natural experiment was the move to an activity-permissive workplace environment, however, additional workplace characteristics also changed with the move. For example, within the new building the workplace was located on a higher floor than the original workplace. This could have resulted in workers climbing more stairs from the ground level to their workstation. Furthermore, the layout and distribution of workers within the building could have influenced how workers interacted and their movement in the workplace. For example, within the new workplace different social networks may have developed due to the proximity to new co-workers and this could have resulted in a change to activity patterns. In addition, the baseline and follow-up assessments occurred during different seasons and this may have resulted in different weather patterns and academic workloads which could influence the activity patterns of the workers. Despite these known limitations, there are many novel aspects to this study and I highlight them in the next section.

6.6 Novel Aspects and Strengths of the Study

This study is novel as it is the first to describe the effect of the transition to a workplace designed specifically to be activity-permissive on objectively determined workplace sitting time. The design and construction of a new building allowed for the unique opportunity to evaluate large scale changes to the workplace physical environment. Another strength of the study was the within person study design that allowed for the observation of the move to the new building and its effect on individuals, not merely a cross-
sectional comparison of two different workplace physical environments. The study design also permitted
the observation of real workplace conditions.

This work is one of very few studies to measure sitting time objectively in the workplace. The study did not rely on self-reported measures of workplace sitting that are subject to multiple biases and the objective activity monitor used (activPAL3) permitted the postural identification of sitting and upright time and their patterns. In addition, the sitting, standing and stepping outcomes captured from the activPAL3 were specific to workplace time as participants’ self-reported workplace time was incorporated into the analysis of the activPAL3 activity monitor data. This allowed for a more accurate measure of workplace sitting, standing and stepping outcomes.

6.7 Implication of Study Findings

Although statistically significant changes were not evident, there are many interesting findings from this exploratory study, which provide insight and direction for future interventions. The design of buildings and their elements are important for activity within the building (6, 12, 112) and should be considered during the planning of new buildings and renovation of existing buildings. A non-statistically significant decrease to total workplace sitting was observed but there was also a non-statistically significant increase in time spent in prolonged sitting; this highlights the importance of measuring the total time and the pattern in which it is accrued as they are not necessarily dependent and interventions may influence these elements differently. Furthermore, the workplace physical environment itself may not be enough to bring about substantial change. Multifaceted interventions that address individual behaviour in addition to the social/organizational structure of the workplace are needed. These results may also extend to other building designs for different occupational settings, schools, or other public buildings.
6.8 Future Directions

This body of literature on the topic of interventions targeting workplace sitting time reduction is in its infancy and much is unknown, however, the potential for impact is far reaching. The working force represents a large proportion of our population and technological advancements that increase convenience and reduce physical effort in the workplace continue to occur and become increasingly accessible. Further research is needed to determine effective strategies to reduce prolonged sitting time in the workplace and identify barriers and enablers to this process. In particular, multifaceted interventions that address the environment, individual and social/organizational factors are required. Additionally, it is important to gain more in-depth knowledge of the workplace physical environment to determine which features are important to reduce prolonged sitting time and which features employees would embrace. A balance needs to be found between satisfying the work requirements for a productive and efficient environment, and creating one that is conducive to healthy living. A reduction in prolonged workplace sitting could not only impact overall health for individuals but also be cost-effective for employers by influencing health costs, absenteeism, presenteeism and productivity. Finally, the current messaging of “sit less move more”(48) is an appropriate approach to disseminate the current state of knowledge, but the optimal sitting time is not known and further research is required to develop guidelines to follow in general and specifically at the workplace. These guidelines would help shape future workplace interventions and provide a strong impetus for change.
CHAPTER 7: SUMMARY AND CONCLUSIONS

7.1 Summary

The activity-permissive workplace investigated in this thesis represents an innovative approach to workplace health promotion. Participants' workplace sitting, standing and stepping time and sit to stand transitions were objectively measured before and after the transition from a conventional workplace to an activity-permissive workplace. Findings from this study show that there were no statistically significant differences in workplace sitting time before and after the transition. Although the intervention did not show a change in behaviour, this exploratory data provides insight into the workplace sitting of office-based workers and identifies promising strategies to effect change.

7.2 Conclusions

Workplace sitting time is identified as an important contributor to adverse health outcomes. This study is a preliminary investigation of the effect of the physical environment on sedentary time in the workplace. In this study, I observed a non-statistically significant decrease in objectively measured workplace sitting and no difference in the pattern in which workers accrued it. The results of this study suggest that future interventions should aim to include a multifaceted approach to complement physical environment changes in order to reduce sitting time.
REFERENCES


## Appendix 1. Activity Log

<table>
<thead>
<tr>
<th>DAY 1</th>
<th>Date: <strong><strong><strong>/</strong></strong><em>/</em></strong>___</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleep</td>
<td></td>
</tr>
<tr>
<td>What time did you wake up today? _________ am / pm</td>
<td></td>
</tr>
<tr>
<td>What time did you go to sleep today? _________ am / pm</td>
<td></td>
</tr>
<tr>
<td>Work</td>
<td></td>
</tr>
<tr>
<td>Did you go to your workplace today? [ ] No [ ] Yes</td>
<td></td>
</tr>
<tr>
<td>If yes, what time did you start work? _________ am / pm</td>
<td></td>
</tr>
<tr>
<td>What time did you finish work? _________ am / pm</td>
<td></td>
</tr>
<tr>
<td>If you left your workplace for &gt; 45 minutes, please indicate when you left / when you returned &amp; the general reason.</td>
<td></td>
</tr>
<tr>
<td>Time left: _______ am / pm returned: _______ am / pm</td>
<td></td>
</tr>
<tr>
<td>Reason: __________________________________________</td>
<td></td>
</tr>
<tr>
<td>Hip Monitor</td>
<td></td>
</tr>
<tr>
<td>Time Hip Monitor on? _________ am / pm</td>
<td></td>
</tr>
<tr>
<td>Time Hip Monitor off? _________ am / pm</td>
<td></td>
</tr>
<tr>
<td>Did you remove your Hip Monitor today for &gt; 10 minutes? [ ] No [ ] Yes If yes, please note time(s) off/on:</td>
<td></td>
</tr>
<tr>
<td>Time off: _______ am / pm Time on: _______ am / pm</td>
<td></td>
</tr>
<tr>
<td>Time off: _______ am / pm Time on: _______ am / pm</td>
<td></td>
</tr>
<tr>
<td>Thigh Monitor</td>
<td></td>
</tr>
<tr>
<td>Time Thigh Monitor on? _________ am / pm</td>
<td></td>
</tr>
<tr>
<td>Did you remove your Thigh Monitor today for &gt; 10 minutes? [ ] No [ ] Yes If yes, please note time off/on:</td>
<td></td>
</tr>
<tr>
<td>Time off: _______ am / pm Time on: _______ am / pm</td>
<td></td>
</tr>
<tr>
<td>Time off: _______ am / pm Time on: _______ am / pm</td>
<td></td>
</tr>
<tr>
<td>Travel</td>
<td></td>
</tr>
<tr>
<td>Time Start: _______ am / pm Finish: _______ am / pm</td>
<td></td>
</tr>
<tr>
<td>Time Start: _______ am / pm Finish: _______ am / pm</td>
<td></td>
</tr>
<tr>
<td>Time Start: _______ am / pm Finish: _______ am / pm</td>
<td></td>
</tr>
<tr>
<td>Time Start: _______ am / pm Finish: _______ am / pm</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 2. Activity Questionnaire (Workplace sitting perceptions questions)

ACTIVITY QUESTIONNAIRE
(To be administered by Project Staff)

Perceptions of workplace sitting

The next questions relate to your perceptions of sitting at your workplace and are not confined to the last week. Time at the workplace includes meal and snack breaks. For these questions I need you to look at Answer Option 3 on your Answer Card.

<table>
<thead>
<tr>
<th>ST 11.</th>
<th>Question</th>
<th>Answer Card Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>While at your workplace, about how much of your time do you think you usually spend sitting?</td>
<td>_______ %</td>
</tr>
<tr>
<td>b.</td>
<td>While at your workplace, about how much of your time would you like to spend sitting, if it was up to you?</td>
<td>_______ %</td>
</tr>
<tr>
<td>c.</td>
<td>How much time do people in your workplace usually spend sitting?</td>
<td>_______ %</td>
</tr>
</tbody>
</table>

The next questions also relate to your perceptions of sitting at your workplace and are not confined to the last week. I will read out a statement and you tell me whether you agree or disagree for each item. For these questions I need you to look at Answer Option 4 on your Answer Card.

<table>
<thead>
<tr>
<th>ST 12.</th>
<th>Question</th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Neither agree nor disagree</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>It is up to me whether I sit or stand while working.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>b.</td>
<td>If I have to sit a lot at my workplace, I feel like exercising in my own time.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>c.</td>
<td>If I have to be mostly on my feet at my workplace, I do not feel like exercising in my own time.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
Activity Patterns in the Workplace: Answer Options 3

Activity Patterns in the Workplace: Answer Options 4

<table>
<thead>
<tr>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Neither agree or disagree</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
### Appendix 3. Workplace Acceptability Questionnaire

**WORKPLACE ACCEPTABILITY**

**DATE: _____________**

Please rate the various aspects of your workplace by placing a tick in the appropriate box. *Please tick one box for each question*

<table>
<thead>
<tr>
<th></th>
<th>Disagree strongly</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Agree strongly</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WA1.</strong> Overall, I enjoy the new workplace.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>WA2.</strong> The move to the new workplace has improved my productivity.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>WA3.</strong> I would rather return to my original workplace set-up.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>WA4.</strong> The new workplace has decreased the amount of time I sit while at work.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>WA5.</strong> My sitting outside of the workplace has decreased.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>WA6.</strong> My standing outside of the workplace has decreased.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

**WA7.** Are there any other comments you would like to make about the new workplace?

_____________________________________________________________________________

_____________________________________________________________________________

_____________________________________________________________________________

_____________________________________________________________________________

_____________________________________________________________________________

_____________________________________________________________________________
Appendix 4. Stair Measures adapted Checklist of Health Promotion Environments at Worksites (CHEW) (148) and Nicoll’s stair specific measures (117).

**Workplace Environmental Audit**

Worksite: ____________________________________________________________

Building: __________________________________________________________

Floor: ____________________________________________________________

Date: __________________________ Time: _________________ Observer: _________________

*Complete one audit per floor, questions concern the floors the worksite occupies and any common areas.

**STAIR CHECKLIST (tick if yes or present)**

<table>
<thead>
<tr>
<th></th>
<th>Stairwell #1</th>
<th>Stairwell #2</th>
<th>Stairwell #3</th>
<th>Stairwell #4</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA1. Location:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BA2. Appeal of the staircase</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1=Basic, 2=Enhanced,3=Articulated)</td>
<td>1 2 3</td>
<td>1 2 3</td>
<td>1 2 3</td>
<td>1 2 3</td>
</tr>
<tr>
<td>BA3. View from the staircase</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0=No view outside, 1=wall or adjacent building, 2=streetscape,3=people–oriented or landscape)</td>
<td>0 1 2 3</td>
<td>0 1 2 3</td>
<td>0 1 2 3</td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>BA4. Carpeted</td>
<td>YES NO</td>
<td>YES NO</td>
<td>YES NO</td>
<td>YES NO</td>
</tr>
<tr>
<td>BA5. Painted/finished walls / Decorated stairwell (art work, etc.)</td>
<td>YES NO</td>
<td>YES NO</td>
<td>YES NO</td>
<td>YES NO</td>
</tr>
<tr>
<td></td>
<td>Stairwell #1</td>
<td>Stairwell #2</td>
<td>Stairwell #3</td>
<td>Stairwell #4</td>
</tr>
<tr>
<td>---</td>
<td>--------------</td>
<td>--------------</td>
<td>--------------</td>
<td>--------------</td>
</tr>
<tr>
<td><strong>BA6.</strong> Utilities not visible in stairwell (e.g. gas pipes, electric wires)</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td><strong>Comfort</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BA7.</strong> Maximum number of risers between landing on stair flight</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BA8.</strong> Stair width</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Convenience</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BA9.</strong> Accessibility (1=no/limited, 2=selective, 3=unrestricted)</td>
<td>1 2 3</td>
<td>1 2 3</td>
<td>1 2 3</td>
<td>1 2 3</td>
</tr>
<tr>
<td><strong>BA10.</strong> Door is unlocked on most floors</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td><strong>BA11.</strong> Door marked “stairs” (not just exit)</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td><strong>BA12.</strong> No warning or cautions on door</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td><strong>BA13.</strong> Floor number labeled inside of stairway</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td><strong>BA14.</strong> Door is ajar on most or all floors</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td><strong>BA15.</strong> No restricted exit (locked from inside)</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td><strong>Legibility</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BA16.</strong> Able to see the staircase (not enclosed in stair well)</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td><strong>BA17.</strong> Able to see stair access from the entrance</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td><strong>BA18.</strong> Signs encouraging use of stairs</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td><strong>BA19.</strong> Imageability (0= other stair, 1= main stair, for circulation)</td>
<td>0 1 0 1 0 1 0 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Safety</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BA20.</strong> Well light</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td><strong>BA21.</strong> Maintenance (0=nonoperational, 1=in disrepair but still operational,</td>
<td>0 1 2 3 0 1 2 3 0 1 2 3 0 1 2 3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## BA22. List any maintenance issues:

### Stairwell #1 Notes:

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

### Stairwell #2 Notes:

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

### Stairwell #3 Notes:

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

### Stairwell #4 Notes:

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
CHEW stair score = \((BA4 + BA5 + BA6 + BA6 + BA10 + BA11 + BA12 + BA13 + BA14 + BA15 + BA16 + BA17 + BA18) / \) number of staircase in the building