Quitting Sitting

QUITTING SITTING: COMMUNICATING STRATEGIES FOR REDUCING SEDENTARY BEHAVIOUR TO HEALTHY, WORKING ADULTS

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CONTRIBUTIONS

This thesis is comprised of two studies linked by an introduction and a discussion. The co-author of these studies had the following roles: second reader for the systematic review, assisted with study design, and execution as well as manuscript revision. Melissa Peachey was responsible for all elements of these studies including: study design, data collection, analysis, and writing.

ABSTRACT

The purpose of this thesis was to determine the effectiveness of strategies to reduce sedentary behaviour (SB) and to communicate these strategies to healthy adults working in academic occupations using an educational video. Study One was a systematic review and meta-analysis of published literature on strategies to reduce SB in the home and workplace environments for healthy adults. Study Two was a single group pre-post study design to determine the effect of an educational video on viewers' health beliefs related to reducing SB and daily sitting time. The information gained from these studies could be used to inform future interventions to reduce SB in the adult population.

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Janelle Gravesande assisted in the data extraction and quality assessment for the systematic review and meta-analysis.

TABLE OF CONTENTS

Page

CONTRIBUTIONS iii

ABSTRACT iv

ACKNOWLEDGEMENTS v

TABLE OF CONTENTS LIST OF TABLES AND FIGURES vi

CHAPTER 1: INTRODUCTION AND LITERATURE REVIEW 1

Introduction and outline of thesis..1

Literature review..2

Sedentary behaviour..2

Prevalence and burden..2

Terminology..3

Relationship between physical activity and sedentary behaviour..4

Inactivity physiology..5

Measurement..9

Target population..11

Determinants of sedentary behaviour..11

Theoretical framework..12

Sedentary behaviour as a public health problem..13

References..17

CHAPTER 2: SYSTEMATIC REVIEW AND META-ANALYSIS.. 21

Title 21

Abstract 21

Introduction 22

Methods........ 24

Results 27

Discussion 45

References 52

CHAPTER 3: VIDEO-BASED INTERVENTION STUDY 59

Title 59

Abstract 59

Introduction 60

Methods 63

Results 71

Discussion 82

References 91

CHAPTER 4: DISCUSSION AND IMPLICATIONS 121

References 133

LIST OF FIGURES, TABLES AND APPENDICES

Chapter 2........ 21

Table 1 25

Figure 1 29

Table 2 30

Figure 2 37

Table 3 38

Table 4 40

Figure 3 41

Figure 4 43

Table 5 44

Supplemental Table 1 57

Supplemental Figure 1 58

Chapter 3 58

Figure 1 65

Table 1 71

Figure 2 72

Table 2 74

Table 3 74

Table 4 75

Table 5 76

Table 6 76

Table 7 77

Table 8 77

Table 9 80

Table 10 81

Table 11 81

Appendix A 94

Appendix B 95

Appendix C 98

Appendix D 99

Appendix E 108

Appendix F 109

Supplemental File 1 111

Supplemental File 2 117

Chapter 1: Introduction and Literature Review

Outline of thesis

The main objectives of this thesis were to determine the effectiveness of strategies to reduce sedentary behaviour (SB) in the home and workplace environments as well as to determine the effect of an educational video on healthy, adults' health beliefs related to reducing daily sitting time. This thesis is composed of two related studies. Study One was a systematic review and meta-analysis (Chapter 2) and Study Two was a single group pre-post study (Chapter 3). The objective of Study One was to systematically review and synthesize the literature on strategies for reducing SB in the home and workplace environments. The objective of Study Two was to determine whether individuals alter their health beliefs and daily sitting time after watching an educational video on the health effects of SB and strategies to reduce SB. The introduction chapter includes a literature review discussing: SB, inactivity physiology, risk factors and determinants of SB in the adult population, the association between total sitting, prolonged periods of SB, and health outcomes in adults, the relationship between SB and physical activity, measurement techniques for assessing SB, limitations in the current literature for interventions to reduce SB in adults, and the theoretical framework used to guide Study Two. A discussion of the findings of this thesis and the implications for future research is also included (Chapter 4).

Literature Review

Sedentary behaviour

Prevalence and burden

Sitting more and moving less is a major public health problem affecting Canadians. Only 15% of Canadian adults are meeting physical activity guidelines by accumulating 150 minutes of moderate-to-vigorous physical activity per week.[1] However, only 5% are accumulating at least 30 minutes of daily physical activity on at least 5 days a week.[1] Instead, the majority of Canadians are spending 70% of their waking hours in sedentary pursuits.[1] The reason sedentariness is such a concern is that compared with less sedentary adults, those who spend 10 or more hours per day in sedentary pursuits are at a 29% greater risk for premature death.[2] A prospective study that followed 17,013 Canadian adults for 12 years identified a dose-response relationship between sitting time and mortality from all causes independent of age, sex, smoking status, and body-mass index (BMI), and sitting was identified as a distinct health threat.[3] Further, a systematic review of 16 prospective (N=769,210) and 2 cross-sectional (N=69,202) studies, found that greater sedentary time was associated with increased risk for cardiovascular events and type 2 diabetes.[4] There is strong evidence linking sedentary behaviour (SB) with all-cause mortality, cardiovascular disease, type 2 diabetes, and metabolic syndrome.[5] There is also moderate evidence linking SB with ovarian, colon, and endometrial cancers.[5]

The health risks associated with SB have serious economic consequences for our healthcare system. Healthcare expenditures are approximated based on estimates of the number of physically inactive people in Canada, the health care costs for treating chronic diseases associated with physical inactivity, and the proportion of each disease that can be attributed to physical inactivity at the population level.[6] The economic burden of physical inactivity in Canada is estimated to be between 1.4-3.7%[7-10] of total healthcare expenditures, with a total cost near $10 billion.[10] Both direct and indirect costs are factored into these estimates. Direct costs include expenditures that are directly related to treatment (i.e. hospital care, physician care, pharmaceuticals), while indirect costs include the estimated economic output lost due to illness, injury, or premature death.[6]

Terminology

The recent and rapid growth of SB research has spurred the need for clear and consistent terminology to more accurately describe the body positions and energy expenditures associated with SBs. The Terminology Consensus Project from the Sedentary Behaviour Research Network (SBRN) met this need by gathering multi-disciplinary researchers, practitioners, and industries together to determine a common language for describing SB.[11] The consensus project provided standardized terminology for: physical inactivity, stationary behaviour, sedentary behaviour, standing, screen time, non-screen-based sedentary time, sitting, reclining, lying, and sedentary behaviour pattern.[11] The SBRN also outlined how the terms 'breaks', 'bouts', and 'interruptions' should be used to describe SBs.[11] According to the consensus project, physical inactivity refers to "an insufficient physical activity level to meet present physical activity recommendations" while stationary behaviour refers to "any waking behaviour done while lying, reclining, sitting, or standing, with no ambulation, irrespective of energy expenditure".[11] Both of these definitions are distinct from SB which is defined as "any waking behaviour characterized by an energy expenditure of ≤1.5 metabolic equivalents (MET) while in a sitting, reclining, or lying posture".[11] This definition covers two important concepts that distinguish SB from physical inactivity: posture and energy expenditure.[11] According to the consensus, a sedentary bout is considered a period of uninterrupted sedentary time of at least 10 minutes in duration whereas an interruption or break from SB describes a non-sedentary bout between two sedentary bouts.[11] Important to the thesis presented here, is the added clarity of context (posture) and time (intensity) used to more accurately describe SBs as a distinct concept from physical inactivity.

Relationship between physical activity and sedentary behaviour

The reason it is so important to distinguish between SB and physical inactivity is because the health risks associated with being sedentary are mediated by physical activity. A meta-analysis of 14 studies (N=829,917) reported a 30% lower relative risk for all-cause mortality among those with high levels of physical activity and high sedentary time (HR = 1.16; 95%CI: 0.84, 1.59) compared to those with low levels of physical activity and high sedentary time (HR = 1.46; 95%CI: 1.22, 1.75).[12] Another recent meta-analysis of 16 studies, which included more than one million adults, reported that 60-75 minutes of moderate exercise a day eliminated the increased risk of death associated with prolonged sitting time.[13] Among the highest active quartile of individuals (>35 MET-hours/week) there was no increased risk of dying at follow-up between those who sat less than four hours per day and those who sat more than 8 hours a day,[13] indicating that high levels of physical activity effectively erase the association between SB and mortality. The study also reported that the mortality risk (58%) for persons who were least active (approximately ~5 minutes of physical activity/day) and most sedentary (>8 hours/day) was similar to that of smoking[14] and obesity.[15] Several important limitations to this study should be noted. First, most of the studies included in the review were conducted with participants 45 years and older which may prohibit generalizability to younger populations. Second, changes in behaviour could not be accounted for since all studies asked participants to self-report SB and physical activity at one point in time. Last, all studies reported SB as total daily sitting time precluding the review authors from comparing the effect to SB accumulated in prolonged uninterrupted bouts. Interestingly, TV-viewing time (>3 hours per day) was associated with increased mortality rates regardless of physical activity level except in the most active quartile where mortality rates only increased once TV-viewing exceeded 5 hours per day.[13] The authors offer two explanations for this finding. First, the stronger association observed between TV-viewing and mortality risk could be due to potential discrepancies in the accuracy of reporting behaviours.[13] However, the authors also reason that since most people watch TV in the evening after eating a meal and prolonged periods of post-prandial sedentary time have been shown to have a detrimental effect on glucose and lipid metabolism,[13] TV-viewing could represent a particularly hazardous SB. The latter explanation is certainly plausible given the emerging evidence about 'inactivity physiology'.[17]

Inactivity physiology

The term 'inactivity physiology' has been coined to explain the unique physiological changes that occur due to inactivity that are distinct from the changes associated with purposeful exercise.[17] However, in light of the recent terminology consensus, "sedentary physiology" is perhaps a more appropriate term.[18] The underlying mechanism linking SB with negative health consequences is not well understood. It has been suggested that the loss of contractile stimulation induced through sitting leads to the suppression of skeletal lipoprotein lipase (LPL) activity and reduced glucose uptake.[17] Skeletal lipoprotein lipase is necessary for triglyceride uptake and HDL cholesterol production.[17] Eleven days of physical inactivity was found to suppress LPL activity in rats and mice of both sexes and in all three skeletal muscle fibre types (Type I, Type IIa, and Type IIb). Treadmill walking increased LPL activity 8-fold within four hours following the 11-day inactivity period indicating a potential mechanism by which these physiologic changes can be mitigated.[17] In healthy humans, 5 days of complete bed rest resulted in increased total cholesterol, plasma triglycerides, glucose, and insulin resistance despite no change in body weight.[19] Following the 5-day period of bed rest, participants experienced a 67% greater insulin response to a glucose load.[19] The effect of breaking up prolonged sedentary periods on postprandial glucose and serum insulin was demonstrated by a recent crossover study.[20] Relative to 7 hours of uninterrupted sitting, interrupting sitting every 20 minutes with short 2-min bouts of low or moderate physical activity reduced postprandial glucose and insulin by 24% and 30%, respectively.[20]

The 2004 to 2005 Australian Diabetes, Obesity, and Lifestyle Study[21] provides further evidence to support the importance of breaking up prolonged sedentary bouts. Accelerometer-derived sedentary time was negatively associated with cardiovascular risk factors including higher waist circumference, blood glucose, and triglyceride levels.[21] Interestingly, adults who had more frequent breaks in their sedentary time had better cardiometabolic health profiles than those with mostly uninterrupted sitting time.[21] The association between sedentary time and cardiometabolic risk was also observed from data on 4757 participants in the 2003/4 and 2005/6 US National Health and Nutrition Examination Survey (NHANES).[22] Consistent across age, sex, and race/ethnicity groups, an inverse association was observed between frequency of breaks in sedentary time and strength of cardiometabolic risk factors including waist circumference and C-reactive protein.[22] Accelerometer-derived data from 4,935 participants aged 20-79 years in the 2007/09 and 2009/11 Canadian Health Measures Survey indicated breaking up prolonged sedentary time (≥20 minutes) was associated with lower waist circumference, systolic blood pressure, triglyceride, glucose, and insulin levels, along with higher HDL-cholesterol,[23] further reinforcing the importance of breaking up prolonged sedentary time.

Intriguing evidence suggests that standing and fidgeting may eliminate the association between excessive sitting and increased risk of mortality. In the UK Women's Cohort study, 12,778 participants, aged 37-78 years, were followed for a mean period of 12 years for ascertainment of mortality.[24] Within this study, fidgeting was defined as small movements of the hands and feet through nervousness, restlessness, or impatience that could be performed seated or standing.[24] Self-reported daily sitting time and overall fidgeting (irrespective of posture) were collected in addition to relevant correlates that included physical activity, diet, smoking status, and alcohol consumption. Adjusting for covariates, sitting for more than 7 hours per day was associated with a 30% increase in all-cause mortality risk (HR = 1.30, 95%CI: 1.02, 1.66) only among women in the low fidgeting group.[24] There was no increased risk of mortality from prolonged sitting time in the middle and high fidgeting groups.[24] To test the concept of 'dynamic' sitting, one study compared energy expenditure using either a chair or footrest that promoted fidgeting with a standard office chair.[25] According to the study authors, the under-desk elasticated foot rest encouraged leg activity while seated by having the user repeatedly bounce their foot, while the seat tilt of the special office chair encouraged lateral movement while seated by allowing the seat to tilt up to 14 degrees in all directions.[25] Energy expenditure was 20% greater using the either fidget apparatus compared to the standard chair.[25]

Standing, a simple alternative to sitting at work, was examined using data from the 1981 Canadian Fitness Survey that followed 16,586 adults between the ages of 18-90 years over the course of 12 years. A clear dose-response relationship was found between self-reported standing time and all-cause mortality.[26] Survey respondents who reported standing for most of the day had a 33% lower risk of all-cause mortality (HR = 0.67; 95%CI: 0.54, 0.85) compared to those who reported standing almost none of the time.[26] Limitations to this study include the lack of baseline data on existing medical conditions and control for dietary intake and changes in lifestyle factors. A recent cross-sectional study reported a beneficial effect on cardiometabolic risk factors including a 2% lower fasting plasma glucose, 11% triglycerides, and 6 % lower total/HDL cholesterol ratio from replacing 2 hours of daily sitting with standing,[27] although further prospective research to understand the long-term health implications was recommended. According to a recent prospective cohort study of 7320 Canadian adults, too much standing may also be a problem.[28] After adjustment for potential confounders including leisure-time physical activity, smoking status, body mass index, and alcohol consumption, occupations involving predominantly standing were associated with nearly a two-fold increase in risk of heart disease compared to occupations involving predominantly sitting.[28] These results should be interpreted in light of the fact that limited information was reported on the amount of time spent sitting or standing in each occupational group and working conditions were assessed at one point in time precluding the adjustment for changes in occupational status over the 12-year period.[28] The study authors conclude that combinations of standing and sitting are likely to have a beneficial effect on cardiovascular health.[28] As such, interventions to introduce this type of work should be focused not only on occupations requiring mostly sitting but those requiring mostly standing as well.[28]

In summary, there is strong evidence underlining the importance of breaking up prolonged bouts of sedentary time. There is preliminary evidence for a beneficial effect on energy expenditure and longevity from standing and fidgeting at work though the cost and long-term effectiveness of implementing workstations that encourage fidgeting and standing have yet to be explored. Displacing sitting time with prolonged standing may pose a unique health risk and instead transitions between sitting and standing should be encouraged. Although the evidence on strategies to reduce SB within and beyond the workplace has not yet been synthesized, interventions to reduce SB for adults working in sedentary occupations are clearly warranted.

Measurement

SB can be measured as a specific behaviour (ex. TV-viewing time), time occurring within a specific domain (ex. occupational or domestic), or the overall amount of daily sedentary time.[29] Currently there is no gold standard for measuring SB.[29] Generally, there are two approaches to the measurement of SB: direct (objective) and reported (subjective). Objective measures typically include accelerometers and inclinometers while subjective reports can involve questionnaires, short-term recalls, and behavioural logs.[18,29] Accelerometers can be used to identify the amount, intensity, duration, frequency, and patterns of movement[18]. However, a major disadvantage is that accelerometers are unable to capture contextual information such as posture or type of sedentary activity.[18] Some accelerometers such as the ActiGraph (GT3X and GT3X+) include inclinometer functions capable of classifying participants' posture however validity may be influenced by point of attachment.[30]

Direct measures of inactivity are not without bias. Researchers must choose cut-points for classifying intensity levels as well as selecting appropriate activity count cut-points. These values vary considerably between studies.[31] There is evidence to support the use of age-specific cut-points suggesting that shorter epochs (10 seconds versus 1 minute) will derive more accurate estimates of physical activity in older adult populations.[32] Another limitation is that accelerometry is less accurate at lower intensities.[32] This is a particular problem for measuring inactivity in older adults with slower gait speeds.[32]

Self-report tools offer cost-effective, low-burden solutions to capturing important contextual information that objective measures lack.[33] Sedentary time can be assessed by a single item questionnaire or by a composite measure of domain-specific SB.[33] When compared to accelerometer-derived sitting time, a domain-specific questionnaire more accurately assessed average sitting time than a single-item question.[34] Self-report measures, however, frequently demonstrate poor validity[29,33] and are subject to recall bias and influence from cultural norms and social desirability.[33] The sporadic and intermittent nature of SB can make accurate recall difficult. Ecological momentary assessment (EMA), a type of self-report measure, provides a solution to this problem. The purpose of EMA is to have participants report SB as it occurs, as well as measuring location and social context.[33] The main limitation to EMA is the increased likelihood for participants to alter their behaviour in response to the intensity of self-monitoring and the possibility for lower adherence given the increased participant burden.[33] Due to the various limitations of both direct and reported measures of SB, it is recommended that multiple sources of assessment be integrated to provide greater context and depth of information[29] and to assess the validity of the information.

Target population

At particular risk for exposure to SB are persons who work in sedentary occupations. Adults who work in office environments are sedentary for 77% of the workday, with nearly half of that time being accumulated in periods of 20 minutes or more.[35] University employees spend nearly 75% of their workday seated, report infrequent breaks from sitting, and engage in low levels of leisure-time physical activity, and are therefore prime candidates for SB intervention.[36] Results from a recent systematic review of 62 studies suggest lower leisure-time physical activity levels are associated with working more than 45-50 hours per week,[37] a workload typical for academic occupations.[38]

Determinants of sedentary behaviour

Placing SB within a socio-ecological framework helps elucidate the relevant individual, social, and environmental factors that influence an individual's behaviour.[39] Unlike purposeful physical activity, SB is a spontaneous, habitual behaviour reinforced by social norms[40] and influenced by environmental context.[39] Strategies to reduce SB must take into account the unique social and temporal determinants of SB in the home and workplace environments. Within the workplace setting, the most common strategy to reduce SB is the use of activity-permissible workstations including height-adjustable desks, treadmill and cycle desks, and standing desks. Of the 26 studies included in a recent systematic review of workplace SB interventions, 11 studies used an activity-permissible workstation as part of the intervention strategy.[41] The results of the review indicated multi-component interventions (educational or behavioural strategies combined with activity-permissible workstation) resulted in greater reductions in sitting time (-88 minutes/day) compared to environmental interventions that used an activity-permissible workstation only (-72.8 minutes/day). Activity-permissible workstations range in price depending on functionality.

Options include standing desktop converters that raise a computer monitor on an existing desk to a standing height, manual and electric desks that adjust from a seated to a standing position, standing desks, treadmill and cycle ergometer desks. Costs for more basic options begin at $100, with more expensive options costing upwards of $2000.[42] While modifying the work environment appears to be an effective strategy for reducing occupational SB, activity-permissible workstations are context-dependent and do not address SB determinants within the home or leisure-time environments.[39]

Although we are beginning to see consistent evidence for SB intervention success,[41,43-44] the process through which an individual reduces his or her sitting time is not clear. Several behaviour change theories have been applied to the study of SB including the Theory of Planned Behaviour (TPB)[45] and Social Cognitive Theory (SCT).[46] A recent systematic review identified only five studies that examined cognitive and social correlates of SB, which included attitudes, depression, and quality of life.[47] Though the evidence base was limited, results indicated a positive association between sedentary time and positive attitudes related to preference, utility, and enjoyment.[47] Social cognitive constructs have been investigated in two studies[45-46] with encouraging results. In one study, intention was the strongest and most consistent predictor of SB[45] while perceived behavioural control significantly mediated the effects of a 3-month workplace SB intervention.[46] Both studies recommended further research to better understand the social and cognitive influences of SB.

Theoretical framework

The Health Belief Model (HBM) has been used to explain weight loss[48] and physical activity[49] behaviours with some success. The HBM was originally developed to explain why people do not engage in preventive health behaviours.[50] According to the HBM an individual is more likely to make a change when they believe they are susceptible to the disease, the condition has severe consequences, taking action will mitigate their susceptibility or the severity of the condition, and the proposed benefits outweigh the costs of a change in behaviour.[51] An individual is ready to act when they feel confident in their capability and are exposed to factors that prompt action.[51] Since the HBM focuses mainly on health determinants, it is thought to be most suitable for addressing problem behaviours that have negative health consequences (ex. physical inactivity).[51] The main criticisms of the HBM are the low predictive capability of the determinants and the lack of clear rules establishing the relationship between variables.[51] To address these limitations, Orji et al. extended the original model by including four additional determinants of health behaviour (self-identity, consideration of future consequences, concern for appearance, and perceived importance).[51] Orji et al.'s extended HBM improved the predictive capability of the original model by 78% (R^2 increased from 40% to 71%).[51] To our knowledge, no other study has investigated whether HBM constructs explain adult SB.

Sedentary behaviour as a public health problem

Given that prioritization for public health action is largely influenced by the prevalence of a health disorder, the magnitude of risk associated with exposure to that disorder, and evidence for the effective prevention and control of exposure to that disorder, SB is an obvious target for public health efforts.[52] In 2010, Owen et al. proposed an ecological model[53] that showcased the four domains of sedentary behaviour (leisure time, household, occupational, and transport) within which the relevant contextual factors (environmental/social/organizational) may operate to influence particular SBs, and may interact with individual-level attributes (ex. preferences, enjoyment or barriers) and proximal social factors (ex. family demands or workplace relationships).[54] Based on the behavioural epidemiology framework,[55] Owen et al.'s population-health research program identified 5 phases for the SB research agenda:

1. Establishing links between behaviour and health
2. Develop methods for measuring the behaviour
3. Identify factors that influence the behaviour
4. Evaluate interventions to change the behaviour
5. Translate research into practice.

Currently, we have a rapidly strengthening evidence base for Phase 1 and a modest evidence base for Phases 2, 3 and 5. However, there is still a very limited evidence base for Phase 4.[55]

The SB research agenda faces several challenges. First, we lack valid and reliable measures of people's prolonged sitting that are also cost-effective, practical and unobtrusive.[56] In order to apply an ecological model we also need information on the contextual determinants of SB that identify where people are and what they are doing while sedentary. Second, we need to better understand the contextual determinants in domestic, workplace, transportation, and recreational contexts that are amenable to intervention.[56] To date, most of the population surveillance surrounding inactivity is from self-report measures. Most commonly, participants are asked about SB in a singular context: leisure time,[57] which only represents a small proportion of the waking day. Until we know more about the contextual determinants of SB it will be difficult to develop interventions to reduce sitting time. At this point, little is known about the causes of change in SB over time.[58] Few studies have gone beyond influence to examine the relationship between mediators and sedentary behaviour.[58] Mediators such as BMI, socioeconomic status, age, and sex may influence SB differently according to the contextual setting. Understanding how these factors exert their influence within the four domains of SB and interact with individual level factors according to Owen et al.'s ecological model is imperative. Third, the feasibility and efficacy of such interventions need to be tested rigorously for different groups (older versus younger) in different settings (workplace, domestic, transit).[56] There are certain SBs that are expected to occur in particular contexts such as TV-viewing in the domestic environment, screen-based sitting at the workplace, and prolonged sitting during transportation.[54] Within a given context, there are likely specific determinants that influence the nature of the sedentary behaviours occurring. For example, normative pressures will be particularly important to address when designing interventions in an occupational environment versus a domestic one. Understanding the correlates of SB in a given setting will be very important for identifying high-risk sub groups and targeting interventions.[54] Although many influences on SB will remain constant throughout the lifetime, like TV-viewing and screen time in the domestic environment, school and occupational sitting are specific SBs. An individual's motivation, preferences, socioeconomic means, and social circles are all determinants of SB and should be carefully considered when designing a targeted intervention.[54] Finally, although knowledge translation efforts have produced SB guidelines in the United Kingdom[59] and Australia[60] that encourage adults to minimize the amount of time spent being sedentary for extended periods, neither of the guidelines provides specific quantifiable recommendations in terms of how much to reduce sedentary time due to a lack of supporting evidence. Quantified recommendations to limit screen time to 2 hours per day are provided in the recently developed 24-hour movement guideline for children and youth in Canada, however this recommendation is largely based on expert consensus.[61]

In summary, SB is a challenging public health issue that requires careful consideration of the relevant social, behavioural, cultural, and environmental determinants acting at the local, regional, and national levels. This will require collaborative efforts between community planners, researchers, educators, policy makers, health professionals, employers, political leaders, and community advocates.

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Chapter 2: Systematic Review and Meta-analysis

Title: Strategies for Quitting Sitting in the Workplace and at Home

*This study has been submitted to Obesity Reviews

SUMMARY

The aim of this systematic review and meta-analysis was to examine the overall effectiveness of interventions for reducing adult sedentary behaviour and to directly compare different intervention settings (workplace and otherwise) and strategies (environmental, behavioural, and multi-component). Five electronic databases were searched through to July, 2017 to identify all controlled trials of interventions that targeted SB. Thirty-eight trials of 5983 participants published between 2003-2017 were included in the qualitative synthesis; 35 were used in the meta-analysis. The pooled intervention effect for all 35 studies showed a significant reduction in daily sitting time of -30.37min/day (95%CI: -40.86 to -19.89) favouring the intervention group. Reductions in sitting time were similar between workplace (-29.96min/day; 95%CI: -44.05, -15.87) and other settings (-30.47min/day; 95%CI: -44.68, -16.26), which included community, domestic, and recreational environments. Environmental strategies reported the largest reduction in daily sitting time (-40.59min/day; 95%CI: -61.65, -19.53), followed closely by multi-component (-35.53min/day; 95%CI: -57.27, -13.79) and behavioural (-23.87min/day; 95%CI: -37.24, -10.49). There is clear and consistent evidence for interventions targeting adult sedentary behaviour to produce clinically meaningful reductions in sitting time. Further investigation of behaviour change strategies and delivery methods more suitable for non-workplace environments is recommended.

INTRODUCTION

Despite the benefits associated with physical activity 85% of Canadians are not meeting the recommended 150 minutes of moderate to vigorous physical activity each week[1]. Instead, Canadians are spending 10 of their waking hours in a sedentary state[2]. Independent of age, sex, smoking status, alcohol consumption, and leisure-time physical activity levels, greater daily sitting time is associated with increased risk of mortality from all causes[3]. Sedentary behaviour (SB) is defined as any waking activity with an energy expenditure of ≤1.5 metabolic energy equivalents[2]. SBs occur in the workplace, during leisure time and in the domestic environment. SBs are often environmentally determined. For example, TV-viewing in domestic environments, desk and computer-based work in occupational environments, and prolonged sitting while commuting by bus, car, or train[4]. SBs may also be reinforced by built environments[4] and social norms that encourage sitting as the most appropriate behaviour[4]. Sitting during meetings and in classes, for example, is encouraged through the provision of chairs and reinforced when those who choose to stand are questioned by their peers[4]. Furthermore, an individual may be more or less likely to engage in SB based on personal motivation and preference[4]. For working-age adults, occupational sitting is likely the biggest contributor to overall sedentary time, however exposure to SBs in the domestic and leisure-time environments is also pervasive.

The goal of SB interventions can be to reduce either total daily sedentary time, or the number of prolonged sedentary periods. Although greater daily sedentary time is positively associated with all-cause mortality as well as cardiovascular disease, Type 2 diabetes, and cancer incidence[5], breaking up prolonged bouts of sitting has significant, beneficial linear associations with lowered waist circumference, systolic blood pressure, triglycerides, glucose, insulin levels, and higher

HDL cholesterol.[6] Reallocating just 30 minutes of SB to light physical activity leads to a 2-4% improvement in cardiometabolic risk biomarkers (ex. Triglycerides, insulin, Beta-cell function).[7]

SB intervention strategies can be broadly categorized into three types: i) environmental interventions that involve changes to a particular behaviour setting (ex. activity-permissible workstations, TV-limiting devices, screen-based prompts); ii) behavioural interventions that target the individual (ex. mobile apps, activity trackers, educational workshops) and iii) multi-component interventions involving both environmental and behavioural components.

To date, four reviews have evaluated the effectiveness of SB interventions in the workplace,[8-11] two of which focused exclusively on activity-permissible workstations.[10-11] To our knowledge, only two reviews have examined SB interventions that are not limited to the workplace environment;[12-13] one of which concluded that interventions with a specific goal of reducing SB are more effective than those which target both an increase in physical activity as well as a reduction in SB.[12] It is important to note that only 8 of 63 and 3 of 36 of the respective studies included in these two reviews examined interventions specifically targeting SB.

Since SBs are determined by a variety of environmental and individual factors, the primary aim of this review was to address existing gaps in the literature and summarize the evidence regarding the effectiveness of interventions for reducing SB within, and beyond, the workplace. The secondary purpose of this review was to evaluate the comparative effectiveness of environmental, behavioural and multi-component intervention strategies.

METHODS

Study Selection Criteria

Studies were eligible if they met the following criteria:

- Study design: randomized controlled trials including quasi-randomized, cluster-randomized, parallel group, pre-post, factorial, and crossover trials
- Population: healthy working adults, 18-65 years of age
- Intervention: any intervention where the primary aim was to change SB
- Comparison: no restrictions were placed on the comparison group
- Outcomes: SB as measured by self-report (ex. questionnaires, logs) or objective measures (ex. accelerometers)

Studies written in languages other than English were excluded from this review.

Search Strategy and Data Sources

Articles were identified by searches of PSYCHINFO, CINAHL, OVID MEDLINE, SPORT DISCUS, and PUBMED through July 2017. We used the following text-word MeSH terms: sedentary, inactivity, screen time, television, computers, sitting, intervention, occupation, workplace, home, community, mobile, and mhealth. An example of the search strategy using PubMed is illustrated in Table 1. The same strategy was modified for each database's respective indexing system.

Table 1 Details of PubMed search strategy, searched up to July 2017

Search set	PubMed
1	Sedentary
2	Inactivity
3	Screen time
4	Television
5	Computers
6	Sitting
7	Intervention
8	Occupation
9	Workplace
10	Home
11	Community
12	Mobile
13	mhealth
14	1 OR 2 OR 3 OR 4 OR 5 OR 6
15	7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13
16	14 AND 15
17	Limit 16 to Adult AND Clinical Trials

Studies were imported into Mendeley reference management software Version 1.16.3 (Elsevier, New York, New York, USA), and duplicate records were removed. Titles and abstracts of all identified records were screened and relevant full-text articles were retrieved. If the available information suggested a study met the inclusion criteria, the full text copy of the study was retrieved for further assessment. If it was unclear as to whether a study met the eligibility criteria, the full text of the study was retrieved for a more detailed review by two independent reviewers (M.M. and J.G.). Rater differences on inclusion were resolved by consensus. The PRISMA four-phase flow diagram was used to summarize study selection processes[14].

Data Extraction

The same reviewers carried out independent data extraction using a pre-tested data extraction form. Data were extracted related to the study population (age, gender, education, employment status, body composition, and disease risk factors), sedentary behaviour intervention (number, frequency, and duration of sessions, delivery mode, and theoretical framework), comparison intervention(s) (wait list, no intervention, or other), outcomes (any sedentary behaviour measures, ex. total sitting minutes per day or per week, television-viewing time, screen-time etc.), and follow-up time.

Quality Assessment

Two reviewers (MM and JG) independently assessed methodological quality of included studies using the Cochrane Handbook's Risk of Bias approach.[15] The domains of random sequence generation, allocation concealment, blinding of participants and assessors, incomplete outcome data and selective reporting were described in this assessment. Items were rated as 'high' or 'low' risk of bias, whereas 'unclear' was indicated for items lacking information or uncertainty over the potential bias. Observed agreement between reviewers was fair (k=0.51).[16] Disagreement was resolved by consensus and inclusion of an expert third reviewer (JR) when needed.

The quality of evidence for the primary outcome was assessed using recommendations from the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) working group.[17] Risk of bias, indirectness, imprecision, inconsistency and publication bias were considered to determine an overall quality score.

Data Treatment and Statistical Analysis

For all analyses Review Manager (RevMan) 5.2 (The Cochrane Collaboration, 2012, The Nordic Cochrane Centre, Copenhagen, Denmark) was used. Data synthesis was based on recommendations from the Cochrane Handbook for Systematic Reviews of Interventions.[18] Mean differences (MD) based on changes from baseline were assumed to be comparable as the MD for final (post-intervention) measurements and were extracted when possible. For studies that did not report the necessary data to be included in meta-analysis, standard deviations were calculated when possible using standard errors and confidence intervals as per the Cochrane Handbook's recommendation.[19] To avoid a unit-of-analysis error, studies with more than two intervention arms were combined into a single intervention group for pairwise comparison with the control arm using the handbook's formula for combining subgroups.[20] Carryover was a concern in the crossover studies included and so only data from the first intervention period was included in the meta-analysis as per the handbook's recommendations.[20] Randomized, parallel group trials were combined with factorial and crossover designs. Cluster-randomized designs were included in the meta-analysis if it was determined that there was appropriate adjustment for clustering.[20] Quasi-randomized designs were also included in the quantitative analysis.

Total sitting minutes per day was chosen as the standard unit in the main and sub-group analysis as it was the most commonly reported unit of measurement in the included studies. Studies that reported sitting minutes per day were combined with studies that reported sitting as minutes per week, hours per day, hours per week, and sitting time as a fraction of the workday. When possible, outcomes were scaled to minutes per day for inclusion in the meta-analysis. A random effects model was used to provide an estimate of the pooled intervention effect (significant P value <0.05). Heterogeneity was explored using Cochrane's I^2 statistic where a value greater than 50% would suggest significant inconsistency.[21]

RESULTS

Description of Studies

The details of study selection are illustrated in Figure 1. The initial search identified 7548 articles. After de-duplication, 6525 records remained. Titles and abstract screening eliminated

5232 articles that did not meet inclusion criteria, leaving 51 to proceed to full-text review. Of these, 38 met all inclusion criteria and were included in the systematic review. Common reasons for exclusion included: non-working-age population (N=8), no SB outcome (N=3), and wrong study design (qualitative, N=1; and within-subjects design, N=1). Studies included were published over a 14-year period between 2003 and 2017. The included studies were conducted in 15 countries with the majority of studies coming from the USA (N=13) and Australia (N=9). Of the 36 RCTs included in this review, 24 were randomized parallel group controlled trials,[22-45] 7 were cluster-randomized,[46-52] 1 was quasi-randomized,[53] 1 was a 2x2 factorial design,[54] 1 was a pre-post design with no control group,[55] and 4 were crossover trials.[56-59]

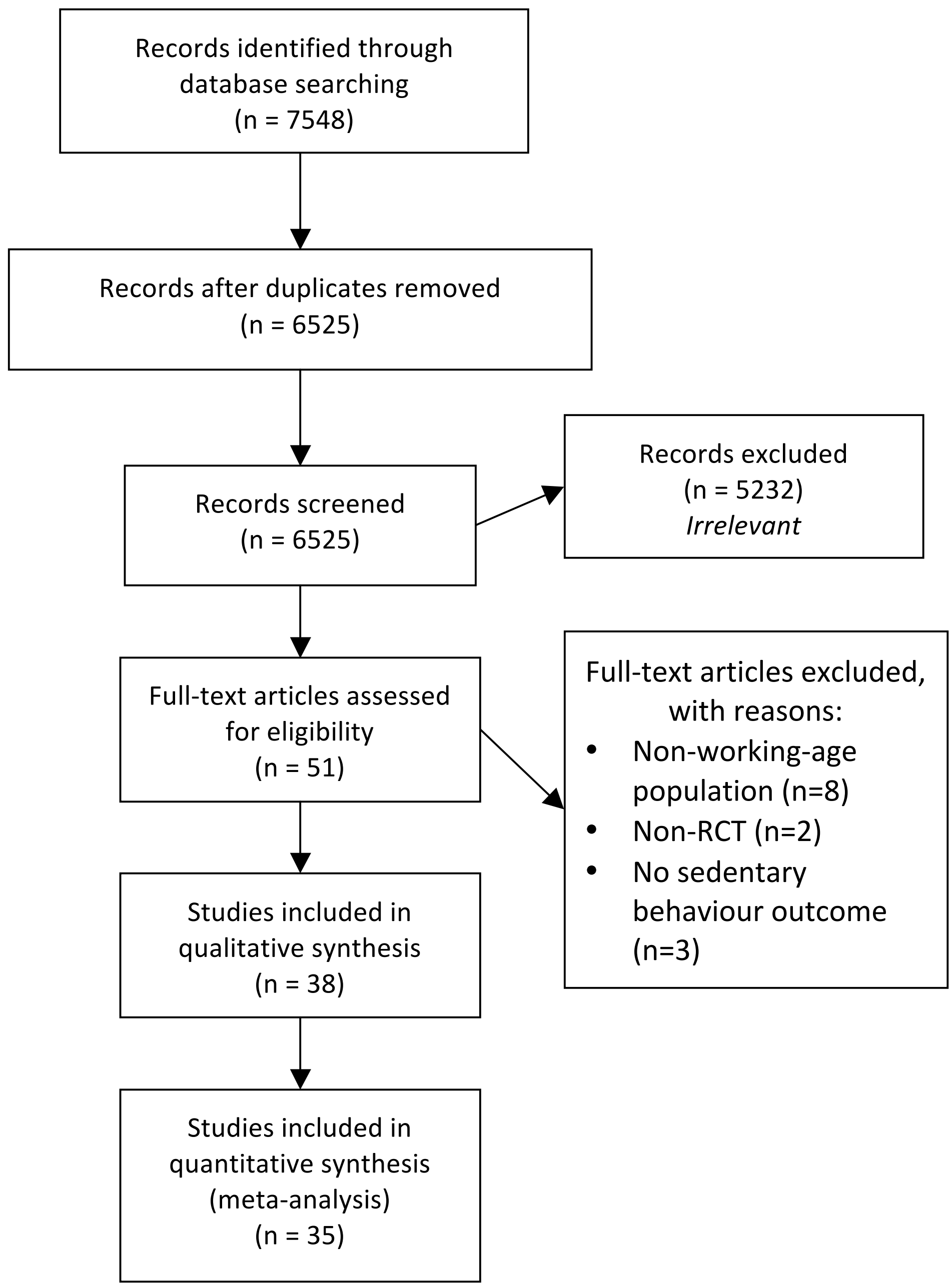


Figure 1 Flow diagram for literature search

In total, data from 5983 participants were included. The sample sizes of the studies ranged from 10[59] to 1480[33] participants. Participants in the studies ranged from 18 to 70 years of age. Nine studies were conducted with overweight or obese adults[23-25,31,34,37-38,43,57] six studies targeted physically inactive but otherwise healthy adults[22-23,36,42,49,57] and four studies included women only.[30,35,48,58] Types of interventions and control conditions are described in Table 2. Twenty-two studies offered an alternative intervention,[24,26,28,30-38,40,42-44,47-48,50,52-53,55] three studies used a waiting-list control,[25,41,56] and control participants from thirteen studies received no intervention at all.[22-23,27,29,39,46,49,51,54,57-59] The intervention period ranged from 1 day to 12 months while follow-up periods ranged from 3 days to 2 years. Drop out rates for the studies ranged from 0% to 53.4%.

Table 2 Intervention Study Characteristics

Study	Design; Country	No. of participants at baseline, age (Mean, SD)	Dropouts N (%)	Intervention Duration	Outcome (unit), measuring tool	Intervention Description
Environmental Interventions						
Carr, 2016	RCT; USA	I: 30, 45.0±10.7 C: 30, 45.2±10.9	6 (10)	16 weeks	Sitting time, percent of occupational time spent sitting (%), GENEActiv (ankle-worn)	I_1: Portable, seated elliptical machine, Ipod Touch with activity tracking app installed, pedaling goal sheet, consultation and three weekly emails for optimizing workstation ergonomics I_2: Ergonomic workstation consultation and three weekly emails only
Chau, 2014	RCT (crossover); Australia	I: 68 C: 68, 38±11	0 (0)	4 weeks	Sitting time, min/8h workday (Mean, SD), activPAL	I: Sit-stand workstation C: No intervention
Donath, 2015	RCT; Switzerland	I: 19, 45±12 C: 19,40±10	7 (18.4)	12 weeks	Sitting time, hours per week (Mean,	I: Daily point of choice prompts and activity-permissible

					SD), ActiGraph wGT3X-BT	workstation C: No intervention
Dutta, 2014	RCT (crossover); USA	I: 17, C: 12, 40.4* average for both groups (no SD)	1(0.03)	4 weeks	Sitting time, minutes per hour (Mean, 95% CI), ActiGraph	I: Height-adjustable working desks (HAWD) with 3 daily screen-based prompts C: HAWD with no prompts
Evans, 2012	RCT; UK	I: 15, 49±8 C: 15, 39±10	2 (6.7)	5 days	Sitting time, hours per 8h workday (Mean, SD), activPAL	I: Education session along with screen-based prompting software C: Education session alone
Graves, 2015	RCT; UK	I: 26, 38.8±9.8, C: 21, 38.4±9.3	3 (6.4)	8 weeks	Sitting time, minutes per 8h workday (Mean, SD), self-reported via ecological momentary assessment diary	I: Sit-to-stand workstation C: No intervention
Li, 2017	RCT; Australia	I: 22, 42±11, C:10, 41±8	1 (0.03)	4 weeks	Sitting time, minutes per 8h workday (Mean, 95%CI), activPAL	I: Activity permissible workstations C: No intervention
Pedersen, 2014	RCT; Australia	I: 17, 41.5±12.4 C: 17, 43.9±9.7	0 (0)	13 weeks	Energy expenditure from sitting, calories per workday (Mean, SD), self-reported via Occupational Physical Activity Questionnaire	I: Screen-based prompts every 45min at work to stand up and engage in short burst of physical activity C: No intervention
Schuna, 2014	RCT; USA	I: 21, 40.0±9.5 C: 20,40.3±10.9	10 (24)	3 months	Sitting time, minutes per hour per workday (Mean, SE), ActiGraph	I: Shared treadmill-desk C: No intervention
Swartz, 2014	RCT; USA	I_1: 38,42.3±11.6 I_2: 40, 46.1±10.5	3 (0.04)	3 days	Sitting time, minutes per day (Mean, SE), activPAL	I_1: Hourly prompts (computer-based and wrist-worn) I_2: Hourly prompts and an additional prompt to walk 100 steps or more upon

						standing
Behavioural Interventions						
Aadahl, 2014	RCT; Denmark	I: 93, 52.2±13.8 C: 73, 51.8±14.3	17 (10.2)	6 months	Sitting time, hours per day (Mean, SD), activPAL	I: Four individual theory-based counseling sessions C: No intervention
Barwais, 2013	RCT; Australia	I: 18, 29.0±4.4 C: 15, 26.4±3.0	0 (0)	4 weeks	Sitting time, hours per day (Mean, SD), self-reported via 7-day Sedentary and Light Intensity Physical Activity Log	I: Online personal activity monitor C: No intervention
Biddle, 2015	RCT; UK	I: 94, 32.4±5.4 C: 93, 33.3±5.8	55 (29.4)	One 3hour session; Follow-up at 3 months	Sitting time, hours per day (Mean, 95% CI), activPAL	I: 3-hour group-based structured education workshop and self-monitoring C: Informational leaflet
Brakenridge, 2016	RCT (cluster); Australia	I:66, 37.6±7.8 C: 87, 40.0±8.0	56 (37)	12 months	Sitting time, minutes per 16h day (Mean, 95% CI), activPAL3	I: Activity tracker plus organizational support from workplace champion C: Organizational support only
Carlson, 2012	RCT; USA	I: 163, 44.3±7.9 C: 189, 42.2±8.7	96 (27.3)	12 months	Sitting time, minutes per day (Median, IQR), Actigraph	I: Interactive web-based program with tailored feedback C: wait-list (women only); general health information website (men only)
Finkelstein, 2015	RCT (crossover); USA	I: 30 C: 30, 52±12	3 (10)	4 weeks	Inactivity time, fraction of day between 8am-midnight (Mean, SD), FitBit accelerometer	I: Inactivity monitoring via mobile application C: No intervention
Joseph, 2015	RCT; USA	I: 14, 35.6±6.2 C: 15, 35.3±3.8	0 (0)	8 weeks	Sitting time, counts per minute (Median, IQR), ActiGraph	I: Culturally-relevant, theory-based, intervention delivered via Facebook and text message C: Non-culturally tailored print-based intervention
Lakerveld, 2013	RCT; Netherlands	I: 314,43.6±5.1 C: 308, 43.4±5.5	132 (21.2)	12 months; Follow-up at 24 months	Sitting time, minutes per day (Mean, SD), self-reported via	I: Counseling intervention aimed at adopting healthy lifestyle behaviors C: Health brochures

					the Activity Questionnaire for Adults & Adolescents	
Lane, 2015	RCT (cluster); Ireland	I: 193, 57.3% were <40 years of age C: 209, 48.3% were <40 years of age	118 (29.4)	9 weeks	Sitting time, minutes per day (Mean, SD), self-reported via IPAQ	I: Mailed a pack with tailored information about local PA options, training plans, stage-matched behaviour change booklets, and a pedometer C: Health promotion leaflets.
Marsaux, 2015	RCT; Europe (Germany, Greece, Ireland, the Netherlands, Poland, Spain, and the United Kingdom)	I_1: 373, 39.7±12.9 I_2: 376, 40.2±12.8 I_3: 371, 40.2±13.1 C: 360, 39.5±3.3	337 (21)	6 months	Sitting time, minutes per week (Mean, SD), TracmorD triaxial accelerometer	I: Website-delivered tailored advice C: Website-delivered generic advice
Marshall, 2003	RCT; Australia	I_1: 328, 43.0±11 I_2: 327,43.0±10	143 (22)	8 weeks; Follow-up at 10 weeks	Sitting time, MET-min/week, (Mean, SE), self-reported via IPAQ	I_1: Interactive stage-targeted intervention delivered via website and email I_2: Stage-targeted print program
Ostbye, 2009	RCT; USA	I: 225, 30.6±5.8 C: 225, 31.2±5.3	29 (6.4)	9 months; Follow-up at 10 months	Television-viewing time, hours per day (Mean, SD), self-reported via 7-day Physical Activity Recall	I: Behavioural intervention including eight healthy-eating classes, ten physical-activity classes, and six telephone-counseling sessions C: Print materials
Pesola, 2014	RCT (cluster); Finland	I: 24, 37.0±5.5 C: 24, 39.0±5.4	7 (14.6)	One 30min session; Follow-up at 2 weeks	Muscle inactivity time, percent (Mean, SD), EMG	I: Lecture and face-to-face counseling to set contractually-binding goals regarding breaking up sitting and increasing family-based physical activity C: No intervention
Priebe, 2015	RCT; Canada	I_1: 35, I_2: 36 I_3: 35 I_4: 36, 40.3±12.02 *average of all groups	46 (32.4)	1 email	Longest period of sitting during workday, minutes (Mean, SD), self-reported via activity	I: Email messages containing descriptive norms about co-workers' behavior

					log	
Puig-Ribera, 2015	RCT (cluster); Spain	I: 129 C: 135, 42±10 *average of groups	74 (28)	19 weeks	Sitting time, minutes per 8h workday (Mean, SD), self-reported via activity log	I: Pedometer + website to encourage displacement of occupational sitting with incidental activity C: No intervention
Slootmaker, 2009	RCT; Netherlands	I: 51, 32.5±3.4 C: 51, 31.2±3.5	22 (22)	12 weeks; Follow-up at 8 months	Sitting time, minutes per week (Median, IQR), self-reported via Activity Questionnaire for Adults & Adolescents	I: Personal activity monitor and web-based tailored advice C: Print materials
Spittaels, 2007	RCT; Belgium	I_1: 173, 43.3±5.7 I_2: 129, 39.6±5.0 C: 132, 40.7±5.3	149 (34.3)	6 months	Weekday sitting time, minutes per day (Mean, SD), self-reported sitting time via IPAQ	I: Website-delivered physical activity intervention with (Group 1) or without (Group 2) repeated feedback C: No intervention
Spring, 2012	RCT; USA	Cohort 1: I_1: 48, 33.4±10.8 I_2: 53, 30.8±10.8 Cohort 2: I_1: 56, 35.0±12.1 I_2: 47, 31.9±9.7	Cohort 1: 1 (1.0) Cohort 2: 3 (2.9)	4 weeks; Follow-up at 20 weeks	Sitting time, minutes per day (Mean, SD), self-reported via activity log	I: Four different combinations of diet and activity advice including 3 weeks of remote coaching supported by mobile decision support technology and financial incentives targeting.
Sternfeld, 2009	RCT (cluster); USA	I: 351, 44.8±10 C: 436, 43.5±11	787 (30)	4 months; Follow-up at 16 weeks	Sitting time, minutes per week (Median, IQR), self-reported via Physical Activity Questionnaire	I: Email program offered individually tailored, small-step goals; a personal homepage with tips; educational materials; and tracking and simulation tools C: No intervention
Verweij, 2012	RCT; Netherlands	I 274, 46.0±8.0 C: 249, 48.0±9.0	53 (10.1)	6 months	Sitting time, minutes per workday (Mean, SD), self-reported via International Physical Activity	I: Occupational health guideline and face-to-face behavioural change counseling sessions C: Usual care

					Questionnaire	
Multi-component Interventions						
Coffeng, 2014	RCT; Netherlands	I_1: 92, 38.0±10.5 I_2: 118, 43.6±10.3 I_3: 96, 42.2±10.5 C: 106, 40.7±9.2	83 (20)	3 months; Follow-up at 12 months	Sitting time, minutes per day (Mean, SD), self-reported via questionnaire	I_1: Combined social and physical intervention I_2: Social intervention (group motivational interviewing, social media) I_3: Physical intervention (shared standing desk, relaxing wall posters, exercise balls and curtains between offices) C: No intervention
French, 2011	RCT (cluster); USA	I: 45 C: 45, 45* average age of both groups	3 (0.03)	12 months	Television-viewing time, hours per day (Mean), self-reported via questionnaire	I: Face to face group sessions, placement of a TV-locking device on all home televisions, and home-based intervention activities C: No intervention
Healy, 2016	RCT (cluster); Australia	I: 136, 44.6±9.1 C: 95, 47.0±9.7	70 (30)	12 months	Sitting time, minutes per 8h workday (Mean change from baseline, 95% CI), activPAL	I: Workplace-delivered intervention addressing organizational, physical environment, and individual behavioral changes to reduce sitting time C: Usual practice
Judice, 2015	RCT (crossover); Portugal	I: 10 C: 10, 50.4±11.5	0 (0)	1 week	Siting time, hours per day (Mean, SD), activPAL	I: Hourly screen-based prompts (at work) and strategies for: reducing sitting, meeting steps goal, and self-monitoring behaviour delivered daily via text-messages (outside of work) C: No intervention
Kerr, 2016	RCT; USA	I_1: 15, 61.6±6.0 I_2: 15, 60±6.0	0 (0)	14 days	Sitting time, minutes per day (Mean, SD), activPAL3	I_1: Three in-person health educator sessions targeting a 2-hour reduction in daily sitting I_2: Standing desks and three in-person health educator

						sessions focusing on accumulating 30 additional brief sit-to-stand transitions per day
Neuhaus, 2014	RCT (quasi); Australia	I_1: 16, 37.3±10.7 I_2: 14, 43.0±10.2 C: 14, 48.0±11.6	4 (9)	3 months	Sitting time, minutes per 8h workday (Mean, SD), activPAL3	I_1: Multi-component intervention (height-adjustable workstations, education, and individual counseling) I_2: height-adjustable workstations-only C: Usual practice
Parry, 2013	RCT; Australia	I_1: 49 I_2: 30 C: 54, 41.4±10.9 *avg across groups	71 (53.4)	12 weeks	Sitting time, minutes per 8h workday (Mean, SD), ActiGraph GT3X+	I_1: 'Active Office Work' (single height-adjustable desk with integrated treadmill or treadmill plus stationary cycle ergometer) I_2: Pedometer challenge to promote physical activity during workday C: 'Office ergonomics', focused on 'active' sitting (moving whilst in the chair) and breaking up computer tasks
Raynor, 2013	RCT; USA	Cohort 1: I_1: 12, 51.7±10.0 I_2: 12, 53.3±8.0 Cohort 2: I_1: 14, 53.3±9.1 I_2: 14,54.9±7.4	Cohort 1: 5 (21) Cohort 2: 7 (25)	8 weeks	Television-viewing, hours per day (Mean, SD), TV allowance devices	Cohort 1: I: 8, 60min group meetings (standard obesity intervention) covering behavioural and cognitive skills to help with changing dietary and TV behaviours I_2: Same as Group 1 but targeting dietary and physical activity behaviours Cohort 2: I_1: Standard obesity intervention plus exercise prescription, pedometer and activity log I_2: Same as Group 1 plus TV-limiting device

Half of the studies (N=19) assessed SB using objective measures while the other half relied on self-report. The primary outcomes reported were: overall daily sitting time in minutes or hours per day (N=18) or per week (N=6), sitting minutes per 8 hour work day (N=6), percentage of assessed time period (N=5), TV-viewing hours per day (N=2), and energy expenditure from sitting (N=1).

Individual Study Quality and Risk of Bias Assessment

A summary of the risk of bias assessment across studies is shown in Figure 2. The individual risk of bias assessment for each study is shown in Table 3. The risk of bias was high in 18 studies, unclear in 13, and low in only 4 studies. The largest risk of bias came from performance bias (inadequate blinding of participants or assessors) and selection bias (issues with allocation concealment). The risk of bias between studies was also determined to be high, primarily due to the risk of bias within studies being rated as high or unclear in most.[15] The GRADE quality of evidence rating[17] for each intervention type is shown in Table 4. Due to the high risk of performance and selection bias within environmental intervention studies, the evidence was considered to be of moderate quality. The evidence for behavioural and multi-component interventions was considered low primarily due to the inclusion of quasi- and cluster-randomized study designs.

Figure 2. Risk of bias item presented as percentages across studies

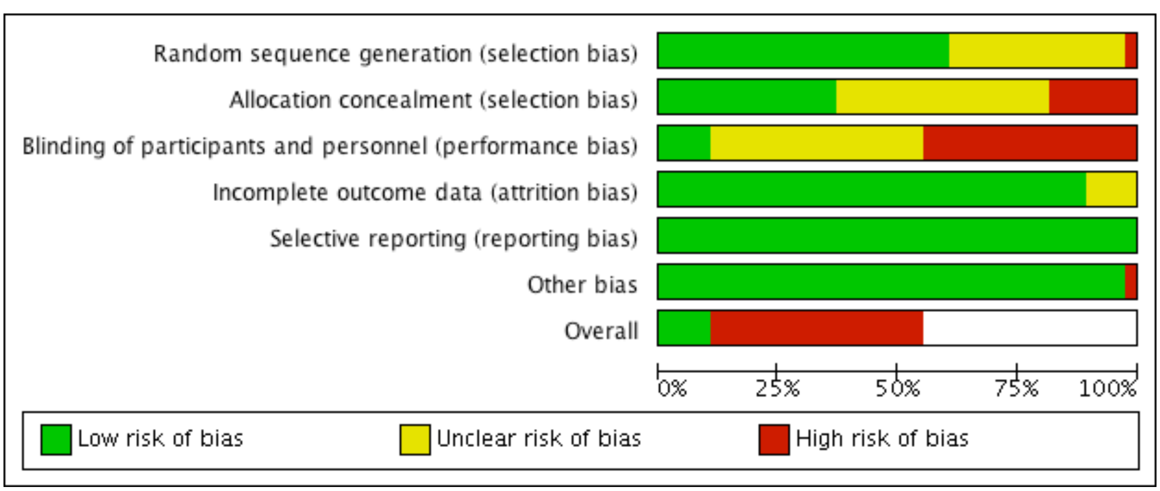


Table 3: Individual risk of bias assessment

	Study	1	2	3	4	5	6	Evaluation
		Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias	Overall
1	Aadbal, 2014	Low	Low	High	Low	Low	Low	High
2	Barwais, 2013	Low	Unclear	Unclear	Unclear	Low	Low	Unclear
3	Biddle, 2015	Low	Low	High	Low	Low	Low	High
4	Brakenridge, 2016	Low	Low	High	Low	Low	Low	High
5	Carlson, 2012	Unclear	Unclear	Unclear	Unclear	Low	High	High
6	Carr, 2016	Low	Low	Low	Low	Low	Low	Low
7	Chau, 2014	Low	High	High	Low	Low	Low	High
8	Coffeng, 2014	Unclear	Unclear	High	Low	Low	Low	High
9	Donath, 2015	Unclear	Unclear	High	Low	Low	Low	High
10	Dutta, 2014	Low	High	High	Low	Low	Low	High
11	Evans, 2012	Low	Low	High	Low	Low	Low	High
12	Finkelstein, 2015	Unclear	Unclear	Unclear	Unclear	Low	Low	Unclear
13	French, 2011	Unclear	Unclear	High	Low	Low	Low	High
14	Graves, 2015	Low	High	High	Low	Low	Low	High
15	Healy, 2016	Low	High	High	Low	Low	Low	High
16	Joseph, 2015	Low	Unclear	Unclear	Low	Low	Low	Unclear
17	Judice, 2015	Low	Low	High	Low	Low	Low	High
18	Kerr, 2016	Low	Low	Low	Low	Low	Low	Low
19	Lakerveld, 2013	Low	Low	High	Low	Low	Low	High
20	Lane, 2015	Unclear	Unclear	Unclear	Unclear	Low	Low	Unclear
21	Li, 2017	Low	Low	High	Low	Low	Low	High
22	Marsaux, 2015	Low	Low	Unclear	Low	Low	Low	Unclear

23	Marshall, 2003	Low	Low	Unclear	Low	Low	Low	Unclear
24	Nehaus, 2014	High	High	High	Low	Low	Low	High
25	Osthye, 2009	Unclear	Unclear	Unclear	Low	Low	Low	Unclear
26	Parry, 2013	Low	Low	Low	Low	Low	Low	Low
27	Pedersen, 2014	Unclear	Unclear	Unclear	Low	Low	Low	Unclear
28	Pesola, 2014	Unclear	Unclear	Unclear	Low	Low	Low	Unclear
29	Priebe, 2015	Low	Unclear	Unclear	Low	Low	Low	Unclear
30	Puig-Ribera, 2015	Unclear	Unclear	Unclear	Low	Low	Low	Unclear
31	Raynor, 2013	Low	High	High	Low	Low	Low	High
32	Schuna, 2014	Unclear	Unclear	Unclear	Low	Low	Low	Unclear
33	Slootmaker, 2009	Unclear	Low	Unclear	Low	Low	Low	Unclear
34	Spittaels, 2007	Unclear	Unclear	Unclear	Low	Low	Low	Unclear
35	Spring, 2012	Low	Unclear	Unclear	Low	Low	Low	Unclear
36	Sternfeld, 2009	Unclear	Unclear	Unclear	Low	Low	Low	Unclear
37	Swartz, 2014	Low	Low	Low	Low	Low	Low	Low
38	Verweij, 2012	Low	High	High	Low	Low	Low	High

Table 4 GRADE assessment of quality of evidence

Interventions for reducing sedentary behaviour			
Outcomes	Illustrative comparative risks* (95% CI) Corresponding risk Interventions to reduce SB	No of Participants (studies)	Quality of the evidence (GRADE)
Behavioural interventions - sitting time (minutes per day), follow-up: 0-24 months	Mean effect in the intervention group was 23.87min/day lower (37.24 to 10.49 lower)	4919 (17)	⊕⊕⊝⊝ **low†¶**
Environmental interventions - sitting time (minutes per day), follow-up: 0-4 months	Mean effect in the intervention group was 40.59min/day lower (61.65 to 19.53 lower)	455 (10)	⊕⊕⊕⊝ **moderate†**
Multi-component interventions -sitting time (minutes per day), follow-up: 0-12 months	Mean effect in the intervention group was 35.53min/day lower (57.27 to 13.79)	609 (8)	⊕⊕⊝⊝ **low†‡¶**

*The basis for the assumed risk (e.g. the median control group risk across studies) is provided in footnotes. The corresponding risk (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).
CI: Confidence interval; GRADE, Grading of Recommendations Assessment, Development and Evaluation; SB, sedentary behaviour
†The majority of studies were of high risk of selection, performance or detection bias.
‡Because of the nature of the quasi-experimental designs risk of bias is unavoidable.
¶Significant heterogeneity between study results.
GRADE Working Group grades of evidence
High quality: Further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: We are very uncertain about the estimate.

Results of Individual Studies

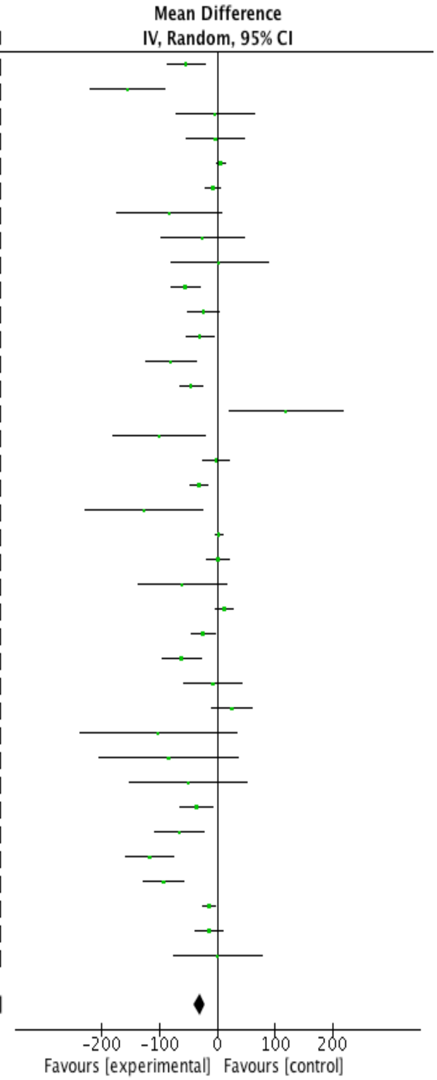
Summary data of each intervention group, including effect estimates and confidence intervals, are shown in Figure 3.

Figure 3 Forest plot of mean differences of sitting time (min/day) from SB interventions; SD, standard deviation; CI, confidence interval; IV, inverse variance

	Experimental			Control				Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Aadhal, 2014	540	102	93	594	108	73	3.2%	-54.00 [-86.30, -21.70]
Barwais, 2013	516	102	18	672	90	15	1.7%	-156.00 [-221.53, -90.47]
Biddle, 2015	-17.4	167.4	38	-13.8	154.8	49	1.6%	-3.60 [-72.24, 65.04]
Brakenridge, 2016	-35	127	66	-32.1	190.8	87	2.2%	-2.90 [-53.36, 47.56]
Carlson, 2012	525.75	37.12	163	519.85	34.93	189	4.6%	5.90 [-1.67, 13.47]
Carr, 2016	407.04	28.32	27	414.72	22.08	27	4.3%	-7.68 [-21.23, 5.87]
Chau, 2014	-73	198.03	36	10	198.03	36	1.0%	-83.00 [-174.48, 8.48]
Coffeng, 2014	378.6	221.8	63	403.8	245.2	96	1.4%	-25.20 [-98.72, 48.32]
Donath, 2015	333.6	128.4	15	330	110.4	16	1.2%	3.60 [-80.95, 88.15]
Dutta, 2014	532.8	54.96	36	588	54.96	36	3.7%	-55.20 [-80.59, -29.81]
Evans, 2012	-18	54	14	6	0.9	14	3.5%	-24.00 [-52.29, 4.29]
French, 2011	90.6	55.8	43	120.6	55.8	44	3.8%	-30.00 [-53.45, -6.55]
Graves, 2015	322	99.3	26	402.2	47.9	21	2.6%	-80.20 [-123.52, -36.88]
Healy, 2016	-58.3	72.98	96	-13	50.74	65	4.1%	-45.30 [-64.41, -26.19]
Judice, 2015	649.2	90.6	10	529.3	131.4	10	0.9%	119.90 [20.98, 218.82]
Kerr, 2016	465.8	103.9	15	567.1	118.5	15	1.3%	-101.30 [-181.05, -21.55]
Lakerveld, 2013	231.5	122.2	242	233	140.7	248	3.8%	-1.50 [-24.82, 21.82]
Lane, 2015	-32.9	74.73	125	-1.2	45.68	159	4.3%	-31.70 [-46.60, -16.80]
Li, 2017	-113	132.3	17	14	122.1	9	0.9%	-127.00 [-228.58, -25.42]
Marsaux, 2015	743.14	35.29	379	740.29	35.71	136	4.6%	2.85 [-4.12, 9.82]
Marshall, 2003	308.3	123.9	327	307.1	126.7	328	4.1%	1.20 [-17.99, 20.39]
Nehaus, 2014	-72.16	127.89	25	-11	107.5	13	1.3%	-61.16 [-138.15, 15.83]
Ostbye, 2009	148.8	82.8	214	136.8	81	207	4.2%	12.00 [-3.65, 27.65]
Parry, 2013	-21.6	46.56	33	3.36	38.4	29	3.9%	-24.96 [-46.12, -3.80]
Pedersen, 2014	295	55	17	357	46	17	3.1%	-62.00 [-96.08, -27.92]
Priebe, 2015	123.7	90.62	23	131.14	89.61	27	2.3%	-7.44 [-57.58, 42.70]
Puig-Ribera, 2015	414.2	129	88	388.9	120	102	3.0%	25.30 [-10.32, 60.92]
Raynor, 2013	108	126	14	210	228	14	0.5%	-102.00 [-238.46, 34.46]
Raynor, 2013	168	168	12	252	132	12	0.6%	-84.00 [-204.88, 36.88]
Schuna, 2014	-26.4	147.6	15	24	144.24	16	0.9%	-50.40 [-153.23, 52.43]
Slootmaker, 2009	443.36	76.21	38	479.39	51.84	42	3.5%	-36.03 [-64.89, -7.17]
Spittaels, 2007	323.3	212.02	302	389	209	132	2.6%	-65.70 [-108.63, -22.77]
Spring, 2012	89.3	65.5	56	206.2	135.2	48	2.7%	-116.90 [-158.82, -74.98]
Spring, 2012	89.5	75.2	53	182.3	100.4	47	3.1%	-92.80 [-127.92, -57.68]
Sternfeld, 2009	-18.95	55.31	129	-5.25	57.99	317	4.4%	-13.70 [-25.18, -2.22]
Swartz, 2014	-25	51.7	29	-10.9	43.4	31	3.7%	-14.10 [-38.34, 10.14]
Verweij, 2012	819	378	181	818	361	178	1.3%	1.00 [-75.45, 77.45]
Total (95% CI)			**3078**			**2905**	**100.0%**	**-30.37 [-40.86, -19.89]**

Heterogeneity: $Tau^2 = 610.51$; $Chi^2 = 209.03$, $df = 36$ ($P < 0.00001$); $I^2 = 83\%$

Test for overall effect: $Z = 5.68$ ($P < 0.00001$)



Synthesis and Analysis of Results

Of the 38 studies included in the review, 29 reported a significant reduction in daily sitting time.[23,25,28-31,34,36-39,41-50,53, 54-59] Of these, 13 employed a behavioural intervention,[23,25,30,34,41,42,44,48-50,55,58] 8 were environmental,[28-29,37,39,44,56-57] and 8 were multi-component interventions.[31,36,38,46-47,53,54,59] One study showed a significant reduction in SB as assessed by self-report but the result was not verified by objective measures.[22] Two studies trended toward significance[26,35] and 6 studies showed no effect.[24, 27, 32-33, 40, 51]

As seen in Figure 3, a total of 35 studies were included in the meta-analysis. Results indicated a significant reduction in sitting time of -30.37min/day (95%CI: -40.86, -19.89) favouring the intervention group. The leave-one-out sensitivity analysis showed that the pooled estimate (range: -27.64 to -32.23) and confidence intervals did not significantly differ when one study was omitted at a time (see online supplementary table 1). Removing the largest study[34] did not change the point estimate considerably (-31.84 min/day, 95%CI: -42.69, - 20.99).

Figure 4 shows intervention effect estimates for individual studies and pooled results by intervention type. All 10 studies (N=455) of environmental interventions were included in the subgroup analysis. Pooled results indicate a reduction in sitting time of -40.59min/day (95%CI -61.65, -19.53, p=0.0002, I^2=69%). Of the 20 behavioural intervention studies (N=5026) included in the review, 17 were included in the subgroup analysis.[22-25,32-35,40-42,44,48,50-52] Pooled results indicate a reduction in sitting time of -23.87min/day (95%CI -37.24, -10.49, p=0.0005, I^2=87%). All 8 studies of multi-component interventions (N=609) were included in the subgroup analysis. Pooled intervention results indicate a reduction in sitting time of -35.53min/day (95%CI -57.27, -13.79, p=0.001, I^2=51%).

Figure 4 Forest plot of the intervention effect for reducing sitting time in min/day by type of intervention

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
1.2.1 Behavioural Interventions								
Aadhal, 2014	540	102	93	594	108	73	3.2%	-54.00 [-86.30, -21.70]
Barwais, 2013	516	102	18	672	90	15	1.7%	-156.00 [-221.53, -90.47]
Biddle, 2015	-17.4	167.4	38	-13.8	154.8	49	1.6%	-3.60 [-72.24, 65.04]
Brakenridge, 2016	-35	127	66	-32.1	190.8	87	2.2%	-2.90 [-53.36, 47.56]
Carlson, 2012	525.75	37.12	163	519.85	34.93	189	4.6%	5.90 [-1.67, 13.47]
Lakerveld, 2013	231.5	122.2	242	233	140.7	248	3.8%	-1.50 [-24.82, 21.82]
Lane, 2015	-32.9	74.73	125	-1.2	45.68	159	4.3%	-31.70 [-46.60, -16.80]
Marsaux, 2015	743.14	35.29	379	740.29	35.71	136	4.6%	2.85 [-4.12, 9.82]
Marshall, 2003	308.3	123.9	327	307.1	126.7	328	4.1%	1.20 [-17.99, 20.39]
Ostbye, 2009	148.8	82.8	214	136.8	81	207	4.2%	12.00 [-3.65, 27.65]
Priebe, 2015	123.7	90.62	23	131.14	89.61	27	2.3%	-7.44 [-57.58, 42.70]
Puig-Ribera, 2015	414.2	129	88	388.9	120	102	3.0%	25.30 [-10.32, 60.92]
Slootmaker, 2009	443.36	76.21	38	479.39	51.84	42	3.5%	-36.03 [-64.89, -7.17]
Spittaels, 2007	323.3	212.02	302	389	209	132	2.6%	-65.70 [-108.63, -22.77]
Spring, 2012	89.5	75.2	53	182.3	100.4	47	3.1%	-92.80 [-127.92, -57.68]
Spring, 2012	89.3	65.5	56	206.2	135.2	48	2.7%	-116.90 [-158.82, -74.98]
Sternfeld, 2009	-18.95	55.31	129	-5.25	57.99	317	4.4%	-13.70 [-25.18, -2.22]
Verweij, 2012	819	378	181	818	361	178	1.3%	1.00 [-75.45, 77.45]
Subtotal (95% CI)			**2535**			**2384**	**57.2%**	**-23.87 [-37.24, -10.49]**
Heterogeneity: Tau² = 553.90; Chi² = 127.95, df = 17 (P < 0.00001); I² = 87%								
Test for overall effect: Z = 3.50 (P = 0.0005)								
1.2.3 Environmental Interventions								
Carr, 2016	407.04	28.32	27	414.72	22.08	27	4.3%	-7.68 [-21.23, 5.87]
Chau, 2014	-73	198.03	36	10	198.03	36	1.0%	-83.00 [-174.48, 8.48]
Donath, 2015	333.6	128.4	15	330	110.4	16	1.2%	3.60 [-80.95, 88.15]
Dutta, 2014	532.8	54.96	36	588	54.96	36	3.7%	-55.20 [-80.59, -29.81]
Evans, 2012	-18	54	14	6	0.9	14	3.5%	-24.00 [-52.29, 4.29]
Graves, 2015	322	99.3	26	402.2	47.9	21	2.6%	-80.20 [-123.52, -36.88]
Li, 2017	-113	132.3	17	14	122.1	9	0.9%	-127.00 [-228.58, -25.42]
Pedersen, 2014	295	55	17	357	46	17	3.1%	-62.00 [-96.08, -27.92]
Schuna, 2014	-26.4	147.6	15	24	144.24	16	0.9%	-50.40 [-153.23, 52.43]
Swartz, 2014	-25	51.7	29	-10.9	43.4	31	3.7%	-14.10 [-38.34, 10.14]
Subtotal (95% CI)			**232**			**223**	**24.9%**	**-40.59 [-61.65, -19.53]**
Heterogeneity: Tau² = 614.78; Chi² = 29.33, df = 9 (P = 0.0006); I² = 69%								
Test for overall effect: Z = 3.78 (P = 0.0002)								
1.2.4 Multi-component Interventions								
Coffeng, 2014	378.6	221.8	63	403.8	245.2	96	1.4%	-25.20 [-98.72, 48.32]
French, 2011	90.6	55.8	43	120.6	55.8	44	3.8%	-30.00 [-53.45, -6.55]
Healy, 2016	-58.3	72.98	96	-13	50.74	65	4.1%	-45.30 [-64.41, -26.19]
Judice, 2015	649.2	90.6	10	529.3	131.4	10	0.9%	119.90 [20.98, 218.82]
Kerr, 2016	465.8	103.9	15	567.1	118.5	15	1.3%	-101.30 [-181.05, -21.55]
Nehaus, 2014	-72.16	127.89	25	-11	107.5	13	1.3%	-61.16 [-138.15, 15.83]
Parry, 2013	-21.6	46.56	33	3.36	38.4	29	3.9%	-24.96 [-46.12, -3.80]
Raynor, 2013	168	168	12	252	132	12	0.6%	-84.00 [-204.88, 36.88]
Raynor, 2013	108	126	14	210	228	14	0.5%	-102.00 [-238.46, 34.46]
Subtotal (95% CI)			**311**			**298**	**17.9%**	**-35.53 [-57.27, -13.79]**
Heterogeneity: Tau² = 399.08; Chi² = 16.30, df = 8 (P = 0.04); I² = 51%								
Test for overall effect: Z = 3.20 (P = 0.001)								
Total (95% CI)			**3078**			**2905**	**100.0%**	**-30.37 [-40.86, -19.89]**
Heterogeneity: Tau² = 610.51; Chi² = 209.03, df = 36 (P < 0.00001); I² = 83%								
Test for overall effect: Z = 5.68 (P < 0.00001)								
Test for subgroup differences: Chi² = 2.03, df = 2 (P = 0.36), I² = 1.4%								

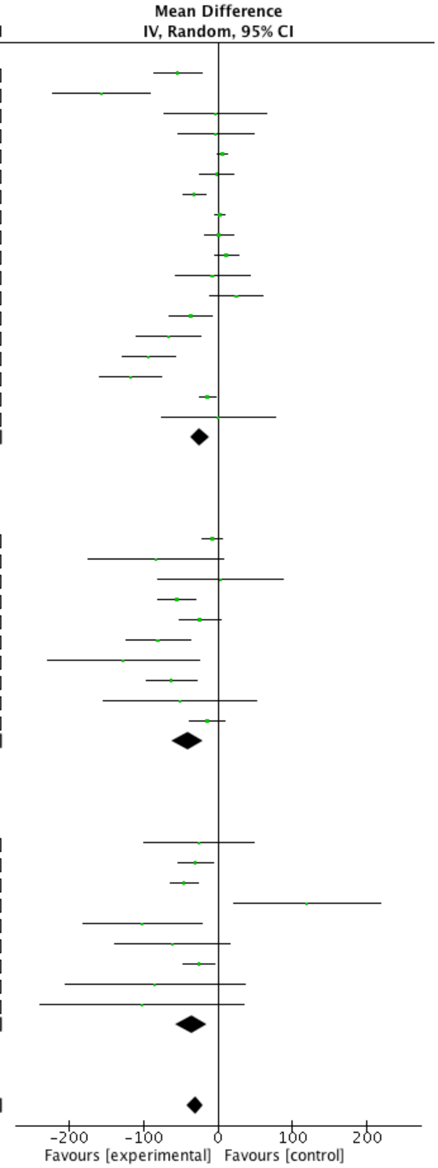


Table 5 presents subgroup analyses by study design, quality, outcome assessment, intervention setting, and follow-up duration. Pooled intervention results of RCTs indicate a reduction in sitting time of -33.65min/day (95%CI -46.27, -21.03, p<0.00001, I^2=84%) compared to -22.66min/day (95%CI -38.15, -7.17, p=0.004, I^2=67%) in cluster and quasi-randomized controlled trials. Interventions of studies rated as low quality showed a slightly higher reduction in sitting time (-30.37min/day, 95%CI: -48.65, -12.10, p=0.001, I^2=78%).

Table 5 Subgroup analyses of intervention effects for reduction of SB by: study design, outcome assessment, setting, follow-up duration, and study quality

Subgroup	No. of studies (Participants)	Pooled intervention effect (min/day), MD (95% CI)	I^2, (P value)
Design			
RCT	28 (4624)	-33.65 (-46.27 to -21.03)	84% (p<0.001)
Non-RCT (cluster and quasi-randomized)	7 (1359)	-22.66 (-38.15 to -7.17)	67% (p=0.006)
Outcome assessment			
Objective	19 (2010)	-24.63 (-37.91 to -11.34)	78% (p<0.001)
Self-report	16 (3973)	-36.01 (-53.14 to -18.88)	85% (p<0.001)
Setting			
Workplace	18 (1627)	-29.96 (-44.05 to -15.87)	61% (p=0.0004)
Other	17 (4356)	-30.47 (-44.68 to -16.26)	88% (p<0.001)
Follow-up duration			
0-3 months	19 (2099)	-34.47 (-52.17 to -16.77)	75% (p<0.001)
3-6 months	10 (2482)	-35.99 (-55.20 to -16.77)	89% (p<0.001)
>6 months	6 (1402)	-15.98 (-38.75 to 6.78)	83% (p=<0.001)
Study quality			
High	4 (206)	-18.75 (-36.54 to-0.95)	54% (p=0.09)
Low	18 (2400)	-30.37 (-48.65 to -12.10)	78% (p<0.001)
Unclear	13 (3377)	-34.43 (-52.14 to -16.72)	89% (p<0.001)

In total, 19 interventions used objective measures while 16 used self-report measures. The pooled intervention results of studies using self-report measures to assess sitting time indicated greater reductions in sitting time (-36.01min/day, 95%CI: -53.14, -18.88, p<0.00001, I^2=85%)

than studies that used objective measures (-24.63min/day, 95%CI: -37.91, -11.34, p=0.0003, I^2=78%).

Significant interventions effects were found in favour of the intervention group for both workplace and 'other' settings, which included community, domestic, and primary care as well as interventions that took place in both workplace and leisure environments. Comparing workplace and 'other' intervention settings revealed no statistically significant difference in reduction of sitting time. Subgroup analysis of follow-up duration indicated intervention effects attenuated after 6 months.

Publication bias

Out of the three categories, only behavioural (N=17) and environmental interventions (N=10) had at least 10 studies making these the only appropriate categories for assessment of publication bias via funnel plot (see online supplementary figure 1).[60] Visual inspection of the funnel plot detected evidence of asymmetry indicating the potential for publication bias towards studies with beneficial effects for reducing SB. However, the asymmetric distribution may be a study size effect.

DISCUSSION

The purpose of this review was to synthesize the evidence on adult SB interventions including, but not limited to, the workplace setting. Thirty-eight controlled trials published between 2003 and 2017 were included, of which 35 were included in the quantitative synthesis. More than a third of studies included in this review were published within the last 2 years representing the growing concern surrounding adult SB. Clear and consistent evidence for moderate reductions in SB across intervention types and settings was found although the overall quality of evidence was low. Findings indicate environmental interventions that involved a change to the behaviour setting resulted in modestly greater reductions in daily sitting time than either behavioural or multi-component interventions. Interventions lasting between 0 and 3 months showed the most significant reductions in SB. Promisingly, intervention effects were evident up to 6 months.

As a whole, it is clear that SB interventions lead to clinically meaningful reductions in daily sitting time. The meta-analysis presented here found the reduction in daily sitting time to be approximately 30 minutes per day in favour of the intervention group, which is consistent with four previous reviews.[8,12-13,61] In contrast to the first review, the latter three were not limited to the workplace environment and instead included all possible intervention settings. Our review differs from previous reviews in two important ways. First, our review focused exclusively on interventions to reduce SB. This is important as two of the previous reviews reported that interventions focused on reducing SB resulted in larger reductions in sitting time than physical activity or lifestyle interventions.[12-13] Second, this is the first review to evaluate the comparative effectiveness of different intervention settings as well as different intervention strategies.

Only one other review[8] has evaluated the comparative effectiveness of different intervention strategies. Our results are consistent with those of Chu *et al*[8] in that environmental interventions showed the greatest reduction in daily sitting time. Interestingly, despite categorizing environmental interventions more broadly to include screen-based prompts, our results are nearly identical to those of Chu *et al.*[8] In contrast to Chu *et al.*,[8] we categorized prompts/cues as environmental, not behavioural intervention strategies, because prompts/cues occur at the time or place of performance[62] and thus involve a change to the behaviour setting. Our findings extend the evidence for workplace intervention strategies beyond what is already known about activity-permissible workstations.[9,11]

In contrast to the findings reported by Chu *et al* [8] who reported multi-component interventions produced the greatest reductions in sitting time compared to environmental or behavioural interventions, we found that multi-component interventions resulted in significant, though slightly less substantial reductions in daily sitting time compared to environmental interventions. Differences in our findings could be explained by the fact that only 5 of 8 studies of multi-component strategies included in the current analysis involved a sit-stand desk. The other three studies included in our review involved either TV-limiting devices[38,46] or screen-based prompts,[59] combined with coaching/counseling. It is possible that multi-component interventions that include sit-stand desks are more effective than those that do not.

Four studies included in this review compared a multi-component intervention to either a behavioural or environmental intervention.[31,36,53,54] All four studies found reductions in sitting time however, only two studies reported greater reductions in sitting time in favour of the multi-component group[31,53] which both included access to dedicated sit-stand desks for each participant.[31,53] For the other two studies that did not report any difference between groups, a single active workstation was provided for all participants in the multi-component intervention to share.[36,54] If multi-component interventions that include sit-stand desks are more effective than those that do not, it would explain why we found environmental interventions produced the greatest reductions in SB. To investigate further, we redid our subgroup analysis to include only those multi-component interventions that included a sit-stand desk. Indeed, results indicated a greater reduction in sitting time of -39.30min/day (95%CI: -56.44, -22.15), which was nearly the same as environmental (-40.59min/day, 95%CI: -61.65, -19.53) and much greater than behavioural interventions (-23.87min/day, 95%CI: -37.24, -10.49) alone. It would appear that multi-component interventions are more effective when sit-stand desks are included as a strategy. Furthermore, individual sit-stand desks seem more effective than a single active workstation shared among intervention participants, however more research is needed to evaluate this relationship directly.

Behavioural interventions, according to Michie's CALORE Taxonomy,[62] included: goal-setting, motivational interviewing, self-monitoring, problem solving and overcoming barriers, action planning, social comparison and facilitation, providing feedback on performance, and providing instruction. As a whole, behavioural interventions were the least effective strategy to reduce SB. Subgroup analysis results indicated a reduction in daily sitting time of (-23.87min/day, 95%CI: -37.24, -10.49) which is consistent with, although slightly greater than, reported by Chu *et al.*[8] Our broad categorization of behavioural interventions, though necessary to differentiate between environmental and multi-component interventions, likely contributed to significant heterogeneity in the study designs and intervention strategies included in the subgroup analysis. Using a random-effects model enabled us to adjust for these issues.

Of the 20 studies of behavioural interventions included in this review, 13 studies reported reductions in sitting time, of which only 8 reported using a specific behaviour change framework or theory.[24,29,33,40-41,47-48,54] These findings are consistent with those of Gardner *et al.*[61] who reported only 42% studies included in their review of SB interventions mentioned a theory of behaviour change. Interestingly, Gardner *et al.*[61] found different patterns according to their coding scheme for intervention promise across workplace and non-workplace settings. Worksites were suggested as more receptive environments for interventions involving pre-planning and routinisation compared to non-worksites where SBs are less predictably structured.[61] It is possible that certain behavioural interventions are likely to be more effective in one setting over another. Further investigation is warranted.

Twenty (53%) of the thirty-eight studies included in this review were set in community environments while the other eighteen were set in the workplace. Workplace interventions had similar reductions in sitting time (-29.96min/day, 95%CI: -44.05, -15.87) compared to community settings (-30.47min/day, 95%CI: -44.68, -16.26). Although reductions in sitting time were observed for all settings, there were no differences between settings. These findings are consistent with those of Martin *et al.*[13] who also examined the comparative effectiveness of workplace and 'other' intervention settings. Based on current evidence, it is possible that intervention setting is not an important factor for consideration. As shown in Table 5, further subgroup analysis by study design, methodological quality, and outcome assessment revealed modest but not significant differences between studies.

The strengths of this review include limiting the selection criteria to include randomized designs, following the methodological criteria outlined for high quality systematic reviews in the Cochrane Handbook,[63] and the multiple subgroup and sensitivity analyses to support the robustness of our findings. The following limitations should be noted. First, the overall quality of included studies was low with only 4 (11%) being rated as high quality. Second, meta-analyses were limited to studies that reported changes in SB as sitting minutes per day. Where possible, studies that reported SB as sitting minutes per 8-hour workday, minutes/week and hours per day were scaled to min/day and combined in the same meta-analysis. Third, no subgroup analysis for gender was undertaken because only 4 studies were conducted in women only and none in men. Last, there was substantial heterogeneity across studies with regard to sample size, intervention type and duration, method of outcome assessment, and follow-up duration. Using a random-effects meta-analysis model and performing multiple subgroup analyses enabled us to adjust for these issues.

CONCLUSION

This review sought to evaluate the effectiveness of interventions to reduce adult SB within, and beyond, the workplace setting. The evidence presented here has important implications for the design of future interventions to reduce SB in the adult population. We were able to source a large number of studies, most of which were published within the last 5 years, indicating the increased interest and investment in addressing SB as a public health issue. Results of our review confirm that interventions focused on reducing SB produce consistent and clinically meaningful reductions in sitting time. Further research directly comparing different intervention strategies and settings is needed. Current evidence suggests that sit-to-stand desks are a potentially important ingredient of successful multi-component interventions, though more high-quality research exploring this finding is encouraged. The findings of this review contribute to a rapidly strengthening body of evidence supporting sit-stand desks as an effective workplace intervention strategy for reducing SB. Knowing that adults who work in office environments are at particular risk of exposure to high levels of occupational sitting, and that the provision of sit-stand desks can produce clinically meaningful reductions in SB, employers should consider incorporating sit-stand desks as part of workplace wellness initiatives. As sit-to-stand desks are likely only suitable for workplace settings, further research is needed to determine the most effective strategies for reducing SB in the home and leisure environments. To better understand the nature of sitting activities that are most effectively influenced by environmental, behavioural, or multi-component interventions, future studies should consider using both objective and domain-specific measures of SB. Though growing, the evidence for interventions to reduce adult SB outside of the workplace setting is limited. Exploring behaviour change strategies and delivery methods more suitable for home and leisure environments should be a priority.

Supporting Information

Table 1. Overall intervention effect with study removed

Figure 1. Funnel plot of the intervention effect for reducing sitting time in min/day in adults by type of intervention

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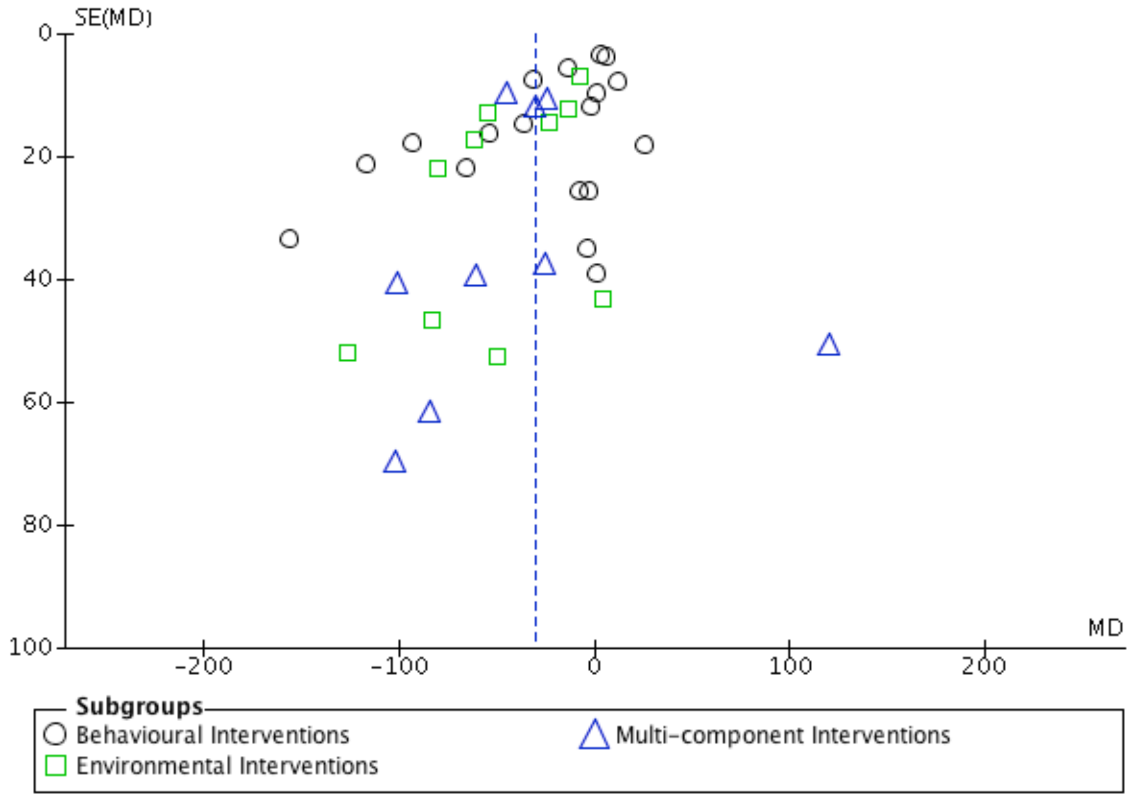
Supplemental Table 1: Overall intervention effect with study removed

Study removed	Effect [95% CI]	Z value	P value
Aadhal, 2014	-29.21 [-39.92, -18.50]	5.34	<0.001
Barwais, 2013	-27.64 [-37.93, -17.35]	5.26	<0.001
Biddle, 2015	-30.57 [-41.31, -19.84]	5.58	<0.001
Brakenridge, 2016	-31.05 [-41.70, -20.40]	5.71	<0.001
Carlson, 2012	-32.21 [-43.49, -20.93]	5.60	<0.001
Carr, 2016	-31.45 [-42.66, -20.24]	5.50	<0.001
Chau, 2014	-29.53 [-40.17, -18.88]	5.44	<0.001
Coffeng, 2014	-30.21 [-40.93, -19.49]	5.52	<0.001
Donath, 2015	-30.54 [-41.25, -19.84]	5.59	<0.001
Dutta, 2014	-28.96 [-39.61, -18.31]	5.33	<0.001
Evans, 2012	-30.41 [-41.30, -19.52]	5.47	<0.001
French, 2011	-30.18 [-41.07, -19.28]	5.43	<0.001
Graves, 2015	-28.58 [-39.16, -18.00]	5.29	<0.001
Healy, 2016	-29.33 [-40.05, -18.61]	5.36	<0.001
Judice, 2015	-31.38 [-41.92, -20.85]	5.84	<0.001
Kerr, 2016	-29.11 [-39.71, -18.51]	5.38	<0.001
Lakerveld, 2013	-31.38 [-42.33, -20.44]	5.62	<0.001
Lane, 2015	-30.13 [-41.08, -19.17]	5.39	<0.001
Li, 2017	-29.46 [-39.91, -19.01]	5.53	<0.001
Marsaux, 2015	-32.23 [-43.75, -20.72]	5.49	<0.001
Marshall, 2003	-31.61 [-42.60, -20.61]	5.63	<0.001
Neuhaus, 2014	-29.68 [-40.36, -19.00]	5.45	<0.001
Ostbye, 2009	-32.10 [-43.02, -21.18]	5.76	<0.001
Parry, 2013	-30.43 [-41.38, -19.48]	5.45	<0.001
Pedersen, 2014	-28.93 [-39.58, -18.27]	5.32	<0.001
Priebe, 2015	-30.69 [-41.48, -19.91]	5.58	<0.001
Puig-Ribera, 2015	-31.89 [-42.65, -21.12]	5.81	<0.001
Raynor, 2013; Cohort 1	-29.74 [-40.39, -19.10]	5.48	<0.001
Raynor, 2013; Cohort 2	-29.71 [-40.34, -19.08]	5.48	<0.001
Schuna, 2014	-29.94 [-40.62, -19.27]	5.50	<0.001
Slootmaker, 2009	-29.91 [-40.75, -19.08]	5.41	<0.001
Spittaels, 2007	-29.04 [-39.71, -18.37]	5.34	<0.001
Spring, 2012; Cohort 1	-27.67 [-38.02, -17.32]	5.24	<0.001
Spring, 2012; Cohort 2	-27.19 [-37.42, -16.97]	5.21	<0.001
Sternfeld, 2009	-31.29 [-42.62, -19.95]	5.41	<0.001
Swartz, 2014	-30.86 [-41.81, -19.92]	5.53	<0.001
Verweij, 2012	-30.57 [-41.29, -19.86]	5.59	<0.001

Supplemental figure 1: Funnel plot of the intervention effect for reducing sitting time in min/day in adults by type of intervention



Chapter 3: Video-based Intervention Study

Title: Influencing health beliefs and sedentary behaviours in working adults: A video-based intervention study.

*A shortened version of this manuscript has been submitted to the American Journal of Preventive Medicine

ABSTRACT

Introduction: Adults working in academic occupations are at particular risk for exposure to sedentary behaviours (SB). The aim of this study was to determine the influence of an educational video on viewers' health beliefs and SBs.

Study design: Single-group, pre-post design. Data were collected between March and April 2017.

Setting/participants: Healthy adults employed as full-time graduate students, faculty members, or research support staff were recruited from an academic institution in Ontario, Canada.

Intervention: Evidence-based strategies to reduce SB at home and at work were summarized and presented as cues to action in a 5-minute video.

Main outcome measures: Self-reported physical activity, SBs, health beliefs, and readiness to change were measured using the International Physical Activity Questionnaire, Sedentary Behaviour Health Belief Questionnaire, and Readiness Ruler, respectively, one week before watching the video (T1), immediately after (T2), and one week later (T3). Occupational and leisure-time sitting time were assessed daily via participant log.

Results: Participants (N=71; 88.2% female; Mean ±SD age= 40.0years ±12.1) reduced weekday and weekend sitting time by -35.9 minutes and -21.1 minutes per day, respectively. Readiness to change increased between T2 and T3 (p=0.004). Perceived severity (p=0.03) and susceptibility (p=0.01) increased from T1 to T2. Consideration of future consequences decreased from T2 to

T3 (p=0.01). No intervention effects were observed for any other health belief subscale. Perceived benefits (r_s=-0.25, p=0.04) scores at T2 were inversely associated with reductions in sitting time from T2 to T3. Participants sat nearly 10hrs/day on weekdays and 8hrs/day on weekend days. Occupational sitting was the greatest contributor to domain-specific SB. The video was considered informative by 93.4% of participants and 88.5% would recommend the video to a friend.

Conclusion: It is possible that exposure to the video influenced several health belief constructs and reduced daily sitting time in healthy adults working in academic occupations.

INTRODUCTION

Despite growing evidence linking sedentary behaviour (SB) with negative health outcomes, 85% of Canadians are not meeting physical activity recommendations and are instead spending 10 of their daily waking hours in a sedentary state.[1] SB, defined as any waking activity with an energy expenditure of ≤1.5 metabolic energy equivalents,[2] is a major public health problem.[1] Greater daily sitting time is associated with increased risk of mortality from all causes.[3] To eliminate the risk of premature mortality from too much sitting, daily physical activity levels must exceed current public health recommendations.[4] Despite the evidence that individuals who accumulate 60-75 minutes of moderate daily physical activity are less vulnerable to the negative health risks associated with SB,[4] this cohort represents a small proportion of the Canadian population. Results from the 2014-2015 Canadian Health Measures Survey indicate that 4 out of 5 adults are not getting the recommended 150 minutes of moderate-to-vigorous physical activity per week, much less 60-75 minutes per day.[5]

Adults who work in office environments are at particular risk for exposure to SB as nearly 77% of a typical workday is spent in a seated position.[6] Not surprisingly, there is a rapidly growing body of literature targeting interventions to reduce occupational sitting in the adult population. A systematic review (2016) of workplace SB interventions reported that 21 of the 26 studies were published in the last 5 years representing the growing public concern over SB.[7] Adults working in academic occupations are a logical target for SB intervention since professors, graduate students, and research support staff spend most of their workday in a seated position.[8] Of 5000 academic staff surveyed in the UK, 66% reported working more than 45 hours per week, and 24% percent reported working more than 55 hours per week.[9] Nearly 45% of the survey sample reported completing more than a fifth of their workload in the evenings and on weekends.[9] Given that university faculty members are sedentary nearly 8 hours of every day,[8] professional staff that work at higher education institutions are sedentary for more than 11 hours every day,[10] and that more than half of Canadian university students are not meeting physical activity guidelines,[11] SB intervention in these populations is warranted.

Interventions to reduce adult SB have been successful and evidence from two recent systematic reviews[12,13] indicate that SB interventions can reduce daily sitting time in the range of 42[12] to 91[13] minutes per day. Reallocating just 30 minutes of SB to light physical activity can lead to a 2-4% improvement in cardiometabolic risk biomarkers (i.e. Tri-glycerides, insulin levels, and Beta-cell function).[14] Results from both reviews suggest that interventions focused on reducing adult SB are more effective than interventions aimed at increasing physical activity and reducing SB simultaneously.[12,13] Intervention strategies were addressed in a further systematic review which identified environmental restructuring, persuasion, and education as most promising for reducing adult SB.[15] Within the workplace setting, there is strong evidence for multi-component interventions incorporating activity-permissible workstations to reduce daily sitting time.[7] However, cost-effectiveness has yet to be explored and will likely impact the feasibility of implementation for many employers.

Although occupational sitting is likely the biggest contributor to overall SB, adults who work in higher education institutions often bring work home. Interventions to reduce SB that are dependent on a particular setting, such as sit-to-stand desks at work, fail to address determinants of SB in the home and leisure environments.[16] An academic professional will have many potential workspaces, which could include an office, a meeting room, a classroom, or a workstation at home. Depending on the nature of the setting, built environments and social norms help to reinforce SB.[16] For example, the provision of chairs in meeting rooms and classrooms designates sitting as the most appropriate behaviour. To accommodate the many settings in which an individual may be sedentary, strategies to reduce sitting must be flexible. Due to high job demands and long work hours typical of academic work,[9] interventions to reduce SB in this population must maximize engagement while minimizing participant burden.

Objectives

The purpose of this study was to examine the effectiveness of using a video to influence health beliefs to reduce SB by providing targeted, evidence-based strategies to reduce sitting time at home and at work for healthy adults working in academic occupations.

Research Questions

<u>Primary Research Question</u>

Does an educational video with strategies to reduce SB at home and in the workplace reduce daily sitting time in healthy adults working in academic occupations?

Secondary Research Questions

1) Does an educational video with strategies to reduce SB at home and in the workplace influence health beliefs in healthy adults working in academic occupations?

2) What are the associations between health belief scores as measured by the SB-HBQ at baseline (T1) and post-intervention (T2) and changes in sitting time from post-intervention (T2) to follow-up (T3)?

3) What is the effect of the intervention on Readiness to Change scores as measured by the readiness ruler from baseline (T1) to post-intervention (T2) and from post-intervention (T2) to follow-up (T3)?

4) What are the associations between Readiness to Change scores at baseline (T1) and post-intervention (T2) and changes in sitting time from post-intervention (T2) to follow-up (T3)?

5) What is the effect of the intervention on domain-specific sitting time as measured by the SB log at baseline (T1) and post-intervention (T2)?

6) What is the adherence rate of using electronic questionnaires to assess daily sitting time and health beliefs in healthy adults working in academic occupations?

7) What is the acceptability of the educational video and how might it be improved?

METHODS

Study population and study design

Sample: Thesis-based graduate students, research support staff, and faculty members were recruited via departmental email within McMaster University's School of Rehabilitation Sciences, Hamilton, Canada. The recruitment email contained a link to an eligibility survey

(Appendix A). Participants were included if they met the following criteria: aged 18-65 years and were a student, full-time or sessional faculty member, or research support staff. Participants were excluded if they had any known musculoskeletal conditions that would prevent them from being less sedentary. Informed consent was obtained from all participants prior to participation in this study. McMaster's Health Research Ethics board approved the experimental protocol, recruitment materials, study questionnaires, and intervention content (2017-1854-GRA).

Completion of the eligibility survey was considered implied consent and participants were immediately enrolled in the study. Participants completed all assessments between March 2017 and April 2017. This study employed a single-group, pre-post design to evaluate sitting time of participants 1-week before, immediately after watching an educational video, and 1-week later.

Intervention

The purpose of the educational video was to influence viewers' health beliefs to reduce their SB by providing targeted, evidence-based strategies for reducing sitting at home and at work. The video was 5 minutes in length and provided participants with a comprehensive overview of the nature, scope, and impact of SB as a public health problem. The video addressed working-age adults' perceived susceptibility to the health risks associated with SB and the severity of those health consequences. The video also contrasted the perceived benefits and barriers and associated with reducing SB with the goal of persuading viewers to take action. The evidence for strategies to reduce SB in the home and workplace environments was systematically reviewed,[17] summarized, and presented as cues to action in the video. Strategies included modifying a workstation to permit standing while using the computer or telephone, suggesting a walking meeting to colleagues, using a watch or smartphone app as a reminder to take breaks from prolonged periods of sitting, and limiting the amount of time spent watching television at home. Viewers were encouraged to implement one or more of the strategies from the video to reduce their SB. The video was uploaded to Vimeo and sent to participants using the following link: https://vimeo.com/210495060.

Outcome measures

Electronic versions of all measures were sent via email using Survey Monkey (http://www.surveymonkey.com). Surveys were sent securely using SSL encryption. Participant responses to the surveys were anonymous. No personal identifiers were collected or stored. Survey responses were stored securely on Survey Monkey's servers.

International Physical Activity Questionnaire (IPAQ)

The primary outcome was the proportion of participants who reduced their sitting time by 30min/day as measured by the Short-form IPAQ[18] (Appendix B). The IPAQ demonstrates excellent test-retest reliability (ICC = 0.76), and fair criterion validity (r=0.30) when compared against accelerometry in samples of middle-aged, well-educated, working adults.[18] Participants were asked to fill out electronic versions of the short-form IPAQ at baseline (T1), immediately after watching the video (T2), and one week later (T3). The assessment timeline is summarized in Figure 1.

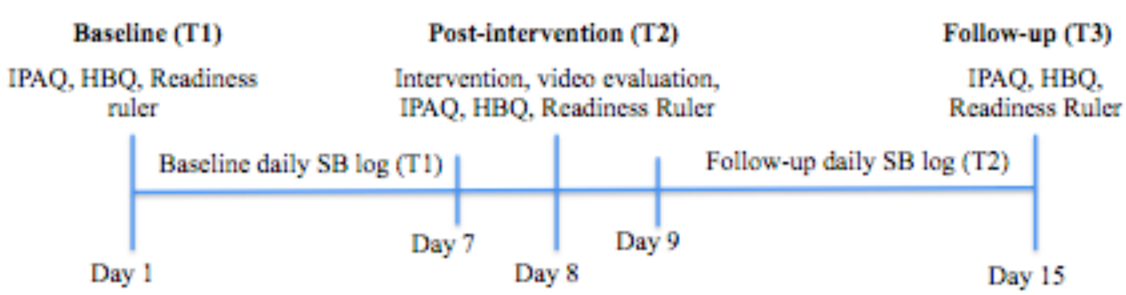


Figure 1. Assessment timeline

Readiness Ruler

An electronic version of a Readiness Ruler (Appendix C) was developed that asked participants to indicate their readiness to change on a 10-point scale, where 1=Not prepared to change and 10=Already changing. The Readiness Ruler was sent to participants at baseline (T1), immediately after watching the video (T2), and one week later (T3).

Sedentary Behaviour Health Belief Questionnaire (SB-HBQ)

We assembled a SB-HBQ (Appendix D) based on an extended version of the Health Belief Model (HBM).[19] The original HBM posits that an individual's readiness to change is influenced by his or her perceptions of the severity of the disease, susceptibility to the disease, the benefits that may come from avoiding the behaviour and the barriers that make changing current behaviour difficult.[19] Including four additional constructs improved the predictive capability of the original model by 78%.[19] These additional constructs include: self-identity; which describes some salient part of one's self-perception as it relates to a particular health behaviour, consideration of future consequences; the extent to which a person considers the future consequences of his/her actions and the extent to which he/she is influenced by these potential outcomes, concern for appearance; indicating a responsibility to engage in healthy behaviours, and perceived importance; the value an individual attaches to the outcomes of a particular health behaviour.[19] For the present study, subscales were developed for each of the nine constructs outlined in Orji et al.'s (2012) extended HBM as follows.

Perceived Benefits and Perceived Barriers Subscales were divided into two parts:

i) Participants were asked to rate statements that described benefits and barriers to reducing SB that were adapted from a previously validated physical activity questionnaire (Cronbach's alpha = 0.76).[20]

ii) Participants were asked to check all appropriate responses from a list of 11 potential benefits and 13 barriers including an option for 'other'. Benefits and barriers were adapted from a previously validated questionnaire assessing HBM constructs as applied to breast self-examination (Kendall's Tau B = 0.88).[21] For example, the perceived barrier item "lack of knowledge about how to exercise/workout" was changed to "lack of knowledge about how to reduce sedentary behaviour".

Perceived Severity and Susceptibility

- Statements were adapted from a previously validated questionnaire assessing perceived severity (Cronbach's alpha = 0.78)[21] and perceived susceptibility (Cronbach's alpha = 0.78)[21] as applied to breast self-examination to reflect sitting and the associated health risks of SB.

Consideration of Future Consequences and Concern for Appearance

- The consideration of future consequences (Cronbach's alpha = 0.86)[22] and concern for appearance (Cronbach's alpha = 0.82)[23] scales were taken directly from the literature and included in the SB-HBQ without modification.

Self-identity

- Statements for the self-identity scale (Cronbach's alpha = 0.82)[24] were adapted from a previously validated questionnaire by replacing reference to nutrition and diet with 'behaviour' to keep consistent with the consideration of future consequences scale.

Cues to Action and Perceived Importance

- A similar approach was taken to modify statements from a previously validated questionnaire to reflect SB rather than physical activity for the cues to action (Kendall's Tau B = 0.79)[20] and perceived importance scales (Cronbach's alpha = 0.80).[25] Cues to action represent both internal and external prompts that trigger an individual to perform the target behaviour.[19] In the case of SB, a cue to action would trigger an individual to interrupt his or her SB by standing or engaging in light physical activity, for example.

For a direct comparison of the original and adapted subscales used to develop the SB-HBQ see supplementary Table 1. Participants were asked to rate statements on a 5-point Likert Scale from 1=Strongly disagree to 5=Strongly agree. Participants were sent the SB-HBQ electronically at three time points: baseline (T1), immediately after watching the video (T2), and 1-week later (T3).

Log

For one week starting at baseline, participants received a daily email reminder to complete and submit an electronic log of the amount of time spent being sedentary in the previous day by clicking on the link provided. The log (Appendix E) prompted individuals to record the amount of time they spent sitting in the following activities: watching television, working, during meals, on their computer at home, during transportation, hobbies, and socializing with friends or family. At the end of each day for the 1-week log period, a generic reminder email was sent to all participants reminding them to fill out and submit their SB log before the end of the day. At the end of the first week, the educational video was sent to participants. For one week following receipt of the video, participants received a daily email reminder to fill out and submit an electronic log of the time spent in SB in the previous day by clicking on the link provided. Again, at the end of each day for the second 1-week log period, a generic reminder email was sent to all participants reminding them to fill out and submit their SB log before the end of the day.

Video Evaluation

Participants were asked to fill out an evaluation survey immediately after watching the video. The survey (Appendix F) used a 5-point Likert scale for participants to rate the content (1=Poor, 5=Excellent), design (1=Totally unacceptable, 5=Extremely acceptable), and impact of the video (1=Not at all influential, 5=Extremely influential). Participants were asked whether they agreed that the video was engaging, motivational, educational, informative, relevant, and easy to understand (0=Disagree, 1=Agree). Participants had the opportunity to provide suggestions for improvement in the comments section.

Sample Size & Prognostic Variables

Sample size calculation was performed using Stata software, version 13 (StataCorp, College Station, TX, USA). Significance level was set at 0.05, power at 0.8, and a minimum detectable difference of 30 minutes of sitting per day (as measured by the IPAQ at baseline and follow-up) was used as the alternative hypothesis, with a standard deviation of 1.25 hours of sitting per day based on a previous intervention in a similar population.[26] The sample size calculated was 52 participants. To account for a potential 20% dropout rate, the investigators aimed to recruit 63 participants. The following descriptive variables were included to evaluate possible mediators and moderators: age, gender, height, and weight. BMI was calculated [$weight(kg)/h(m)^2$] to describe the sample based on literature that has identified overweight and obese individuals as an understudied population in interventions that target sedentary behaviour.[27]

Statistical analysis

Statistical analysis was conducted using Stata software, version 13 (StataCorp, College Station, TX, USA). Baseline characteristics are presented as means and standard deviations for data that was normally distributed, medians and interquartile range for data not normally distributed, and number of participants and percentages for categorical data. Data was collected and stored on secure servers at the Institute of Applied Health Sciences at McMaster University.

Primary research question

To determine the effect of the intervention on daily sitting time as measured by the IPAQ, a paired sample t-test, was used or Wilcoxon signed-rank test when appropriate, to calculate the difference in sitting time between T1 and T2 as well as between T2 and T3.

Secondary research questions

1) To determine the effect of the intervention on health beliefs as measured by the SB-HBQ, we performed a paired sample t-test, or Wilcoxon signed-rank test when appropriate, to calculate the difference in health belief subscale scores between T1 and T2 as well as between T2 and T3.

2) To determine the effect of the intervention on Readiness to Change scores we performed two paired sample t-tests, or Wilcoxon signed-rank tests when appropriate, to calculate the differences in scores between T1 and T2 and between T2 and T3.

3) To determine the association between health beliefs and sitting time we performed two separate Spearman's Rank correlations. First between SB-HBQ subscale scores at T1 and changes in sitting time between T2 and T3; and second, between SB-HBQ scores at T2 and changes in sitting time between T2 and T3.

4) To determine the effect of the intervention on Readiness To Change we performed two separate paired sample t-tests, or Wilcoxon signed-rank tests when appropriate, comparing Readiness To Change scores at T1 and T2 and between T2 and T3.

5) To determine the association between Readiness to Change and sitting time we performed two separate Spearman's Rank correlations between Readiness To Change scores at T1 and T2 and changes in sitting time from T2 to T3.

6) To determine the effect of the intervention on domain-specific sitting time as measured by the SB log we performed paired sample t-tests, or Wilcoxon signed-rank tests when appropriate, between log data at T1 and T2.

7) Adherence to the SB log was calculated as the number of days the log was completed divided by the total number of days the log was sent to participants.

8) Acceptability of the video intervention and suggestions for improvement were evaluated based on responses to the video evaluation survey.

RESULTS

A total of 77 participants were assessed for eligibility, of which one person was excluded due to a pre-existing musculoskeletal condition (Figure 2). Of the 76 eligible participants, 71 completed the baseline assessment. Three participants did not complete the baseline assessments as they were on vacation. Assessments at all three time-points including baseline, post-intervention, and one week follow-up, were completed by 51 (72%) participants. In total, 19 (27%) participants were lost to follow-up and 2 (3%) participants dropped out of the study. Overall, participants were mostly female, middle-aged, and reported a normal to overweight BMI. Baseline group characteristics are presented in Table 1.

Table 1 Demographic characteristics of study participants

	All participants (N=71)
Age, Mean (SD)	40.0 (12.1)
Female, n (%)	60 (88.2)
Occupation	
Student, n (%)	31 (45.6)
Faculty, n (%)	20 (29.4)
Research support staff, n (%)	17 (25)
Body Mass Index, Mean (SD)	26.3 (6.4)

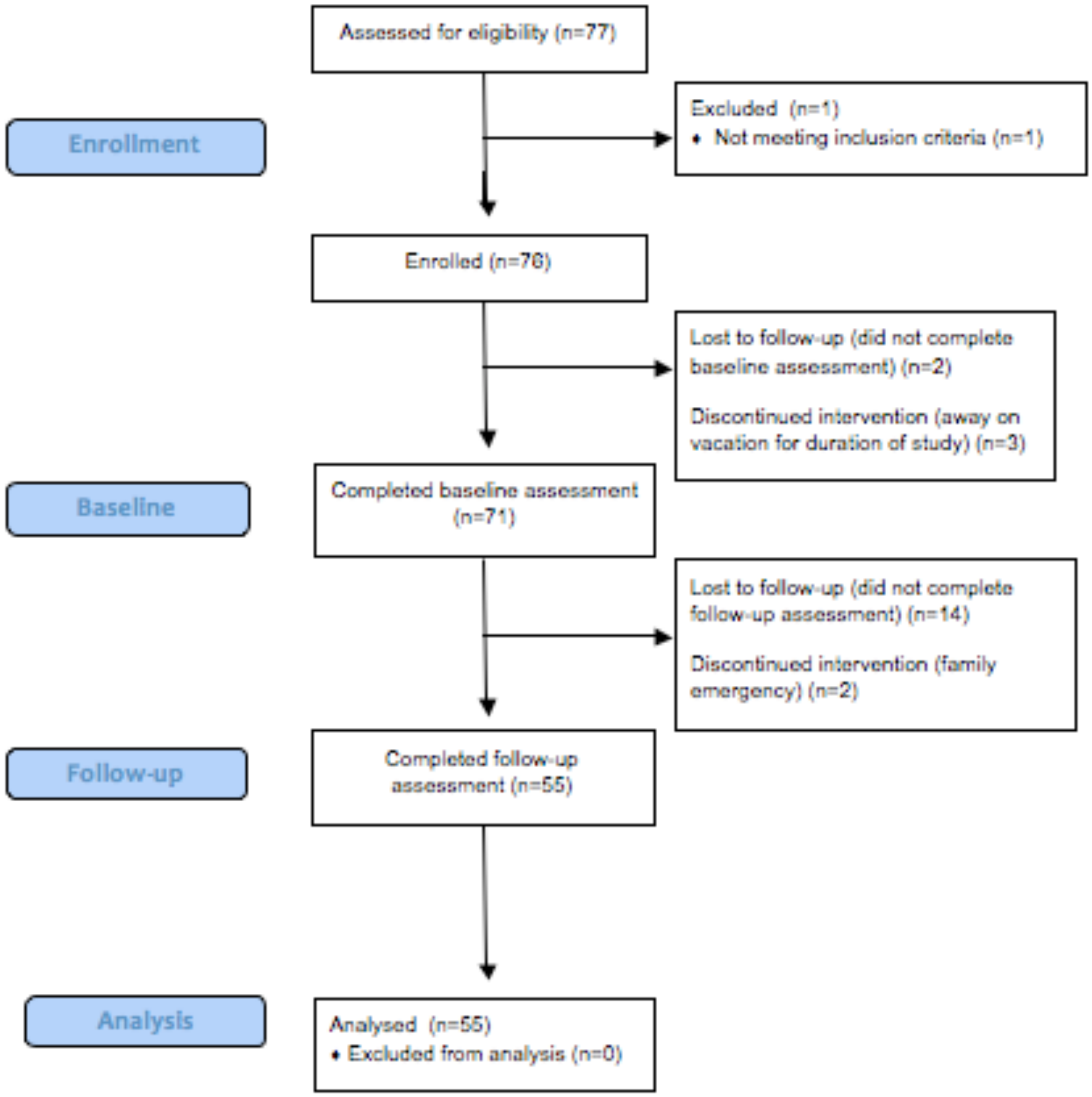


Figure 2 CONSORT Flow Diagram

Response Rate

Questionnaire response rate was highest at baseline (T1) at 92%. Response rate dropped to 85% at post-intervention (T2) and to 75% at follow-up (T3). For the SB logs, response rate varied between a low of 71% on a Sunday to a high of 89% on a Monday. Average response rate was 82% for the logs and 84% for the primary outcome questionnaires.

Missing Data

Missing data may be missing completely at random (MCAR), missing at random (MAR), or non-ignorable responses.[28] Data that is MCAR does not depend on the dependent variable, covariates, or study design.[28] MAR, or ignorable non-response, occurs when the probability of the missing response depends only on the independent variables and not on the dependent variables.[28] Non-ignorable response occurs when the probability of the missing response depends on the value of the dependent variable.[28] The amount of missing data differed at each time point (Table 2). However, Little's MCAR test showed that our data were missing completely at random for all but one variable, self-efficacy (Chi-squared = 16.22, DF= 8, p=0.04) (Table 3). Missing data were imputed by carrying the last observation forward.[28] Statistical analyses were performed two ways: with and without the imputed data. The results using either method differed slightly. The difference in results using complete cases analyses were as follows: increases in weekday sitting time from T1 to T2 were not significant (p=0.08), increases in Readiness to Change from T2 to T3 were not significant (p=0.10), concern for appearance (r_s=0.33, p=0.02) subscale scores at T1 were positively associated with changes in weekend sitting time from T2 to T3, and perceived benefits (r_s=-0.37 p=0.01) and consideration of future consequences (r_s=-0.36, p=0.01) scores at T2 were negatively associated with changes in sitting time from T2 to T3. Complete cases analyses are provided in supplemental file 2. Results for analyses with imputed data are shown below.

Table 2. Number of participants with missing data at each time point

Primary Outcome	Complete N (%)	Missing T1 N (%)	Missing T2 N (%)	Missing T3 N (%)
Weekday sitting time	46 (63)	10 (14)	14 (19)	19 (26)
Weekend sitting time	44 (60)	11 (15)	15 (21)	19 (26)
Readiness To Change	49 (67)	7 (10)	14 (19)	18 (25)
Perceived Susceptibility	49 (67)	7 (10)	13 (18)	18 (25)
Perceived Severity	50 (68.5)	6 (8)	13 (18)	18 (25)
Perceived Benefits	49 (67)	7 (10)	13 (18)	18 (25)
Perceived Barriers	50 (68.5)	6 (8)	13 (18)	18 (25)
Concern for Appearance	49 (67)	7 (10)	14 (19)	18 (25)
Consideration of Future Consequences	50 (68.5)	6 (8)	14 (19)	18 (25)
Self-identity	50 (68.5)	6 (8)	14 (19)	19 (26)
Self-efficacy	48 (66)	7 (10)	13 (18)	19 (26)
Perceived Importance	50 (68.5)	6 (8)	14 (19)	18 (25)

Table 3. Results of Little's MCAR Test

Primary Outcome	MCAR'S TEST (Chi2, DF, p=)
Weekday sitting time	Chi-squared = 8.32, DF=8, p=0.40
Weekend sitting time	Chi-squared = 7.75, DF= 8, p=0.46
Readiness To Change	Chi-squared = 6.94, DF= 8, p= 0.54
Perceived Susceptibility	Chi-squared = 11.78, DF= 8, p= 0.16
Perceived Severity	Chi-squared = 2.32, DF =8, p= 0.97
Perceived Benefits	Chi-squared = 7.7, DF = 8, p= 0.47
Perceived Barriers	Chi-squared = 12.8, DF= 8, p= 0.12
Concern for Appearance	Chi-squared= 8.78, DF= 8, p= 0.36
Consideration of Future Consequences	Chi-squared = 4.10, DF= 8, p=0.85
Self-identity	Chi-squared = 13.57, DF= 7, p=0.06
Self-efficacy	**Chi-squared = 16.22, DF= 8, p=0.04**
Perceived Importance	Chi-squared = 12.05, DF=8, p=0.15

International Physical Activity Questionnaire (IPAQ)

Table 4 illustrates mean changes in IPAQ scores from baseline (T1) to post-intervention (T2) and from post-intervention (T2) to follow-up (T3). Weekday sitting time increased from T1 to T2 (460.1 minutes/day, 482.5 minutes/day, p=0.04). There was a decrease in SB between T2 and T3 for both weekday (482.5 minutes/day, 446.6 minutes/day, p=0.03) and weekend sitting time (341.4 minutes/day, 320.3 minutes/day, p=0.01). There were no differences observed in sitting time between T1 and T2. The number of days participants walked at least 10 minutes per day increased from T1 to T2 (p=0.001)

Table 4. International Physical Activity Questionnaire; Mean (SD)

	Baseline (T1); N=71	Post-intervention (T2); N=71	Follow-up (T3); N=71	Mean change (T2-T1)	Mean change (T3-T2)
Weekday sitting time (min)	460.1 (148.8)	482.5 (153.0)	446.6 (147.8)	**22.40 (106.3); p=0.04**	**-35.92 (132.4); p=0.03**
Weekend sitting time (min)	326.2 (138.3)	341.4 (138.6)	320.3 (150.5)	15.21 (124.6); p=0.64	**-21.13 (154.3); p=0.01**
Walking (days/week)	4.8 (2.2)	5.1 (2.1)	5.25 (2.04)	**0.3 (1.6); p=0.001**	0.141 (0.975); p=0.37
Walking (min/day)	49.1 (53.9)	50.6 (56.9)	51.5 (50.6)	1.48 (29.2); p=0.18	0.88 (43.35); p=0.26
Moderate PA[1] (days/week)	2.5 (2.2)	2.3 (2.2)	2.47 (1.74)	0.27 (1.7); p=0.53	0.20 (1.88); p=0.38
Moderate PA (min/day)	55.6 (60.2)	56.9 (61.0)	62.4 (59.5)	1.25 (61.4); p=0.76	5.46 (57.1); p=0.57
Vigorous PA (days/week)	2.0 (1.8)	2.0 (1.8)	2.1 (1.9)	0.1 (1.4); p=0.82	0.1 (1.2); p=0.78
Vigorous PA (min/day)	50.9 (40.7)	46.8 (45.2)	53.4 (52.9)	-3.48 (35.7); p=0.30	6.57 (43.6); p=0.47

[1]Abbreviation: PA, physical activity

Readiness To Change

Readiness to Change scores are presented in Table 5. Changes between T1 and T2 were not observed, however Readiness to Change increased from T2 to T3 (6, 7, p=0.04). Readiness to Change scores at T1 were not associated with changes in sitting time from T2 to T3. Readiness to Change scores at T2 were inversely associated with changes in sitting time from T2 to T3 (r_s =-0.26, p=0.03).

Table 5. Readiness Ruler; Median (IQR)

Scale (1-10)	Baseline (T1)	Post-intervention (T2)	Follow-up (T3)	Mean change (T2-T1)	Mean change (T3-T2)
All participants (N=71)	6 (5-7)	6 (5-8)	7 (6-8)	0 (-1)-1; p=0.51	**0 (0-1); p=0.04**

Table 6. Correlation between Readiness Ruler Scores and Changes in Sitting Time, Mean (SD)

	Change in Sitting Time T2 to T3	
Readiness to Change Scores	Weekday sitting time	Weekend sitting time
Baseline (T1) (N=71)	r_s =-0.07, p=0.58	r_s = 0.12, p=0.30
Post-intervention (T2) (N=71)	**r_s =-0.26, p=0.03**	r_s = 0.10, p=0.41

Participant Characteristics and Change in Sitting Time

Mean changes in sitting time by BMI and occupation are summarized in Table 7. Participants with BMI >25kg/m^2 reported greater reductions in weekday sitting time (-55.5 ±119.6) from T2 to T3 while participants with BMI<25kg/m^2 reported greater reductions in weekend sitting time from T2 to T3 (-28.1 ±124.9). Research support staff made the greatest reductions in weekday sitting time (-84.7min/day ±116.3) from T2 to T3 while faculty members reduced weekend sitting time (-64.5min/day ±129.6) the most. Students made the smallest reduction to weekday sitting time (-2min/day ±101.8) and reported an increase in weekend sitting time (14min/day ±162.6) from T2 to T3.

Table 7. Change in Sitting Time from T2 to T3 by BMI and Occupation, Mean (SD)

	Change in Sitting Time between T2 and T3	
Demographic variable	Weekday sitting time (min/day)	Weekend sitting time (min/day)
BMI		
<25kg/m^2 (N=31)	-10.6 (119.6)	-28.1 (124.9)
>25kg/m^2 (N=40)	-55.5 (119.6)	-15.8 (175.1)
Occupation		
Student (N=30)	-2 (101.8)	14 (162.6)
Faculty (N=20)	-48 (181.4)	-64.5 (129.6)
Support staff (N=17)	-84.7 (116.3)	-37.1 (176.7)

Health Beliefs

Table 8 illustrates mean changes in health beliefs as assessed by the SB-HBQ at all three time-points. Changes in health beliefs were observed for two subscales, both perceived susceptibility (13, 14.5, p=0.01) and perceived severity (21.5, 23, p=0.03) increased from T1 to T2. No intervention effects were observed for any of the other subscales between T1 and T2. A decrease in consideration of future consequences subscale scores was observed between post-intervention (T2) and follow-up (T3) (36, 35, p=0.01). No intervention effects were observed for any other subscale between T2 and T3.

Table 8. Sedentary Behaviour Health Belief Questionnaire Subscale Scores; Median (IQR)

Subscale (score range)	Baseline (T1); N=71	Post-intervention (T2); N=71	Follow-up (T3); N=71	Mean change (T2-T1)	Mean change (T3-T2)
Perceived Susceptibility (5-25)	13 (11-16)	14.5 (11-16.5)	14 (11-16.5)	**0 (0-2);p=0.01**	0 (0-1); p=0.41
Perceived Severity (5-25)	21.5 (20-24)	23 (21-24)	22 (20-24)	**0 (0-1);p=0.03**	0 (-1)-0; p= 0.11

Perceived Benefits (4-20)	16 (15-18)	16 (15-18)	16 (15-19)	0 (-1)-1; p=0.45	0 (-0.5)-1; p=0.60
Perceived Barriers (7-35)	22.5 (18-26)	23 (19.5-25.5)	24 (20-26)	0 (-1.5)-2; p=0.73	0 (-1)-2; p=0.23
Self-efficacy (2-10)	8 (7-8)	8 (8-8)	8 (7.5-8)	0 (0-0); p=0.93	0 (0-0); p=0.27
Concern for Appearance (4-20)	16 (14-16)	16 (14-17)	16 (14-17)	0 (0-0); p=0.30	0 (0-0); p=0.52
Consideration of Future Consequences (12-60)	36 (33-38)	36 (34-39)	35 (33-38)	0 (-1)-1; p=0.98	**0 (-2)-0; p=0.005**
Self-identity (3-15)	12 (11-15)	12 (12-14)	12 (12-15)	0 (0-0); p=0.96	0 (0-0); p=0.54
Perceived Importance (3-15)	12 (11-13)	12 (11-13)	12 (11-12)	0 (0-0); p=0.89	0 (0-0); p=0.40

Perceived Benefits

Participants were instructed to check all appropriate responses based on what they perceived to be the benefits of changing their SB from a list of 11 potential benefits including an option for 'other'. The top three benefits that participants reported at baseline included 'improve my health' (94.0%), 'make me more active' (83.1%), and 'improve my fitness' (80.6%), which were also indicated among the top benefits at follow-up, with the addition of 'help me maintain a healthy weight' (80.0%). The least frequently reported benefits at baseline included 'allow me to spend more time with friends and family' (26.9%), 'improve my self-esteem' (50.8%), and 'help me lose weight' (50.8%). At follow-up, the same three benefits were least frequently reported at

20.0%, 38.2%, and 47.3%, respectively. Perceived benefits identified as 'other' by participants included reduced muscle stiffness (N=2), joint pain (N=4), and stress (N=1) as well as improved mobility (N=2), and flexibility (N=1).

Perceived Barriers

Participants were instructed to check all appropriate responses based on what they perceived to be the barriers of changing their SB from a list of 12 potential barriers, including an option for 'other'. The top three barriers to reducing SB reported at baseline were 'the nature of my job' (80.6%), 'job workload' (67.2%), and 'not having a standing desk' (58.2%). At follow-up the same three barriers were reported most frequently at 85.5%, 63.6%, and 70.9%, respectively. The least reported barriers at baseline included, 'lack of sleep' (23.9%), 'lack of knowledge about how to reduce my SB' (23.9%), 'stress' (19.4%), and 'inactive friends or colleagues' (14.9%). At follow-up, the least frequently reported barriers included 'stress' (18.2%), 'weather' (18.2%), 'lack of sleep' (10.9%), and 'lack of knowledge about how to reduce my SB' (1.8%). Perceived Barriers identified as 'other' by participants included having young children (N=1), a necessary commute to work (N=2) and driving children to sporting activities (N=1), nature of hobbies (N=1), lack of sidewalks in rural area (N=1), not having support from management (N=2), and chronic pain (N=2).

Cues to Action

Participants were instructed to check all appropriate responses based on what they perceived to be cues to action for changing their SB from a list of 11 potential cues, including an option for 'other'. Cues to action reported most frequently at baseline included 'being prompted/reminded to break up prolonged bouts of sitting' (76.1%), 'having a standing desk' (68.7%), and 'having walking meetings' (67.2%). At follow-up, the most frequently reported cues to action included 'having a standing desk' (80.0%), 'seeing others stand during meetings or during class' (80.0%), and 'being prompted/reminded to break up prolonged bouts of sitting' (80.0%). The least frequently reported cues to action at baseline were 'being reminded of the health benefits of reducing my SB' (26.8%), 'receiving motivational emails or text-messages' (37.3%), 'having a supportive partner at home' (40.3%), and 'avoiding watching television' (40.3%). At follow-up the same four barriers were reported least frequently at 25.5%, 36.4%, 29.1%, and 36.4%, respectively. Cues to action identified as 'other' by participants included support from management at work (N=2), and being free from chronic pain that is relieved when seated (N=1).

Video Evaluation

Results of the video evaluation are summarized in Table 9. Following the intervention, participants were asked to rate the content, design, and impact of the video. Over a third (37.7%) of participants rated the video's content as 'excellent' (5), with a median rating of 4. Median ratings for the video's design, graphics, and music were a 4. Forty-seven percent of participants rated the impact of the video as a 4. Median rating for overall impression of the video was a 4 with close to 32% of participants rating their impression as a 5/5. When asked if they would recommend the video to a friend, 88.5% of participants said 'yes'. Suggestions for improvement included adding audio or voiceover (N=7), increasing the speed of the video (N=5), and shortening the overall length (N=5).

Table 9. Video Evaluation Survey; Frequencies (% Agree)

Video Content	Participant Rating; N=61
Educational	47 (77.1)
Informative	57 (93.4)
Motivational	30 (49.2)
Relevant	41 (67.2)
Engaging	20 (32.8)
Easy to understand	59 (96.7)

Log Data

Participants were asked to fill out a daily log of the previous day's SB. Log data is presented as total daily sitting time in Table 10, and domain-specific sitting time in Table 11. In general, participants reported greater daily sitting time at baseline than at follow-up, and sat less on weekends compared to weekdays. The greatest amount of domain-specific sitting time reported was for completing paperwork at work and at home. Total sitting time on Mondays (p<0.001), Wednesdays (p=0.02), and Thursdays (p=0.01) significantly decreased. Sitting while completing paperwork at work (p=0.002) and hobbies (p<0.001) significantly decreased.

Table 10. Sedentary Behaviour Logs; Total Daily Sitting Time for All Participants; Mean (SD)

	Total daily sitting time (hours)		
	Baseline (T1); N=59	Follow-up (T2); N=59	Mean change (T2-T1)
Monday	11.0 (3.0)	9.4 (2.3)	**-1.6 (3.0); p<0.001**
Tuesday	9.7 (2.7)	9.4 (2.1)	-0.3 (2.6); p=0.37
Wednesday	9.9 (2.7)	9.0 (2.6)	**-0.9 (3.0), p=0.02**
Thursday	10.0 (2.2)	9.2 (2.7)	**-0.8 (2.3), p=0.01**
Friday	9.8 (3.0)	8.9 (2.9)	-1.2 (3.7); p=0.02
Saturday	8.1 (3.0)	8.0 (3.4)	-0.2 (3.9); p=0.52
Sunday	8.3 (2.9)	7.7 (3.1)	-0.65 (2.9); p=0.14

Table 11. Sedentary Behaviour Logs; Total Daily Domain-specific Sitting Time for All Participants; Mean (SD)

	Total time spent sitting per week (hours)		
	Baseline (T1); N=70	Follow-up (T2); N=64	Mean change (T2-T1)
Watching TV	6.5 (5.2)	6.6 (5.4)	0.2 (4.2); p=0.69
Paperwork at work	12.8 (7.7)	11.2 (8.8)	**-2.1 (7.8); p=0.002**
During meals	6.1 (3.9)	6.3 (3.2)	-0.3 (3.2); p=0.82
Paperwork at home	13.3 (8.2)	14.4 (9.8)	0.2 (7.7); p=0.59
Commuting	6.0 (4.5)	6.8 (3.6)	0.2 (3.8), p=0.23
Hobbies	2.1 (3.1)	1.3 (2.1)	**-1.0 (2.8); p<0.001**
Socializing	5.6 (4.6)	5.8 (4.2)	-0.3 (4.0); p=0.71
Reading	1.5 (3.0)	1.4 (2.8)	-0.2 (1.9); p=0.40
Combined activities[1]	3.3 (3.7)	3.8 (4.2)	0.3 (3.5); p=0.70

[1]Combined activities refers to participating in more than one activity while seated (ex. watching TV and eating)

Health Belief Subscale Scores and Changes in Sitting Time

Associations between health belief subscale scores and mean changes sitting time are summarized in Supplemental Tables 8 and 9. No association was observed between any health belief subscale score at baseline (T1) and changes in sitting time between T2 and T3. Perceived benefits (r_s = -0.25, p=0.04) scores at T2 were inversely associated with changes in sitting time from T2 to T3. No other associations between health belief subscale scores and changes in sitting time were observed.

DISCUSSION

The purpose of this study was to determine whether exposure to evidence-based strategies for reducing sitting at home and at work via an educational video altered the health beliefs and reduced daily sitting time of healthy adults working in academic occupations. Following the intervention, participants reduced their weekday sitting by -35.9 minutes/day and weekend sitting by -21.2 minutes/day. Weekday, but not weekend sitting time increased during the baseline log period from T1 to T2 indicating that logging SB may have influenced participants' behaviour. Following the video intervention, both weekday and weekend sitting time decreased and thus it is possible participants decreased their sitting time in response to the intervention. Importantly, the reduction in weekday sitting observed between T2 and T3 (-35.9min/day) exceeded 30 minutes. Replacing 30 minutes of SB with light-intensity activity has been shown to lead to beneficial changes in clinical biomarkers (i.e. Tri-glycerides, insulin levels, and Beta-cell function)[14] and thus exceeding this threshold could be considered an indication of intervention success. These findings are consistent with two recent systematic reviews and meta-analyses.[7,17] The first review (34 included studies) indicated SB-focused interventions were capable of reducing sitting time by -41 minutes/day,[7] while the second (38 included studies) reported an average reduction in sitting time of -30 minutes/day for SB-focused interventions.[17]

Accelerometer data from the 2003-2006 National Health and Nutrition Examination Survey (NHANES) indicates that for less-active individuals (<5.8hrs total activity/day), replacing 1 hour of sedentary time with light or moderate-to-vigorous physical activity is associated with an 18-42% lower risk of mortality.[29] Though no changes were observed for moderate or vigorous physical activity in this study, the IPAQ does not ask participants about the amount of time they spend in light or incidental physical activity. Given the strong inverse association between SB and light physical activity,[30] it is likely that participants in this study displaced sitting time with standing and light ambulation. Changes in light physical activity are beneficially associated with decreased waist circumference and 2-hour plasma glucose levels[30,31] and are thus a desirable outcome for a SB intervention.

Consistent with data from the Canadian Health Measures Survey, SB logs confirmed participants sat nearly 10 hours on weekdays and 8 hours on weekend days.[5] Sitting during occupational tasks contributed the greatest amount of time to domain-specific SB. As expected, adults working in academic occupations reported high levels of SB. This is consistent with evidence from two systematic reviews reporting positive associations between educational attainment, socioeconomic status, and working in a professional role with occupational sitting time.[32,33]

Interestingly, participants who reported a higher BMI at baseline made greater reductions in their weekday sitting time. Given that all participants spent more time sitting during weekdays than weekend days, this finding is very encouraging. A recent review of 10 systematic reviews suggested there is insufficient evidence to conclude there is an association between SB and adiposity from longitudinal studies in adulthood, however SB in childhood and adolescence was linked to higher obesity and increased BMI in adulthood.[34] Frequency of breaks was associated with lower BMI in adults[34] suggesting that breaking up prolonged periods of sitting may be a more important intervention strategy than reducing overall sitting time in overweight and obese adults. Despite that lack of evidence to support a causal relationship between SB and BMI,[34] overweight and obese adults are less likely to meet physical activity recommendations[35] making this population more vulnerable to the deleterious health effects of excessive sitting.[4] Our study results are very encouraging given the importance of reducing SB in overweight and obese adults. More high-quality research examining the effectiveness of SB interventions targeting this at-risk population is needed.

An increase in readiness to change was observed between T2 and T3 indicating that participants were more likely to be prepared to change or were already changing their SB after watching the video. Two studies[36,37] included in a recent systematic review[32] of correlates of SB in adults aged 18-65 years reported a negative association between intention and sedentariness. Based on the evidence, we would have expected Readiness to Change scores to be positively associated with reductions in sitting time; however Readiness to Change scores at T1 were not associated with changes in sitting time. Since no changes were observed after the 1-week logging period, it is possible that it was the combination of logging SB with the video intervention that influenced participant's Readiness to Change. The literature examining intention and SB has produced mixed results. Two studies reported greater intentions to reduce SB to be associated with less

SB[36,38] while one study found no association.[39] Further, two studies found planning to reduce SB to be associated with less SB, however one was conducted in older adults[39] and the other in adolescents.[40] Another study found no association.[34]

Based on the literature, it is likely that reducing SB is intentional whereas engaging in SB is not intentional.[36] Emerging evidence has identified important intra- and interpersonal factors that influence intention to reduce SB.[36] One study that measured the frequency and automaticity of SB habits and intention to reduce SB demonstrated that intention fluctuated with concurrent physical activity and day of the week.[36] In general, individuals with stronger SB habits (i.e. higher frequency and stronger automaticity of SBs) engaged in more SB.[36] The role of perceived control over SB is not yet clear. One study found no relationship between perceived control and intention[37] while another reported an increase in perceived control and confidence in overcoming barriers following a multi-component intervention.[41] To date, there is insufficient evidence to draw conclusions regarding Readiness To Change, intention, planning, and SB.

The aim of the video was to influence viewers' health beliefs and indeed, an increase was observed between T1 and T2 for perceived severity, and susceptibility subscale scores. However, no other changes in health belief subscale scores were observed between T1 and T2. Overall, consideration of future consequences scores were lower at T3 than at T2 indicating that participants were less concerned with the future consequences of their SB by the end of the study. The consideration of future consequences scale has been used to predict a range of health behaviours including healthy eating and exercise.[42] One study conducted both explanatory and confirmatory factor analyses of the consideration of future consequences scale in a sample of college students in the United States.[42] The results indicated that focusing on future consequences was related to a promotional approach to engage in more healthy behaviours, whereas focusing on immediate consequences was related to prevention practices of reducing less healthy behaviours.[42] Consideration of immediate consequences predicted eating behaviour while consideration of more distant, future consequences predicted exercise behaviour.[42] It is possible that the act of changing a negative health behaviour such as SB could make an individual feel less concerned about the future consequences of his or her actions by providing a sense of affirmative action towards their future health. More likely, as suggested in the literature, the value of short-term costs and benefits are more important determinants of preventive health behaviours than the value of long-term consequences.[43] Whether the consideration of immediate consequences is a more important determinant of SB in the adult population than consideration of future consequences is not yet known.

Feedback on the video was generally positive as 93.4% of participants agreed the video was informative and 96.7% agreed it was easy to understand. Despite 88.5% of participants saying they would recommend the video to a friend, engagement and motivational ratings for the video were relatively low at 32.8% and 49.2%, respectively. Several participants suggested increasing the speed of the video and adding voiceover or subtitles to improve engagement. Based on the suggestions for improvement, it is possible the term 'engaging' was confused with 'interactive' when participants were evaluating the video. An interactive video is more likely to encourage viewers' participation, while an engaging video would capture and retain the attention of the audience. The aim of the video developed for this intervention was to be engaging. Further testing of the video with a focus group would help us understand whether the video was indeed engaging, but not interactive, and how we might improve the video to be both. The low motivational rating received on the video evaluation could be explained by the short duration of the intervention. It is possible that a tradeoff exists between time spent engaged in an intervention and the level of participant motivation. A video is a free resource that is only experienced once and for a very brief time, which may not be enough to increase motivation compared to the time and financial investment spent interacting with a health coach, for example.

Strengths & Limitations

The current study is not without limitations. First, the small, homogeneous sample of faculty members, graduate students, and research support staff at a single university is likely not representative of academic workers. SB patterns vary for different occupations within an academic setting[10] and thus generalizability of our study results may be limited. It is possible that due to the education level and research focus on physical function and activity, graduate students and faculty members recruited from McMaster University's School of Rehabilitation Sciences may have been aware of the health effects of SB and had already taken steps to reduce their sitting. Results from a focus group conducted in a similar demographic to the sample included in the present study indicated that middle-aged, female, full-time employees were aware that prolonged sitting was bad for health and that occupational sitting was the biggest contributor to daily SB.[44] For this reason, baseline IPAQ scores helped to capture participant's physical activity and SB status prior to participation in the study. Second, without a control group, the true effect of the intervention on SB cannot be isolated from outside factors. To account for any temporal changes in SB, each participant was asked to log his or her daily sitting time for one week prior to receiving the intervention. We were then able to make a meaningful comparison between a participant's usual SB at baseline and any changes to SB made one week after watching the educational video. Third, all measures were self-reported and are thus subject to recall bias as well as perception bias. Adapting previously validated scales into the SB-HBQ may have introduced measurement error, however we were not able to identify another measure of SB health beliefs. The measures of this study were chosen to maximize adherence and minimize participant burden. Participants were able to complete the questionnaires at their own convenience, in the privacy of their own home or place of work, and the survey completion was easy to assess. Fourth, our study was only two-weeks in duration, which represents a short window of observation into participants' usual pattern of SB and limits our ability to determine whether changes in sitting persisted longer-term. Finally, the intervention was delivered entirely online, making it difficult to ensure participants had watched the entire video, so we are unable to comment on the exposure or dose associated with the intervention. Treatment fidelity could have been compromised should participants have watched some, but not all, of the video. The video was kept to a maximum duration of 5 minutes to minimize participant burden. The number of views (N=83) on the video exceeded the number of participants enrolled in the study (N=76) suggesting that all participants had watched the video at least once, although we cannot be certain as to the number of unique versus repeated video views.

Despite these limitations, web-based interventions offer several advantages including increased: accessibility, data completion, and standardization, as well as reduced cost.[45] This study was designed to be low risk and low burden to appropriately meet the needs of a healthy, working-age adult population. The main strength of this study was that media was successfully used to convey an important, evidence-based, public health message that was well received by its audience. The feedback from participants was very positive overall. The video developed for this intervention has the potential to be scaled up for much larger audiences. It would not be difficult for an employer or organization to circulate the video to its employees or for a healthcare provider to share with his or her patients.

CONCLUSION

A brief, 5-minute educational video influenced health beliefs and reduced daily sitting time in a sample of healthy adults working in sedentary occupations. By the end of the two-week intervention, participants had reduced their total weekly sitting time by nearly 220 minutes. Eighty-eight percent of participants would recommend the educational video to a friend, indicating the intervention was well received. Our video-based intervention was designed to minimize participant burden given the limited time individuals in an academic environment have due to extended work hours and increased occupational demands. This study population was targeted given their increased risk of exposure to SB due to the sedentary nature of academic work. This study is among the first to explore the relationship between health belief constructs and adult SB. It is not clear whether theoretical constructs such as intention and perceived control apply to SB in the same way as for other preventive health behaviours. To further our understanding, interventions that acknowledge the individual-level decision-making processes that influence the intention to become less sedentary on a day-to-day basis need to be undertaken.

Our findings do align with the limited literature on health beliefs and SB, though our results are limited by a lack of control group, use of some author-developed measures, a small sample size, and lack of long-term follow-up. There is a need to develop validated instruments for assessing health belief constructs specific to SB in the adult population. It is not yet clear how changes in health beliefs may influence changes in sitting time. The extended HBM Model, as proposed by Orji et al.[19] has the potential to expand our understanding of the determinants of adult SB and how they might be influenced through intervention. Given the success of our brief video-based intervention, future testing with a more heterogeneous sample over a longer duration is warranted. Further research exploring the relationship and interactions between health belief constructs and SB in adults is also warranted.

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Appendix A

Eligibility Survey

Question 1: Do you wish to participate in this study?
- ☐ Yes
- ☐ No

Question 2: What year were you born?
Answer: _______

Question 3: Please indicate whether you are a:

- ☐ Student
- ☐ Faculty member (including sessional faculty)
- ☐ Support staff (research assistant or coordinator)

Question 4: Do you have any known musculoskeletal conditions that may prevent you from becoming less sedentary?

- ☐ Yes
- ☐ No

Thank you!

If you meet our eligibility requirements our study investigators will be in touch with you shortly.

Appendix B

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE
(August 2002)

SHORT LAST 7 DAYS SELF-ADMINISTERED FORMAT

FOR USE WITH YOUNG AND MIDDLE-AGED ADULTS (15-69 years)

The International Physical Activity Questionnaires (IPAQ) comprises a set of 4 questionnaires. Long (5 activity domains asked independently) and short (4 generic items) versions for use by either telephone or self-administered methods are available. The purpose of the questionnaires is to provide common instruments that can be used to obtain internationally comparable data on health–related physical activity.

Background on IPAQ
The development of an international measure for physical activity commenced in Geneva in 1998 and was followed by extensive reliability and validity testing undertaken across 12 countries (14 sites) during 2000. The final results suggest that these measures have acceptable

measurement properties for use in many settings and in different languages, and are suitable for national population-based prevalence studies of participation in physical activity.

Using IPAQ

Use of the IPAQ instruments for monitoring and research purposes is encouraged. It is recommended that no changes be made to the order or wording of the questions as this will affect the psychometric properties of the instruments.

Translation from English and Cultural Adaptation

Translation from English is supported to facilitate worldwide use of IPAQ. Information on the availability of IPAQ in different languages can be obtained at www.ipaq.ki.se. If a new translation is undertaken we highly recommend using the prescribed back translation methods available on the IPAQ website. If possible please consider making your translated version of IPAQ available to others by contributing it to the IPAQ website. Further details on translation and cultural adaptation can be downloaded from the website.

Further Developments of IPAQ

International collaboration on IPAQ is on-going and an ***International Physical Activity Prevalence Study*** is in progress. For further information see the IPAQ website.

More Information

More detailed information on the IPAQ process and the research methods used in the development of IPAQ instruments is available at www.ipaq.ki.se and Booth, M.L. (2000). *Assessment of Physical Activity: An International Perspective*. Research Quarterly for Exercise and Sport, 71 (2): s114-20. Other scientific publications and presentations on the use of IPAQ are summarized on the website. SHORT LAST 7 DAYS SELF-ADMINISTERED version of the IPAQ. Revised August 2002.

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

_____ **days per week**
☐ No vigorous physical activities ***Skip to question 3***

2. How much time did you usually spend doing **vigorous** physical activities on one of those

days?

_____ hours per day
_____ minutes per day
☐ Don't know/Not sure

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

_____ days per week
☐ No moderate physical activities ***Skip to question 5***

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

_____ hours per day
_____ minutes per day
☐ Don't know/Not sure

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you have done solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?
_____ days per week
☐ No walking ***Skip to question 7***

6. How much time did you usually spend **walking** on one of those days?

_____ hours per day
_____ minutes per day
☐ Don't know/Not sure

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

_____ hours per day
_____ minutes per day
☐ Don't know/Not sure

8. During the last 7 days, how much time did you spend **sitting** on a **weekend day?**

_____ **hours per day**
_____ **minutes per day**
☐ Don't know/Not sure

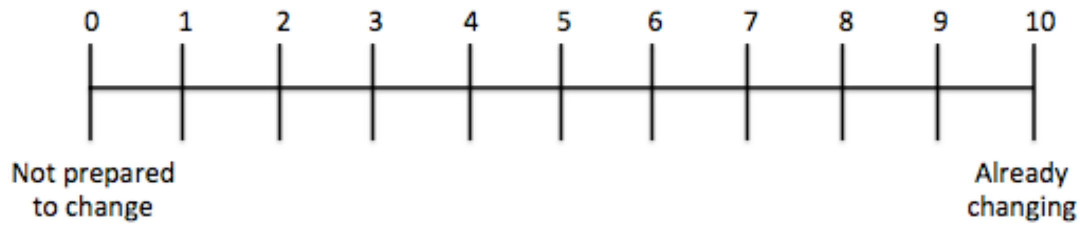
This is the end of the questionnaire, thank you for participating.

Appendix C

READINESS RULER

Below, mark on this line how ready you are to change your sedentary behaviour

Are you not prepared to change, already changing or somewhere in the middle?


0
1
2
3
4
5
6
7
8
9
10
Not prepared to change
Already changing

Appendix D

Sedentary Behaviour Health Belief Questionnaire (SB-HBQ)

The purpose of this questionnaire is to assess your health beliefs surrounding sedentary behaviour. Sedentary behaviour is considered any waking activity performed in a sitting or lying position that requires very low energy expenditure. We are interested in learning about your values and how they affect your thoughts and attitudes towards changing your sedentary behaviour. The questionnaire is broken up into 10 different sections based on important predictors of health behaviour. Please answer the following questions to the best of your ability.

Section One: Perceived Susceptibility

What do you feel is the likelihood you will develop and/or experience each of the following?

	Extremely unlikely (1)	Unlikely (2)	Neutral (3)	Likely (4)	Extremely likely (5)
Cancer					
Diabetes					
Heart disease					
Obesity					
Weight gain					

Section Two: Perceived Severity

How would you rate the seriousness of each of the following?

	Not at all serious (1)	Somewhat serious (2)	Neutral (3)	Serious (4)	Extremely serious (5)
Cancer					
Diabetes					
Heart disease					
Obesity					
Weight gain					

Section Three: Perceived Benefits to Reducing Sedentary Behaviour

A) To what extent do you agree with the following statements:

	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)
Reducing sitting time will prevent future problems for me					
I have a lot to gain by reducing my sitting time					
Reducing sitting time can help lower my risk of developing cardiovascular disease, diabetes, obesity, or cancer.					
I would not be as anxious about cardiovascular disease, diabetes, obesity, or cancer if I reduced my daily sitting time.					

B) Reducing my sedentary behaviour would…

(Check all that apply)

- ☐ Improve my health
- ☐ Improve my appearance
- ☐ Improve my fitness
- ☐ Help me maintain a healthy weight
- ☐ Help me lose weight
- ☐ Reduce my stress
- ☐ Increase my energy
- ☐ Improve my self-esteem
- ☐ Help me sleep better
- ☐ Allow me to spend more time with friends and family
- ☐ Make me more active
- ☐ Other

<u>Section Four: Perceived Barriers to Reducing Sedentary Behaviour</u>

A) To what extent do you agree with the following statements?

	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)
It is difficult for me to reduce my daily sitting time					
In order to reduce my daily sitting time I have to give up quite a bit					
Reducing sitting time will decrease my productivity					
Reducing sitting time will interfere with my work					
Reducing sitting time would require starting a new habit, which is difficult					
I am afraid I would not be able to reduce my sitting time at work					
I am afraid I would not be able to reduce my sitting time at home					

B) Barriers to reducing my sedentary behaviour include…

(Check all that apply)

- ☐ Stress
- ☐ Lack of sleep
- ☐ Lack of motivation
- ☐ Inactive friends or colleagues
- ☐ Nature of my job
- ☐ Commuting to work
- ☐ Not having a standing desk
- ☐ School workload
- ☐ Job workload
- ☐ Weather
- ☐ Awkwardness of standing in class or during meetings
- ☐ Lack of knowledge about how to reduce my sedentary behaviour
- ☐ Other

Section Five: Cues to Reduce Sedentary Behaviour

Which of the following would motivate you to reduce your sedentary behaviour?

(Check all that apply)

- ☐ Having a standing desk
- ☐ Seeing others stand during meetings or during class
- ☐ Wearing an activity monitor (ex. FitBit)
- ☐ Being prompted/reminded to break up prolonged bouts of sitting
- ☐ Being reminded of the health benefits of reducing sedentary behaviour
- ☐ Receiving motivational emails or text-messages
- ☐ Participating in competitive activities or challenges
- ☐ Having a supportive partner at home
- ☐ Avoiding watching television
- ☐ Having walking meetings
- ☐ Standing while talking on the telephone
- ☐ Other

Section Six: Self-efficacy

To what extent do you agree with the following statements?

	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)
If I tried, I am confident that I could reduce my sedentary behaviour most days over the next 7-day period.					
If I wanted to, I feel that I would be able to reduce my sedentary behaviour most days over the next 7-day period.					

Section Seven: Concern for appearance

How important is it to you to…

	Not at all important (1)	Not very important (2)	Neutral (3)	Important (4)	Very important (5)
Be attractive to others					
Be well dressed					
Have good complexion					
Have good posture					

Section Eight: Consideration of future consequences

To what extent do the following statements describe you?

	Extremely uncharacteristic (1)	Somewhat uncharacteristic (2)	Uncertain (3)	Somewhat characteristic (4)	Extremely characteristic (5)
I consider how things might be in the future, and try to influence those things with my day-to-day behaviour.					
Often I engage in a particular behaviour in order to achieve outcomes that may not result for many years.					

I only act to satisfy immediate concerns, I think the future will take care of itself.					
My behaviour is only influenced by the immediate (i.e. a matter of days or weeks) outcomes of my actions					
My convenienc e is a big factor in the decisions I make or the actions I take.					
I am willing to sacrifice my immediate happiness or well-being in order to achieve future outcomes.					
I think it is important to take warnings about negative					

outcomes seriously even if the negative outcome will not occur for many years.					
I think it is t to perform th important ıences than a ı less- ediate					
I generally ignore warnings about possible future problems because I think the problems will be resolved before they reach crisis level.					
I think that sacrificing now is usually unnecessary since future outcomes can be dealt with at a later time.					
I only act to satisfy immediate concerns, as I believe that I will					

take care of future problems that may occur at a later date.					
Since my day-to-day work has specific outcomes, it is more important to me than behaviour that has distant outcomes.					

<u>Section Nine: Self-identity</u>

To what extent do you agree with the following statements?

	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)
I care about the long-term health effects of my behaviour.					
I think about the health consequences of my behaviour.					
I am a health-conscious person.					

<u>Section Ten: Perceived importance</u>

How important is it to you to…

	Not at all importan t (1)	Not very important (2)	Neutral (3)	Important (4)	Very important (5)
Reduce your overall sitting time?					

Reduce your sitting time when you are at work?					
Reduce your sitting time when you are at home?					

Appendix E

Sedentary Behaviour: Previous Day Recall

How much time did you spend sitting (from when you woke up to when you went to sleep) yesterday doing the following?

	None	15 min or less	30 min	1 hr	2 hrs	3 hrs	4 hrs	5 hrs	6 hrs or more
1. Watching television									
2. Doing paperwork or using the computer at work									
3. During meals									
4. Doing paperwork or using your computer at home									
5. Sitting and driving in a car, bus, or train									
6. Doing hobbies									
7. Socializing with friends or family									
8. Reading a book or magazine at home									
9. Combined activities (ex. eating and watching TV). Please specify:									

Appendix F

Video Evaluation Survey:
Strategies for Reducing Sedentary Behaviour at Home and at Work

Instructions: *Please slide the square along the line to indicate your answer*

Section One: Content

A) How would you rate the content of this video?

Poor Excellent

B) Would you consider this video…

(Check all that apply)

- ☐ Educational
- ☐ Informative
- ☐ Motivational
- ☐ Relevant
- ☐ Engaging
- ☐ Easy to understand

Section Two: Design

How would you rate the design of this video?

Totally unacceptable Extremely acceptable

How would you rate the graphics in this video?

Totally unacceptable Extremely acceptable

How would you rate the music in this video?

Totally unacceptable Extremely acceptable

Section Three: Impact

A) How would you rate the impact of this video?

Not at all influential Extremely influential

B) How would you rate your overall impression?

Poor ■ Excellent

C) Would you share this video with a friend?

- ☐ Yes
- ☐ No

<u>Section Four: Feedback</u>

Do you have any suggestions for how this video could be improved?

Supplemental File 1. Sedentary Behaviour Health Belief Questionnaire Subscale Comparison

SELF-IDENTITY	
• Population: Stratified sample (region/gender/SES) of UK citizens • Validity/Reliability: Cronbach's alpha for these three items = 0.82 • REF: Sparks, P, and Guthrie, CA. Self-identity and the Theory of Planned Behavior: A useful addition or an unhelpful artifice? *J Appl Soc Psychol*. 1998;28(15):1393–1410. Doi: 10.1111/j.1559-1816.1998.tb01683.x	
Original	**SB-HBQ**
o I think of myself as the sort of person who is concerned about the long-term health effects of my food choices o I think of myself as someone who generally thinks carefully about the health consequences of my food choices o I think of myself as a health-conscious person	o I care about the long-term health effects of my behaviour. o I think about the health consequences of my behaviour. o I am a health-conscious person.

CONSIDERATION OF FUTURE CONSEQUENCES	
• Population: College students at the University of Missouri • Validity/Reliability: Internal reliability = 0.8-0.86, test-re-test reliability = 0.72 • REF: Strathman, A., Gleicher, F., Boninger, D. S., and Edwards, C. S., 1994. The consideration of future consequences: Weighing immediate and distant outcomes of behavior. Journal of Personality and Social Psychology, 66, 742–752	
Original	**SB-HBQ**
1. I consider how things might be in the future, and try to influence those things with my day to day behaviour 2. Often I engage in a particular behaviour in order to achieve outcomes that may not result for many years. 3. I only act to satisfy immediate concerns, figuring the future will take care of itself. 4. My behaviour is only influenced by the immediate (i.e. a matter of days or weeks) outcomes of my actions. 5. My convenience is a big fact in the decisions I make or the actions I take. 6. I am willing to sacrifice my immediate happiness or well-being in order to achieve future outcomes. 7. I think it is important to take warnings about negative outcomes seriously even if the negative outcome will not occur for many years. 8. I think it is more important to perform a behaviour with important distant consequences than a behaviour with less-important immediate consequences. 9. I generally ignore warnings about possible future problems because I think the problems will be resolved	Exact same

before they reach crisis level. 10. I think that sacrificing now is usually unnecessary since future outcomes can be dealt with at a later time. 11. I only act to satisfy immediate concerns, figuring that I will take care of future problems that may occur at a later date. 12. Since my day to day work has specific outcomes, it is more important to me than behaviour that has distant outcomes.	

CONCERN FOR APPEARANCE

- Population: 18-83 year old suburban Chicago residents
- Reliability: Cronbach's alpha = 0.819
- REF: Hayes, D, & Ross, CE. Concern with appearance, health beliefs, and eating habits. *J Health Soc Behav*. 1987;28(2):120–130

Original	**SB-HBQ**
How important is it to you to… (1) be attractive to the opposite sex, (2) be well dressed (3) have a good complexion and, (4) have good posture?	Exact same

PERCEIVED IMPORTANCE

- Population: 194 Canadian University undergraduate students
- Reliability: Cronbach's alpha = 0.80 (r=0.67)
- REF: Deshpande, S, Basil, MD, Basil, DZ. Facotrs influencing health eating habits among college students: An application of the Health Belief Model. *Health Marketing Quarterly*. 2009;26(2):145-164.

Original	**SB-HBQ**
o How important is it to you to eat a diet high in nutrition? o How important is nutrition to you when you shop for food?	o Reduce your overall sitting time? o Reduce your sitting time when you are at work? o Reduce your sitting time when you are at home?

PERCEIVED BARRIERS

PART 1

- Population: 480 college students from a Midwestern university (mostly Caucasian)
- Test-retest reliability (Kendall's Tau B) = 0.884

<table>
<tr><td colspan="2">REF: King KA, Vidourek, RA, English, L, Merianos, AL. Vigorous physical activit 2014;4(2): 267-9. doi: 10.5628/aehd.v4i2.153</td></tr>
<tr><td>Original</td><td>HBQ</td></tr>
<tr><td>School workload
Lack of motivation
Job
Lack of sleep
Want to do other things with my time
No exercise partner
Inactive friends
Do not enjoy exercising
Social invitations/parties
Too hung over to exercise
Lack of knowledge about how to exercise/workout
Embarrassed to exercise with others
Lack of a place to exercise
Current health problems
Other
Do not think exercising is important</td><td>Stress
Lack of sleep
Lack of motivation
Inactive friends or colleagues
Nature of my job
Commuting to work
Not having a standing desk
School workload
Job workload
Weather
Awkwardness of standing in class or during meetings
Lack of knowledge about how to reduce my sedentary behaviour
Other</td></tr>
<tr><td colspan="2">PART 2
Population: 301 women from a large metropolitan area, mostly white, married, and at least high school education
Reliability: Cronbach's alpha = 0.76
REF: Champion VL. Instrument development for health belief model constructs. ANS Adv Nurs Sci. 1984;6(3):73-85.</td></tr>
<tr><td>It is embarrassing for me to do monthly breast exams.
In order for me to do monthly breast exams I have to give up quite a bit.
Self-breast exams can be painful.
Self-breast exams are time-consuming.
My family would make fun of me if I did self-breast exams.
The practice of self-breast exams interferes with my activities.
Doing self-breast exams would require starting a new habit, which is difficult.
I am afraid I would not be able to do self-breast exams.</td><td>It is difficult for me to reduce my daily sitting time
In order to reduce my daily sitting time I have to give up quite a bit
Reducing sitting time will decrease my productivity
Reducing sitting time will interfere with my work
Reducing sitting time would require starting a new habit, which is difficult
I am afraid I would not be able to reduce my sitting time at work
I am afraid I would not be able to reduce my sitting time at home</td></tr>
</table>

<table>
<tr><td colspan="2">PERCEIVED BENEFITS</td></tr>
<tr><td colspan="2">PART 1
• Population: 480 college students from a Midwestern university (mostly Caucasian)
• Test-retest reliability (Kendall's Tau B) = 0.884
• REF: King KA, Vidourek, RA, English, L, Merianos, AL. Vigorous physical activity among college students: using the health belief model to assess involvement and social support. Arch Exerc Health Dis. 2014;4(2): 267-9. doi: 10.5628/aehd.v4i2.153</td></tr>
<tr><td>Original</td><td>SB-HBQ</td></tr>
<tr><td>o Improving health
o Improving appearance
o Maintaining a healthy weight
o Losing weight
o Improving fitness
o Increasing strength
o Reducing stress
o Increasing energy
o Improving self-esteem
o Enjoyment/fun
o Doing something active with others
o Meeting new people (socializing)
o Learning a new activity/sport
o Increasing dating opportunities
o Other</td><td>o Improve my health
o Improve my appearance
o Improve my fitness
o Help me maintain a healthy weight
o Help me lose weight
o Reduce my stress
o Increase my energy
o Improve my self-esteem
o Help me sleep better
o Allow me to spend more time with friends and family
o Make me more active
o Other</td></tr>
<tr><td colspan="2">PART 2
• Population: 301 women from a large metropolitan area, mostly white, married, and at least high school education
• Reliability: Cronbach's alpha = 0.61
• REF: Champion VL. Instrument development for health belief model constructs. ANS Adv Nurs Sci. 1984;6(3):73-85.</td></tr>
<tr><td>o Doing self-breast exams prevents future problems for me.
o I have a lot to gain by doing self-breast exams.
o Self-breast exams can help me find lumps in my breast.
o If I do monthly breast exams I may find a lump before it is discovered by regular health exams.
o I would not be as anxious about breast cancer if I did monthly exams</td><td>o Reducing sitting time will prevent future problems for me
o I have a lot of gain by reducing my sitting time
o Reducing my sitting time can help lower my risk of developing cardiovascular disease, diabetes, obesity, or cancer
o I would not be as anxious abo cardiovascular disease, diabet</td></tr>
</table>

	obesity, or cancer if I reduced daily sitting time

CUES TO ACTION	
• Population: 480 college students from a Midwestern university (mostly Caucasian) • Test-retest reliability (Kendall's Tau B) = 0.792 • REF: King KA, Vidourek, RA, English, L, Merianos, AL. Vigorous physical activit 2014;4(2): 267-9. doi: 10.5628/aehd.v4i2.153	
Original	**SB-HBQ**
o Wanting to look physically fit o Looking at myself in the mirror o Having an exercise partner o Having a friend who exercises o Seeing spring/summer clothes you would like to buy (i.e. shorts, tank tops, bathing suits) o Being reminded of the health benefits of physical activity o Participating in competitive activities or fitness challenges o Seeing pictures of physically fit people in magazines, TV, or on the internet o Reading about exercise in magazines o Meeting people at recreation/fitness centres o Having a parent who exercises o Watching people exercise on television o Watching exercise channels on television o Learning how to set up an exercise program o Other o Receiving motivational email reminders to exercise	o Having a standing desk o Seeing others stand during meetings or during class o Wearing an activity monitor (ex. FitBit) o Being prompted/reminded to break up prolonged bouts of sitting o Being reminded of the health benefits of reducing sedentary behaviour o Receiving motivational emails or text-messages o Participating in competitive activities or challenges o Having a supportive partner at home o Avoiding watching television o Having walking meetings o Standing while talking on the telephone o Other

PERCEIVED SUSCEPTIBILITY	
• Population: 301 women from a large metropolitan area, mostly white, married, and at least high school education • Reliability (Cronbach's alpha) = 0.78 • REF: Champion VL. Instrument development for health belief model constructs. *ANS Adv Nurs Sci*. 1984;6(3):73-85	
Original	**SB-HBQ**
o My chances of getting breast cancer are great. o My physical health makes it more likely that I will get breast cancer.	What do you feel is the likelihood you will develop and/or experience each of the following?

○ I feel that my chances of getting breast cancer in the future are good. ○ There is a good possibility that I will get breast cancer. ○ I worry a lot about getting breast cancer. ○ Within the next year I will get breast cancer.	○ Cancer ○ Diabetes ○ Weight gain ○ Obesity ○ Heart disease

PERCEIVED SEVERITY	
• Population: 301 women from a large metropolitan area, mostly white, married, and at least high school education • Reliability (Cronbach's alpha) = 0.78 • REF: Champion VL. Instrument development for health belief model constructs. *ANS Adv Nurs Sci*. 1984;6(3):73-85	
Original	**SB-HBQ**
○ The thought of breast cancer scares me. ○ When I think about breast cancer I feel nauseous. ○ If I had breast cancer my career would be endangered. ○ When I think about breast cancer my heart beats faster. ○ Breast cancer would endanger my marriage (or a significant relationship). ○ Breast cancer is a hopeless disease. ○ My feelings about myself would change if I got breast cancer. ○ I am afraid to even think about breast cancer. ○ My financial security would be endangered if I got breast cancer. ○ Problems I would experience from breast cancer would last a long time. ○ If I got breast cancer, it would be more serious than other diseases. ○ If I had breast cancer, my whole life would change.	How would you rate the seriousness of each of the following? ○ Cancer ○ Diabetes ○ Weight gain ○ Obesity ○ Heart disease

Supplemental File 2. Complete cases analysis and additional results tables

Supplemental Table 1. Complete cases analysis International Physical Activity Questionnaire; Mean (SD)

	Baseline (T1); N=63	Post-intervention (T2); N=59	Follow-up (T3); N=54	Mean change (T2-T1)	Mean change (T3-T2)
Weekday sitting time (min)	470.5 (147.3)	494.7 (156.3)	455 (152.9)	31.18 (-3.9, 66.3); p=0.08	**-49.2 (-92.8, -5.6); p=0.03**
Weekend sitting time (min)	330 (135.7)	357.4 (140.4)	326.1 (157.9)	22.04 (-21.0, 65.1); p=0.31	**-38.57 (-82.0, 4.8); p=0.01**
Walking (days/week)	4.82 (2.21)	5.15 (2.08)	5.24 (1.94)	**0.36 (1.86); p=0.01**	0.14 (1.08); p=0.50
Walking (min/day)	48.4 (55.5)	43.2 (37.3)	51.1 (54.2)	2.14 (35.2); p=0.22	5.82 (38.0); p=0.17
Moderate PA (days/week)	2.58 (2.26)	2.12 (2.02)	2.31 (1.66)	-0.37 (1.95); p=0.44	0.38 (1.98); p=0.33
Moderate PA (min/day)	58.1 (64.0)	57.6 (66.2)	58.6 (55.8)	2.24 (82.8); p=0.66	8.80 (70.3); p=0.52
Vigorous PA (days/week)	1.91 (1.74)	2.03 (1.77)	2.04 (1.70)	0.07 (1.55); p=0.79	0.14 (1.37); p=0.51
Vigorous PA (min/day)	53.4 (32.3)	47.2 (48.6)	55.1 (52.3)	-5.85 (46.4); p=0.30	11.8 (50.1); p=0.23

Abbreviation: PA, physical activity

Supplemental Table 2. Complete cases analysis Readiness Ruler; Median (IQR)

Scale (1-10)	Baseline (T1); N=66	Post-intervention (T2); N=59	Follow-up (T3); N=55	Mean change (T2-T1)	Mean change (T3-T2)
All participants	6 (5-7)	6 (5-8)	7 (6-8)	0 (-1,0); p=0.42	0 (0,1); p=0.10

Supplemental Table 3. Complete cases analysis Correlation between Readiness Ruler Scores and Changes in Sitting Time, Mean (SD)

	Change in Sitting Time T2 to T3	
Readiness to Change Scores	Weekday sitting time	Weekend sitting time
Baseline (T1) (N=48)	r_s= 0.04, p=0.78	r_s= 0.08, p=0.60
Post-intervention (T2) (N=50)	r_s=-0.22, p=0.12	r_s= 0.16, p=0.28

Supplemental Table 4. Complete cases analysis Change in Sitting Time from T2 to T3 by BMI and Occupation, Mean (SD)

	Change in Sitting Time between T2 and T3	
Demographic variable	Weekday sitting time (min/day)	Weekend sitting time (min/day)
BMI		
<25kg/m^2 (N=25)	-3.6 (129.7)	-31.2 (13.57)
>25kg/m^2 (N=25)	-94.8 (164.0)	-46.3 (168.3)
Occupation		
Student (N=19)	1.58 (125.9)	-6.31(123.1)
Faculty (N=16)	-67.5 (197.3)	-72 (146.0)
Support staff (N=14)	-94.3 (123.9)	-49.3 (193.2)

Supplemental Table 5. Complete cases analysis Sedentary Behaviour Health Belief Questionnaire Subscale Scores; Median (IQR)

Subscale (score range)	Baseline (T1); N=67	Post-intervention (T2); N=59	Follow-up (T3); N=55	Mean change (T2-T1)	Mean change (T3-T2)
Perceived Susceptibility (5-25)	13.5 (11-16)	15 (11-16.5)	14 (12-17)	**0.5 (0,2); p=0.01**	0 (-1,1); p=0.42
Perceived Severity (5-25)	21 (20-24)	23 (21-24)	22 (20-24)	**0 (0,1); p=0.03**	0 (-1,0); p=0.09
Perceived Benefits (4-20)	23 (18-26)	23 (20-25)	24 (20-26)	0 (-2,1); p=0.47	0 (-1,1); p=0.63
Perceived Barriers (7-	16	15.5	16	0	0

35)	(15-18)	(15-18)	(15-19)	(-2,3); p=0.66	(-2,3); p=0.36
Self-efficacy (2-10)	8 (7-8)	8 (8-8)	8 (7-8)	0 (0,0); p=0.90	0 (-1,0); p=0.06
Concern for Appearance (4-20)	16 (15-16)	16 (14-16)	16 (14-17)	0 (-1,0); p=0.33	0 (-1,0); p=0.36
Consideration of Future Consequences (12-60)	36 (33-38)	36 (34-39)	35 (33-38)	0 (-1,1); p=0.97	**0 (-2,0); p=0.01**
Self-identity (3-15)	12 (11-15)	12 (12-14)	12 (11-14)	0 (-1,1); p=0.90	0 (-1,0); p=0.52
Perceived Importance (3-15)	12 (11-3)	12 (11-12)	12 (11-12)	0 (-1,1); p=0.85	0 (-1,0); p=0.34

Supplemental Table 6. Complete cases analysis Correlations between Baseline Health Belief Subscale Scores and Changes in Sitting Time from T2 to T3

	Change in Sitting Time from T2 to T3	
Health Belief Subscale at T1 (N=66)	Weekday sitting time	Weekend sitting time
Perceived Susceptibility	r_s=-0.18, p=0.21	r_s=-0.13, p=0.39
Perceived Severity	r_s=-0.18, p=0.21	r_s=-0.10, p=0.49
Perceived Benefits	r_s=-0.25, p=0.08	r_s=-0.21, p=0.16
Perceived Barriers	r_s=-0.07, p=0.64	r_s=0.04, p=0.80
Self-efficacy	r_s=0.09, p=0.55	r_s=-0.10, p=0.50
Concern for Appearance	r_s=0.03, p=0.85	**r_s=0.33, p=0.02**
Consideration of Future Consequences	r_s=0.08, p=0.56	r_s=-0.18, p=0.23
Self-identity	r_s=0.03, p=0.85	r_s=0.21, p=0.16
Perceived Importance	r_s=-0.09, p=0.55	r_s=0.03, 0.83

Supplemental Table 7. Correlations between Post-intervention Health Belief Subscale Scores and Change in Sitting Time from T2 to T3

Health Belief Subscale Scores at T2 (N=60)	Changes in weekday sitting time (min)	Changes in weekend sitting time (min)
Perceived Susceptibility	r_s= -0.12, p=0.39	r_s=-0.06, p=0.70

Perceived Severity	r_s=-0.25, p=0.07	r_s=-0.09, p=0.54
Perceived Benefits	**r_s=-0.37 p=0.01**	r_s=-0.17, p=0.24
Perceived Barriers	r_s=0.16, p=0.27	r_s=0.01, p=0.97
Self-efficacy	r_s=-0.22, p=0.13	r_s=0.02, p=0.87
Concern for Appearance	r_s=-0.17, p=0.23	r_s=0.20, p=0.18
Consideration of Future Consequences	r_s=0.02, p=0.90	**r_s=-0.36, p=0.01**
Self-identity	r_s=-0.09, p=0.54	r_s=0.14, p=0.36
Perceived Importance	r_s=-0.15, p=0.31	r_s=-0.01, p=0.93

Supplemental Table 8. Correlations between Baseline Health Belief Subscale Scores and Changes in Sitting Time

	Change in Sitting Time Post-intervention to Follow-up	
Health Belief Subscale Scores at T1 (N=71)	Weekday sitting time	Weekend sitting time
Perceived Susceptibility	r_s =-0.15, p=0.22	r_s =-0.13, p=0.30
Perceived Severity	r_s = -0.13 p=0.30	r_s = -0.01, p=0.92
Perceived Benefits	r_s = -0.17, p=0.15	r_s = -0.04; p=0.72
Perceived Barriers	r_s = 0.02, p=0.86	r_s = -0.08, p=0.51
Self-efficacy	r_s = 0.08, p=0.50	r_s = 0.04, p=0.75
Concern for Appearance	r_s = -0.10, p=0.42	r_s = 0.13, p= 0.27
Consideration of Future Consequences	r_s = 0.11, p=0.37	r_s = -0.09, p=0.45
Self-identity	r_s = 0.02, p=0.90	r_s = 0.21, p= 0.08
Perceived Importance	r_s = -0.07, p=0.55	r_s = 0.12, p=0.33

Supplemental Table 9. Correlations between Post-intervention (T2) Health Belief Subscale Scores and Change in Sitting Time from T2 to T3

	Change in Sitting Time T2 to T3	
Health Belief Subscale Score at T2 (N=71)	Weekday sitting time	Weekend sitting time
Perceived Susceptibility	r_s = 0.17, p= 0.17	r_s = -0.14, p=0.25
Perceived Severity	r_s = -0.19, p=0.12	r_s = -0.04, p=0.72
Perceived Benefits	**r_s = -0.25, p=0.04**	r_s = -0.04, p=0.75
Perceived Barriers	r_s = 0.10, p=0.43	r_s = -0.07, p=0.57
Self-efficacy	r_s = -0.16, p=0.17	r_s = 0.11, p=0.37
Concern for Appearance	r_s = -0.23, p=0.06	r_s = 0.11, p=0.38
Consideration of Future Consequences	r_s = 0.04, p=0.74	r_s = -0.21, p=0.07
Self-identity	r_s = -0.10, p=0.40	r_s = 0.10, p=0.38
Perceived Importance	r_s = -0.12, p=0.33	r_s = 0.07, p=0.58

Chapter 4: Discussion and Implications

Summary

The overall objective of this thesis was to synthesize the literature on context-specific strategies for reducing sedentary behaviour (SB) in the workplace and at home into an educational video that could be used to influence health beliefs and reduce sitting time in healthy adults working in academic occupations. This thesis consists of two related studies. The first study was a systematic review and meta-analysis on strategies to reduce SB at home and in the workplace. This study found environmental strategies to be most effective at reducing daily sitting time followed closely by multi-component strategies, while behavioural strategies were the least effective. However, when the subgroup analysis of multi-component interventions was limited to studies including an activity-permissible workstation, a greater reduction in sitting time was observed compared to either environmental or behavioural strategies alone. Based on the results, it appears activity-permissible workstations may be the 'active ingredient' necessary to the success of multi-component interventions. The second study was a single group pre-post design to determine the effects of an educational video on health beliefs and daily sitting time in a sample of healthy adults working in academic occupations. Strategies to reduce SB at home and in the workplace were synthesized from Study One and incorporated into the video (the intervention) in Study Two. The video intervention increased readiness to change; increased several health beliefs, including perceived susceptibility and perceived severity; and, reduced weekday and weekend sitting time by 35.9 and 21.1 minutes, respectively. Data from participant logs indicated that work-related sitting was the biggest contributor to daily sedentary time for adults working in academic occupations, confirming this is an important population for targeted intervention.

Main Contributions

This thesis has made several substantive contributions to the SB literature. The systematic review and meta-analysis provides further evidence for the efficacy of SB interventions to produce clinically meaningful reductions in sitting time. The video intervention provides preliminary evidence for the efficacy of video-based interventions to influence health beliefs, readiness to change, and daily sitting time in adults working in sedentary academic occupations. The main contributions of each study to the SB literature are discussed below.

The purpose of the systematic review and meta-analysis review was to address several limitations in the literature. Our review was the first to directly compare behavioural, environmental, and multi-component strategies targeting SB that were not limited to the workplace setting. The results of our review point to several important considerations for future intervention designs. First, interventions targeting SB, regardless of setting, were effective in reducing daily sitting time by approximately 30 minutes suggesting that where an intervention takes place may not be important. It is likely that the success of a SB intervention is influenced more by intervention strategy than setting. Second, multi-component interventions that included activity-permissible workstations produced greater reductions in sitting time than environmental or behavioural interventions alone. Our findings suggest that modifying an individual's workstation maximizes the reduction in sitting time produced by multi-component interventions. Third, the effect from all interventions was attenuated after six months, indicating that reductions in sitting time are not sustained by any intervention strategy. None of the studies of environmental interventions reported a follow-up beyond the length of the intervention period, and of these studies the longest intervention lasted 13 weeks. Whether reductions in sitting time would have been sustained for longer periods had participants continued to use activity-permissible workstations is unclear. This finding further underscores our limited understanding of the unique motivational and behaviour change processes associated with reducing SB long-term. Surprisingly, of the 13 studies of behavioural interventions that reported reductions in sitting time, only eight reported using a specific behaviour change framework or theory. Since theory can inform the selection of intervention components and improve the effectiveness of behaviour change,[1-2] the SB literature is hindered by a lack of attention to the integration of theory and theoretical approaches to the planning of SB interventions. Of the 26 studies included in a recent systematic review of behaviour change techniques used in SB interventions, only 11 studies (42%) mentioned a theory of behaviour change.[3]According to this review, interventions that used the most behaviour change techniques showed the most promise. Studies were considered very promising if they reported significant reductions in at least one SB indicator (such as self-reported or accelerometer-derived sitting time) within the intervention group that was greater than observed in at least one comparator arm. The authors argued that identifying strategies associated with promising interventions could help elucidate the possible psychological pathways through which SB might be reduced, and conversely would save intervention developers from exploring unhelpful strategies.[3]

There is sufficient evidence from the current reviews, including our review, that environmental interventions produce meaningful reductions in sitting time. Future work should aim to place environmental restructuring within a causal behaviour change pathway and identify the relevant covariates, mediators, and moderators associated with successful SB change. Studies included in our review that used self-report measures of SB resulted in greater reductions in sitting time than those with objective measures. This finding is not consistent with three other reviews[4-6] that reported greater reductions in sitting time for studies using objective measures. However, this discrepancy may be explained by the fact that self-report measures are susceptible to self-presentation bias.[7] It is possible that individuals felt the need to present their behaviour in a more favourable way to be more consistent with societal expectations.[7] Ideally, future interventions would integrate multiple sources of assessment, including both observed and reported measures, to enrich the data being captured, and to help to identify possible opportunities for intervention that would otherwise be missed by relying on one source of information. For example, although observed measures of sedentary time indicate the intensity of a participant's activity, they do not identify where the participant is or what they are doing while sedentary. Without the relevant contextual information, it is difficult to assess whether a period of sedentary time was amenable to intervention, say watching TV, or beyond the participants control such as driving a car to commute from home and from work.

Attention to cultural and gender differences that may influence SB patterns and the subsequent success of interventions is lacking. Of the 38 studies included in our review, only one study was designed to be culturally relevant to the target population[8]. To date, there is insufficient evidence to conclude about the effectiveness of culturally relevant SB interventions compared to more generic interventions, however this is an important direction for future research. Only 4 studies in our review were conducted with women only and none with men only. The results of one systematic review and meta-analysis of SB interventions indicated a subgroup difference for gender.[5] Studies with men only (N=2, 434 men) resulted in reductions in sedentary time in favour of the intervention group, while studies in women only (N=10, 1541 women) did not observe a reduction in sitting time.[5] However, of the 12 studies included in the subgroup analysis, only four targeted SB as the primary outcome, one of which was with men only and the other three with women only. The difference observed between genders could be explained by the fact that reducing SB was not the primary aim for most of the included studies.[5]

Although our review focused on adults 18-65 years of age, a clear next step would be to investigate SB interventions in older adults. To our knowledge, no such review exists. Finally, studies rated as low quality in our review resulted in greater reductions in SB than studies rated as higher quality. Another review of SB interventions performed a subgroup analysis based on study quality and found no difference,[4] however only 7 studies were included in the analysis compared to 35 in the present analysis. The subgroup analysis of one other review reported a greater reduction in sitting time for studies rated as good-to-high quality compared to studies rated fair.[6] However, only two of the 21 studies included in the review were rated as high quality.[6] Further, although the criteria for rating methodological quality were outlined, it was not clear how overall quality score was determined. Despite the inconsistency in results between reviews, high-quality SB intervention studies are clearly lacking in the literature. Currently the quality of SB intervention studies is downgraded in most reviews because of issues such as inadequate descriptions of group allocation[6] and allocation concealment,[4,6,9] lack of blinding of: participants,[4-5,9] personnel delivering the intervention,[4,9] and those assessing outcomes,[4] lack of control for baseline SB,[6] and imprecision of results.[4-6,9] To improve the overall quality of the evidence base, future intervention designs should strive to minimize these sources of bias.

The purpose of Study Two was to determine the influence of an educational video on strategies to reduce SB at home and in the workplace on health beliefs and daily sitting time in adults working in academic occupations. The evidence about strategies to reduce SB synthesized from Study One informed the content of the video intervention. The intervention was successful in terms of increasing readiness to change, influencing some health beliefs, and reducing daily sitting time. Our intervention could be considered innovative, as the literature on video-based SB interventions is sparse. A 2012 systematic review examining the effectiveness of videos for modifying health behaviours included 28 studies, none of which targeted SB.[10] To our knowledge this is the first study to use a video to influence, not only health beliefs, but also SB in a sample of adults. Our brief, 5-minute video has the potential to be up-scaled for larger audiences. Based on our initial success using the video to influence the health beliefs and daily sitting time of adults working as graduate students, faculty, and research support staff within the rehabilitation sciences, we are encouraged to test the video with different faculties and departments across the university setting. It is possible our target population as faculty, graduate students, and administrative staff within a School of Rehabilitation Science, differs in their motivation to reduce SB compared to individuals in other faculties based on their professional focus on mobility and function. We acknowledge several areas for improvement that can be gleaned from the systematic review on video-based education interventions described above. The results of the review indicated that the use of modeling and message-framing may play a greater role in the success of video-based interventions than other factors such as theoretical frameworks.[10] Gain-framed, as opposed to loss-framed, (e.g. focusing on the benefits of reducing SB rather than the harms associated with SB) messages may be more effective in promoting certain types of behaviour.[10] Modeling refers to the demonstration of desired behaviours through visual representation.[10] Modeling was found to be more effective when videos were designed to be culturally relevant to the target population.[10] Together with participant feedback, our video could be improved by paying special attention to gain-framed messaging and tailoring our video to the target audience. For example, to tailor our video more specifically to academic audiences we could focus on the strength of the evidence for each strategy rather than focusing on the strategy itself. As well, our video could have featured a faculty member or graduate student demonstrating the strategies to reduce SB instead of an animated character.

Although the relationships between health belief constructs and SB are not yet clear, our intervention added to some of the understanding. We acknowledge that the psychometric properties of the health belief questionnaire developed for this study have not been tested.

No assessment tool was available and the development of such an assessment tool was beyond the work of this thesis. The modifications that were made from previously validated health belief questionnaires were relatively minor and the item stems remained unchanged, but referred to SB as opposed to nutrition or exercise. Therefore, it may be unlikely that the established psychometric properties were altered to any large degree. However, the present study (Chapter 3) does provide preliminary evidence for a relationship between several health belief constructs and sitting time. As one of the few studies to use behaviour change theory to inform a SB intervention, our results warrant further investigation. First, the psychometric properties of the instrument developed for this study need to be identified. Next steps include confirming the utility of the model by investigating whether changes in health beliefs predict changes in SB. Evaluations of how health beliefs change in reaction to different SB intervention strategies, how beliefs change over time, and how positive changes can be sustained will further contribute to our understanding of how to best decrease SB.

Due to the limitations of measuring SB with the International Physical Activity Questionnaire (IPAQ),[12] even though weekday and weekend sitting time decreased following the video intervention, it is not clear whether participants reduced the number of prolonged bouts of SB or the duration of each bout, and whether sitting time was displaced by standing or light physical activity. The IPAQ asks participants to indicate the total amount of time spent sitting on a typical weekend and weekday within the last 7 days.[12] Based on the results of the terminology consensus project described in Chapter One, it is important that more comprehensive measures of SB be developed and tested in the adult population. To further our understanding of how SB interventions influence behaviour, future questionnaires should include assessments of physical inactivity, stationary behaviour, screen and non-screen-based sedentary time, standing, and breaks from SB. Ideally, future interventions would employ both direct and reported measures to fully capture relevant contextual factors, postures, and energy expenditures associated with participants' SB.

Strengths and Limitations

This is the first review to synthesize strategies to reduce SB within, and beyond, the workplace environment; as well, we have undertaken a study that is the first to incorporate a SB health beliefs questionnaire and to use a video-based intervention to reduce daily sitting time in healthy adults working in an academic environment. The strengths of this thesis include the large number of studies included in the systematic review and meta-analysis (all of which targeted SB), and the incorporation of the evidence-based strategies identified in the review into the educational video intervention. Results of the systematic review and meta-analysis were limited by the overall low quality and substantial heterogeneity observed between studies, though using a random-effects meta-analysis model and performing multiple subgroup analyses enabled us to adjust for these issues. Based on our findings, several recommendations for future research can be made. First, more high-quality research confirming the importance of activity-permissible workstations for the success of multi-component interventions is needed. Second, including both observed and reported measures within SB intervention studies will further our understanding about the nature and context of SB as influenced by environmental, behavioural, or multi-component interventions. Finally, we encourage the exploration of behaviour change strategies and delivery methods more suitable for home and leisure environments.

Limitations of the intervention study include the small, homogeneous sample of university faculty, graduate students, and administrative staff; the reliance on self-report measures of sitting time; the possibility of measurement error introduced by modifying scales for the health belief questionnaire and lack of validation of this instrument; the short-term duration of the intervention representing a relatively short window for observation of participants' behaviour, and, lack of longer-term follow-up. Ultimately this study was designed to maximize adherence and minimize participant burden. Despite the limitations, this study demonstrated that a brief video-based intervention influenced several health beliefs and reduced daily sitting time in a sample of adults working in sedentary academic occupations. Moreover, the intervention was well received by study participants.

Public Health Implications

In summary, based on the high prevalence, associated health risks, and evidence for successful intervention, SB should be prioritized as a public health issue. This will require collaborative efforts from city planners, architects, researchers, educators, policy makers, community advocates, the private sector, and the community population itself. According to the behavioural epidemiology framework[13] presented in Chapter One, efforts can be simultaneously targeted at each of the five phases of the SB research agenda. Phases 1-3 require further research and testing while Phases 4-5 require evaluation and translation of knowledge. To further the knowledge body in Phases 1-3, collaborative research efforts are needed. Together, researchers from the health, social, and life sciences can help to further our understanding of the association between SB, disease risk, and premature mortality. Further exploration of mechanistic factors is also needed. Approaches from health psychology and anthropology can be applied to help elucidate determinants and influences of SB for different age groups, ethnicities, and nationalities. Technologies developed through collaboration between the health and computer sciences may enhance our capability to measure SB more accurately and with greater depth of information. Efforts to tackle Phase 4 may benefit from participatory action approaches that involve participants in the iterative process of intervention development, testing, and evaluation. In the real-world setting, community populations, community planners, and architects can help identify opportunities to alter the built environment to encourage standing and light physical activity, as well as ways to support active transportation. To identify such opportunities, city planners will require support from municipalities and community advocates. Together, members of parliament and not-for-profit organizations such as the YMCA and Heart and Stroke Foundation, may also act as advocates and support networks for community initiatives. Phase 5 requires that current evidence be translated into practice. This necessitates education and training for health professionals and policy-makers. Although there is insufficient evidence to quantify SB recommendations, encouraging adults to reduce their SB and replace it with light physical activity is warranted, and developing a SB guideline for Canadian adults seems a logical next step. Policy-makers and private-sector employers could then use the guideline to make recommendations for reducing SB in schools and workplaces. Media could reinforce this message by advertising a 'sit less, move more' message in public places. Workplace and community champions can act as role models helping to change social norms. Standing on public transit or in meetings and classes is one way to encourage others to do the same. All together, there are many opportunities to further the SB research agenda. It is important to recognize that SB is pervasive in everyday life and is strongly reinforced by social norms. Efforts to reduce sedentariness in the adult population will necessitate collaboration from a wide variety of disciplines.

Concluding Thoughts

Together with the results of our systematic review and meta-analysis, our findings provide preliminary evidence for the use of video-based interventions to influence health beliefs and reduce daily sitting time in healthy adults working in academic occupations. It is possible that combining a brief video intervention with the provision of activity-permissible workstations could lead to greater reductions in occupational sitting time, however this may not be feasible for all employers. Evaluations of the cost-effectiveness of activity-permissible workstations are needed. Although promising, environmental interventions are by definition limited to a certain environment. The pervasive nature of SB requires flexible and adaptive solutions that appropriately meet the needs of different age groups. Further exploration of the psychosocial determinants of SB will enhance our understanding of the process through which SB is influenced and how this process may be mediated by age, ethnicity, and socioeconomic status. Many opportunities exist for influencing SB in the adult population. Identifying these opportunities requires collaboration between researchers, health professionals, and community members.

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