Examining the Relationship between Exercise and Sedentary Behaviour among Cardiac Rehabilitation Patients to Inform Intervention Strategies

by

Aviroop Biswas

A thesis submitted in conformity with the requirements for the degree of Doctor of Philosophy

Institute of Health Policy, Management and Evaluation, University of Toronto

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Abstract

Prolonged time in sedentary behaviours is associated with cardio-metabolic disease risk and mortality in adult populations. Yet, the association between sedentary behaviour and exercise participation on health outcomes is unclear. Six inter-related studies were conducted in the pursuit of the following objectives: to understand the risks and determinants of sedentary behaviour among patients participating in exercise-based cardiac rehabilitation (CR), and inform the development of sedentary behaviour interventions among these individuals. Prolonged sedentary time was found to be associated with cardio-metabolic disorders and mortality independent of physical activity, with greater mortality risks for those with low physical activity levels compared to those with greater levels. Among CR patients, exercise participation did not influence their sedentary time and were found to be highly sedentary (>8 hours per day) at the initiation of, and throughout CR, irrespective of whether physical activity guidelines were met. Patients and staff placed a lower priority in reducing sedentary behaviour than improving physical activity and other health behaviours. Intrapersonal factors (biological,
psychological), and environmental factors (behaviour settings, the information environment, social-cultural factors, natural environment) were perceived to be facilitators of sedentary behaviour, and barriers to reducing sedentary behaviour. It was also determined that the exercise focus of CR might be beneficial to individuals who are unable to reallocate sedentary time to exercise and light physical activity. Alternatively, a focus on light-intensity physical activity alone may be suitable for those patients who are unable to participate in exercise. Lastly, it was found that CR programs do not benefit all patients equally, and an intervention strategy must be individually targeted. Taken together, these findings contribute towards a better understanding of whether prolonged sedentary time is a distinct health risk factor, and inform the development and pilot testing of future sedentary behaviour interventions for CR patients.
This dissertation is dedicated to my grandma Dr. Jyotsna Roy Choudhury (“mummum”).

Thank you for sparking my sense of wonder, curiosity, and enthusiasm for learning.
You are the best teacher and friend I ever had.

_I miss you everyday._
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Contributions

The candidate takes full responsibility for the contents of this thesis. With guidance and contributions from his thesis committee (Dr. David Alter, Dr. Paul Oh and Dr. Guy Faulkner), the candidate conceived the research objectives, developed the study protocols, recruited the participants from the UHN-Toronto Rehabilitation Institute Cardiac Rehabilitation and Secondary Prevention Program, conducted all of the interviews and data collection, performed all of the data analysis, and wrote this manuscript.

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List of Acronyms

Cardiac Rehabilitation (CR)

Confidence Interval (CI)

Hazard Ratio (HR)

Kilocalories (Kcal)

Light-Intensity Physical Activity (LIPA)

Metabolic EquivalenT (MET)

Moderate to Vigorous-intensity Physical Activity (MVPA)

Number Needed to Treat (NNT)

Physical Activity (PA)

Rhythmic Auditory Stimulation (RAS)

Sedentary Behaviour (SB)

Sedentary Behaviour Questionnaire (SBQ)

Theory of Planned Behaviour (TPB)

Toronto Rehabilitation Institute (TRI)

TransTheoretical Model (TTM)

University Health Network (UHN)
Chapter 1

1 Introduction, Background, Rationale & Research Objectives

1.1 Introduction

Inadequate physical activity is widely recognized as an independent, modifiable risk factor for the premature development of cardiovascular disease, type 2 diabetes, certain cancers, and other health disorders (Lee, Shiroma et al. 2012). Accordingly, the promotion of moderate to vigorous-intensity physical activity (MVPA) has historically been a key component of primary/secondary disease prevention and lifestyle management strategies (Giannuzzi, Mezzani et al. 2003). Yet, MVPA only accounts for a small proportion of an average adult’s waking day, with the majority (approximately 70%) usually spent in sedentary behaviours characterized by sitting-based activities such as watching the television, sitting while working, reading, and driving a car (Troiano, Berrigan et al. 2008, Colley, Garriguet et al. 2011). This lifestyle is potentially a serious public health concern given the relatively recent proliferation of research showing a relationship between prolonged sedentary time and various cardio-metabolic risk markers and negative health outcomes, with different physiological mechanisms of action from physical inactivity (Owen, Sparling et al. 2010, Tremblay, Colley et al. 2010). As such, it is becoming commonly accepted that sedentary behaviour is a novel modifiable health risk factor (Pate, O’Neill et al. 2008).

While research studies increasingly highlight the need to reduce prolonged sedentary behaviours in addition to engaging in MVPA, many important questions must be answered before interventions and public health/clinical strategies can be implemented. Foremost, more
compelling evidence is needed to determine whether prolonged sedentary time is in fact a causal risk factor for health outcomes. However, determining causality can be challenging and few high quality, controlled studies exist to explain the associations between prolonged sedentary time and cardio-metabolic risk markers, and none explain disease onset (Proper, Singh et al. 2011, Thorp, Owen et al. 2011). Alternatively, risk factor causation can be strengthened by examining whether there are strong associations with health outcomes when important confounders are controlled, uncovering dose-response relationships, examining underlying physiological mechanisms, and if similar relationships exist for different populations (Furberg, Hennekens et al. 1996). In addition, the effectiveness and benefits of interventions to reduce sedentary time are not fully understood, and intervention trials and studies gathering experimental evidence are the next crucial elements on the sedentary behaviour research agenda (Owen 2012).

This thesis aimed to advance the field of sedentary behaviour research by gathering comprehensive evidence to unravel the associations between sedentary behaviour and MVPA participation on health outcomes in order to make a case for prolonged sedentary time as a distinct modifiable health risk factor. In addition, the nature of a future intervention and who to target for the intervention to be effective are also informed. The next section provides a brief overview and background of what was known in the field of sedentary behaviour research upon undertaking this dissertation, and this is followed by the rationale and objectives for the research studies undertaken.
1.2 Background

1.2.1 Physical Activity and Health

It is well established that regular moderate to vigorous-intensity physical activity (MVPA) (herein, the terms exercise and MVPA will be used interchangeably as exercise can refer specifically to intentional physical activity carried out for health purposes) contributes to the prevention and risk-attenuation of several chronic diseases (such as cardiovascular disease, type 2 diabetes and certain cancers), psychological distress, and premature death (Lee, Sesso et al. 2003, Katzmarzyk, Rhodes et al. 2007). These benefits are largely due to the increased physical fitness (cardiovascular fitness, musculoskeletal fitness, body composition and metabolism) of individuals engaged in MVPA (Warburton, Nicol et al. 2006). The linear relationship between the total duration of MVPA and health status suggests that those who are the most physically active are likely to be at lowest risk for negative health outcomes. However, the greatest improvements in health status have been seen when the least-fit become physically active and subsequently more fit (Erikssen 2001). Moreover, a recent meta-analysis of previous studies showed that individuals who engage in the equivalent of 150 minutes per week of MVPA have a 15% to 20% lower risk of developing coronary artery disease than those who undertake no leisure time physical activity (Sattelmair, Pertman et al. 2011, Woodcock, Franco et al. 2011). It is important to note that even individuals who did 75 minutes of moderate-intensity physical activity per week had reduced risk of cardiovascular disease, which lends credence to the notion that some physical activity is better than none and that additional benefits occur with more physical activity (Sattelmair, Pertman et al. 2011).
Several physiological mechanisms may explain why MVPA reduces the risk of, and improves survival from chronic disease. For example, regular MVPA has been shown to improve body composition (e.g., through reduced abdominal adiposity and improved weight control), enhance lipid lipoprotein profiles, improve insulin sensitivity, reduce blood pressure, improve autonomic tone, reduce systemic inflammation, improve arterial blood flow, augment cardiac function, and enhance endothelial function (Warburton, Nicol et al. 2006). As such, Canadian and many international health recommendations advocate for general adult populations to participate in a minimum weekly duration of 150 minutes of MVPA or an average weekly energy expenditure of about 1000 kcal to achieve health benefits (Canadian Society for Exercise Physiology 2013).

While cardio-metabolic health benefits tend to increase with the intensity of activity, the volume of physical activity diminishes with increasing intensity. Being more common than MVPA, light-intensity physical activities (LIPA) [1.6 to 2.9 METs] such as in leisurely walking and performing light housework may be more readily attainable and easier to promote than MVPA. There is evidence to suggest that accumulated LIPA, apart from increasing overall daily energy expenditure (Ainsworth, Haskell et al. 2011), increase muscular activity to boost healthful metabolic change (Powell, Paluch et al. 2011) and lower blood glucose levels (Healy, Dunstan et al. 2007). As such, some physical activity is better than none and increasing the overall daily volume of activity is likely to provide additional health benefits. Furthermore, older populations participating in LIPA for at least 300 minutes or more were found to be 18% healthier overall than peers with low levels of LIPA (Healy, Matthews et al. 2011). Given these health benefits and the possibility that older and clinical populations may be reluctant to participate in MVPA because of health concerns and fear of injury (Bann, Hire et al. 2015), LIPA may be an important
first step in increasing MVPA participation and more preferable to sitting and sedentary
behaviours.

1.2.2 Sedentary Behaviour and Health

Prevalence studies have shown that adults typically spend their non-exercise time in two states:
1) sedentary behaviour, defined as sitting, lying down, and expending very little energy
(approximately 1.0-1.5 metabolic equivalents [METs]), and 2) light-intensity physical activity
(LIPA), such as standing, slow walking, and activities of daily living (approximately 1.6-2.9
METs) (Hagstromer, Oja et al. 2007, Troiano, Berrigan et al. 2008). However, it is in sedentary
behaviours that adults spend the majority of their waking day (Matthews, Chen et al. 2008,
Colley, Garriguet et al. 2011). Such a lifestyle trend is particularly worrying as mounting
evidence suggests that prolonged sedentary time and not simply the absence of MVPA may be
associated with an increased risk for cardio-metabolic disorders and all-cause mortality (Wilmot,
Edwardson et al. 2012).

The body of epidemiological evidence on the adverse health outcomes associated with sedentary
behaviour is accumulating rapidly. Yet, little is known about the physiological and cellular
mechanisms that cause the hazards associated with prolonged sedentary time in humans, where
the physiological evidence have been primarily based on animal models. Contractile inactivity of
the skeletal muscles and the activity decline of certain metabolic enzymes have been postulated
as potential mechanisms (Hamilton, Healy et al. 2008). During standing, postural muscles
(predominantly of the lower limbs) are continually contracting in order to keep the body upright
and prevent a loss of balance. Frequent contractions in these muscle groups are largely absent
while an individual is sedentary. In animal studies, these changes have been shown to lead to poor metabolic health, where skeletal muscle lipoprotein lipase production necessary for the breakdown of certain fats in the bloodstream is suppressed. This can cause elevated levels of triglycerides along with the reduced breakdown and use of glucose leading to elevated levels in the bloodstream (Hamilton, Etienne et al. 1998, Hamilton, Healy et al. 2008). This is usually accompanied by weight gain and obesity and may explain why sedentary time is associated with metabolic syndrome, insulin resistance, certain obesity-related cancers (such as colorectal and endometrial cancers), and type 2 diabetes (Hamilton, Hamilton et al. 2007). In addition, individuals spending long periods of time in sedentary behaviours may already be smokers, have unhealthy diets, or other lifestyle factors that enhance the risk for chronic diseases and cancer (Schmid and Leitzmann 2014).

In contrast, there is much larger evidence to suggest that regular MVPA has a protective dose-response relationship with the risk of various chronic diseases, where different enzymes and genes are influenced. Accordingly, some have hypothesized that the specific cellular and molecular mechanistic pathways that explain the effects of sedentary time and physical inactivity (inadequate physical activity) are different (Hamilton, Etienne et al. 1998). Critically, it is thought that sedentary behaviours and physical inactivity differ enough that sedentary behaviour can no longer be considered to be at the lowest end of the physical activity continuum. As a substantial portion of an individual’s daily routine and a significant but largely overlooked component of an individual’s total weekly energy expenditure, light-intensity activity may be a good alternative to decrease the length of inactivity for people unable or willing to increase their moderate-vigorous physical activity levels (Healy, Dunstan et al. 2007).
1.2.3 Behaviour Change

Several behaviour change theories feature prominently in the field of ‘activity psychology’ and physical activity motivation. These include the Theory of Planned Behaviour (TPB), the Trans-theoretical Model (TTM) and the Behavioural Choice Theory (Ajzen 1991, Bandura 1991, Prochaska and Marcus 1994). As the maintenance of physical activity and health behaviours continues to be problematic, an increasing number of physical activity and lifestyle interventions such as cardiac rehabilitation programs (CR) are informed by behaviour change models to improve their effectiveness (Bock, Albrecht et al. 1997). For example, the TTM model proposes that individuals move through a series of sequential steps or “stages” while adopting a new behaviour. In addition to examining behaviour change as a dynamic rather than fixed process, the model allows interventions to be matched to an individual’s stage of motivational readiness (Prochaska and Marcus 1994). The TPB proposes that individuals will intend to perform a behaviour when they evaluate it positively, believe that it is important that others think they should perform it, and perceive it to be under their control (Ajzen 1991). As it has been shown that exercise intention accounts for a significant variance in exercise behaviour, the TPB model can be useful to understanding the determinants of exercise intentions in CR programs (Blanchard, Courneya et al. 2002).

While these models have been widely studied and applied to physical activity-based interventions, specialized behavioural theory to explain ‘sedentary psychology’ are sparse in comparison (Biddle 2011). The major utility of the TTM and TPB is in an individual’s intention to change their behaviour. However, it is uncertain whether intention plays as significant of a role in sedentary behaviours due to emerging research suggesting that sedentary behaviours are
largely influenced by habit and not by conscious decision-making (de Bruijn, Kremers et al. 2009). Amidst the absence of behavioural change theories specifically for sedentary behaviour, an ecological framework has been outlined to highlight the multiple levels of influencers of sedentary behaviour in certain settings (Owen, Sugiyama et al. 2011). Adopted from a model applied to physical activity, the framework is based on empirical evidence and suggests that sedentary behaviours are context and environment-specific with manifold determinants including individual, social, organizational/community, environmental, and policy. The ecological framework holds promise for studies aiming to understand the particular domains that may discourage, encourage or reinforce sedentary behaviours. Importantly, the framework address the intention-behaviour gap, where it is thought that intentions alone cannot completely lead to behaviour change but should be supplemented and supported by external and environmental influences. Furthermore, this ecological model is closely tied to Social Cognitive Theory (Bandura 1991) which is a prominent behaviour change theory used extensively to design physical activity programs for older adults and clinical populations (Booth, Owen et al. 2000, Lee, Arthur et al. 2008, Ashford, Edmunds et al. 2010). The premise of social cognitive theory is that individuals learn not only through their own experiences but by also observing the actions of others and the results of those actions.

To date, few studies have examined the impact of prolonged sedentary behaviour on subsequent levels of spontaneous physical activity (or vice versa). It has been suggested that physical activity may be centrally controlled by an “activitystat” such that individuals unconsciously increase or decrease their activity level to match energy intake or other internal cues (Gomersall, Rowlands et al. 2013). If true, this would suggest that adults could increase their physical activity
levels following a period of prolonged sitting. In support of this hypothesis, it has been reported that the introduction of structured physical activity may fail to increase (Gomersall, Norton et al. 2015), or may even reduce (Baggett 2008) total physical activity levels as a result of reductions in spontaneous physical activity and increases in sedentary behaviour. However, the impact of prolonged sedentary time on subsequent physical activity levels is presently unknown.

1.2.4 Measuring Sedentary Behaviour

The measurement of sedentary behaviour is evolving and it is still considered to be in the early stages in comparison to physical activity measurement (Atkin, Gorely et al. 2012). Sedentary behaviour can be measured both subjectively and objectively.

Subjectively

The majority of self-reported questionnaires to measure sedentary behaviour have relied on measuring overall television viewing time (Bryant, Lucove et al. 2007, Clark, Sugiyama et al. 2009). Many of the questionnaires used to capture television viewing time have not reported reliability and validity data, and in those that have provided data for adults, reliability was found to be high (test-retest $r=0.32$-$0.93$), but concurrent validity was highly variable ($r=0.19$-$0.80$) (Clark, Sugiyama et al. 2009). Another major limitation of measuring television viewing time is that it may not necessarily capture all the domains of sedentary behaviours and overall sedentary behaviour (Sugiyama, Healy et al. 2008, Biddle, Gorely et al. 2009).

Total daily sitting time has been measured in self-report questionnaires but their use and measurement properties have not been widely demonstrated in research studies as yet (Marshall,
Miller et al. 2010). Comparison of test–retest results in adults does not clearly demonstrate that one recall period or administration format is superior to another. There is some evidence that concurrent validity may be better in adults when participants recall a typical day compared with a 7-day or 12-month recall period. However, these observations derive from studies in different populations and use different referent measures (Clark, Sugiyama et al. 2009). The strengths of self-report questionnaires are that they are cost-effective, readily accessible to the majority of the population and have a relatively low participant burden. Self-report tools can also be used to identify the type of behaviour and the context in which it occurs, information that may be used to inform intervention design. A key limitation of self-report measures is that they consistently demonstrate poor validity. A major impediment to establishing validity is the lack of an accepted ‘gold standard’ referent measure of sedentary behaviour (Rennie and Wareham 1998). A further limitation of self-report tools is that they are vulnerable to influence by cultural norms and perceived social desirability. Further, measuring sedentary behaviours can be complicated by concurrent behaviours such as when an individual can be watching the television and using their cell phone at the same time). Therefore, data collection using global measures of self-reported sedentary behaviour rather than specific behaviour types may have greater utility. Although subjective measures of sedentary behaviour have low participant burden and are generally cost- and time-efficient, they are also prone to recall and social desirability bias (Atkin, Gorely et al. 2012). Depending on the specific study, these biases can result in an overestimation or underestimation of the true associations between sedentary behaviour and other variables (Reilly, Penpraze et al. 2008).
Objective

Objective measures are believed to provide more accurate estimates of sedentary behaviour because they are less prone to many of the reporting biases of subjective measures (Carr and Mahar 2012). However, the high cost of many accelerometer devices (both for the device and software licensing) has limited their use in the majority of population-based studies. One commonly used device for sedentary behaviour (and physical activity) measurement is the accelerometer. Accelerometers are small lightweight devices that are usually worn on an elastic belt positioned on the hip or lower back. Accelerometers measure the frequency and amplitude of acceleration of the body segment to which they are attached and often integrate this information in the form of movement “counts” (Chen and Bassett 2005). Accelerometers can be used to estimate the total volume of sedentary behaviour through the accumulation of low movement counts at specified cut points. They can also be used to detect short incidental breaks in sedentary time defined by periods where movement counts exceed the specified threshold which may not be feasibly recorded by self-report measures (Healy, Dunstan et al. 2008). In addition, as the collected information include time stamps, specific segments of the day or week can be extracted such as time at work. A key limitation of traditional (count-based) accelerometers as a measure of sedentary behaviour is that they assess intensity of movement and thus are less able to distinguish between low-intensity postures such as sitting and lying or standing still. Consequently, periods of standing still may be misclassified as sedentary time and vice versa (Clemes, David et al. 2012). Newer accelerometer models include an inclinometer function, which classifies participants’ posture into four categories (device removed, standing, lying and sitting). Preliminary evidence however, indicates that the validity of this function is limited and may be influenced by point of attachment (Dahlgren, Carlsson et al. 2010).
The utility of multi-site/multi-sensor devices has been examined widely in the clinical setting (e.g. mobility assessments in older adults), but their potential in large population studies is largely unknown (Culhane, O’Connor et al. 2005). Typically, these devices use multiple accelerometers, inclinometers or physiological sensors attached to various points on the body. Sensor signals are then integrated to enable classification of different postures and types of movement. However, the validity and feasibility of using these devices under free-living conditions has not been extensively tested (Atkin, Gorely et al. 2012). Limitations in battery and memory capacity and the computational and analytical complexity associated with processing multi-sensor data also limit their applicability in an epidemiological context at present. These devices may however, be valuable as criterion measures in the validation of other sedentary behaviour measurement tools. Further development and validation work are required to examine the utility of multi-unit devices in field settings.

1.2.5 Strategies to Reduce Sedentary Behaviours

The majority of strategies seeking to reduce sedentary behaviours have been primarily conducted on children. In comparison, strategies to reduce the sedentary time of adults are fewer with many targeted towards limiting screen time (e.g. watching the television and using the computer) (Owen, Sugiyama et al. 2011). However, screen time serves as an inaccurate representation of overall sedentary time as it does not necessarily correspond with sedentary behaviours engaged at work, in leisure time, and during transportation (Owen, Sugiyama et al. 2011). Furthermore, limiting screen time may not be indicative of improved health outcomes if individuals do not replace this time with health promoting activities.
There has yet to be a clear consensus on which sedentary behaviour reduction strategies are most effective given that studies informing these strategies are generally of poor methodological quality, have a high risk of bias, and have produced dissimilar outcomes across different populations (Prince, Saunders et al. 2014, Martin, Fitzsimons et al. 2015, Shrestha, Kukkonen-Harjula et al. 2016). The sample sizes of the majority of interventions may not be large enough for random allocation to sufficiently spread confounding factors across study groups. Furthermore, self-reported methods are commonly used to assess sedentary time and are prone to self-report bias particularly from those participants who may be aware of the goals of the intervention and over report their outcomes.

A cross-sectional study of total sedentary time in adults using both self-reported and objective methods found an association between frequently interrupted sedentary time with short duration light intensity physical activity breaks during working hours and reductions in various markers of metabolic risk (Healy, Dunstan et al. 2008). This association had been further examined in a randomized controlled trial which found that interrupting 20 minutes of sitting time with 2 minutes breaks of physical activity significantly reduced markers for cardiovascular disease (such as levels of postprandial glucose, cholesterol and insulin) irrespective of the intensity of the activity (Dunstan, Kingwell et al. 2012). Other interventions have encouraged physical activity through changes in the workplace environment and design such as creating activity-permissive environments and replacing ordinary work desks with sit-stand desks or height adjustable desks to allows the user to alternate posture between sitting and standing (Gilson, Burton et al. 2011, Straker, Dunstan et al. 2016). Interventions have also been designed to
promote more information such as motivational prompts and messages to sit less and move more (Alkhajah, Reeves et al. 2012, Pedersen, Cooley et al. 2014) (Evans, Fawole et al. 2012). Yet, a review of the effectiveness of these workplace-based interventions found that while some of these interventions reduced sitting at the workplace, the available evidence was predominantly of low methodological quality.
1.3 Rationale & Conceptual Framework

As the literature suggests, prolonged sedentary time is associated with poor health as a consequence of distinct physiological mechanisms from those associated with insufficient MVPA for health. Yet, many important questions within sedentary behaviour research need to be answered before effective sedentary behaviour interventions can be developed and translated to clinical guidelines and public health initiatives. Figure 1 outlines a conceptual framework for research on sedentary behaviour that was informed by ideas and concepts described by other research (Sallis and Owen 1998, Sallis, Owen et al. 2000, Owen, Sugiyama et al. 2011).

Guided by the research framework, this thesis aimed to contribute to the field by examining whether prolonged sedentary time is a distinct modifiable risk factor for health, and inform an intervention specific to reducing sedentary behaviour. As the correlates of sedentary behaviour and physical activity vary by the contexts in which they are undertaken, it is important to examine these questions when focused within a particular setting (Owen, Sugiyama et al. 2011). An exercise-based cardiac rehabilitation (CR) program was chosen as this setting for several reasons. First, numerous clinical trials have proven the efficacy of these programs in reducing the mortality risk for patients with a history of cardiovascular disease (Anderson and Taylor 2014) by promoting the uptake and sustainable participation of healthy lifestyles through exercise training, patient education, psychosocial counselling and behaviour change (Heran, Chen et al. 2011, Lawler, Filion et al. 2011). However, while moderate physical exertion in leisure time activities is routinely promoted, recommendations specifically for reducing sedentary behaviour are not part of clinical guidelines. As such, the CR patient population provides a convenience sample of individuals to investigate whether exercise-based lifestyle programs can have spill
over influences on reducing sedentary time, or whether additional strategies need to be considered. Second, CR programs feature validated health and fitness measurement tools and protocols that facilitate the evaluation of health outcomes associated with physical activity and sedentary behaviour. Third, the stakes of a sedentary lifestyle may be higher for CR patients as most have had a recent cardiovascular event and are expected to be particularly vulnerable to rehospitalisation and lifestyle-related risk factors than general populations. As such, the risk of sedentary behaviours for CR patients is an important area of research and clinical interest.

All primary data collection was conducted at the University Health Network-Toronto Rehabilitation Institute’s Cardiac Rehabilitation and Secondary Prevention program. This Toronto-based outpatient centre is a national leader in the provision of comprehensive CR care and is among the largest of its kind in North America (Hamm and Kavanagh 2000). The 6-month program follows Canadian CR service delivery guidelines (CACR 2009), and is supported by an interdisciplinary team of healthcare professionals delivering exercise testing/training, education, counselling and support. Approximately 1,600 patients are benefited each year, and services are provided free of charge as part of Canada’s universal healthcare system.
1.4 Figures
Figure 1

The conceptual framework for sedentary behaviour research used to guide this research work. Check marks highlight areas that were a focus of this thesis, and bullet points and dotted boxes are areas intended for future research.

**Sedentary Behaviour Risk Factor Establishment**
- Conduct controlled clinical trials
- Understand relationship and strength of association between sedentary behaviour, exercise, and health outcomes
- Determine whether sedentary behaviour antedates the onset of disease
- Determine if association is biologically plausible/determine mechanisms in humans
- Establish dose-response relationship

**Identify Suitable Research Setting/Population**
- General
- Workplace
- Clinical

**Inform Intervention Components**

*Behaviour Characteristics*
- Awareness
- Intention
- Self-efficacy
- Preferences

*Environmental/Social Characteristics*
- Social environment
- Physical environment
- Information environment

*Intervention Characteristics*
- Type/intensity
- Duration

*Individual Characteristics*
- Biological/clinical/psychological
- Socio-demographic

**Pilot and Implement Sedentary Behaviour Intervention**
- Examine changes in intermediate/long-term health outcomes

**Inform and Evaluate Large-Scale Innovations and Policy Initiatives**
1.5 Research Objectives

The overall objectives of this research were to understand the relationship between exercise and sedentary behaviour among patients participating in an exercise-based CR program, and explore factors that should be considered in the design and development of future interventions targeted towards sedentary behaviour change in these individuals.

The following objectives are addressed in this thesis:

1. To determine the health risks associated with prolonged sedentary time in adults independent of exercise participation, and whether high levels of exercise attenuate the health risks compared to low levels.

2. To examine whether exercise participation influences the sedentary behaviour of exercise-engaged individuals.

3. To explore and identify factors that can inform future sedentary behaviour interventions for exercise-engaged individuals.

It was hypothesized that:

1. The health risks associated with prolonged sedentary time are not equivalent for exercising and non-exercising individuals.

2. Exercise participation has little influence on the sedentary time of individuals.

3. There are subgroups of individuals who are at higher risk for the health risks associated with prolonged sedentary time than others, and in greater need of intervention. Interventions need to be tailored to the characteristics and risk profile of these individuals.
1.6 Dissertation Outline

The objectives of this dissertation are addressed in six original studies described in the following three chapters. The final chapter summarizes the findings, discusses the strengths and limitations, outlines suggestions for future research, and suggests clinical and public health implications.

**Chapter 2:** To determine the health risks associated with prolonged sedentary time in adults independent of exercise participation, and whether high levels of exercise attenuate the health risks compared to low levels.

- The available literature was evaluated to quantify the association between prolonged sedentary time and health outcomes in adults independently of physical activity, and the extent to which they are modified by high or low physical activity participation. Findings serve to justify the importance of reducing sedentary behaviours among exercising and non-exercising populations.

**Chapter 3:** To examine whether exercise participation in a CR program influences the sedentary behaviour of patients

- The influence of exercise participation in CR programs on the sedentary behaviour of patients was examined, and consequently, it was determined whether additional interventions are required to reduce sedentary behaviour. This was explored on two independent samples of CR patients, corresponding to two parts:

**Part 1:** Examining the influence of exercise participation on the sedentary time of CR patients
Patients were objectively and subjectively assessed at the start and midpoint of their CR program to assess whether exercise participation in CR influenced their sedentary time. In particular, patients were characterised into four potential risk categories: 1) meeting or exceeding physical activity recommendations (150 minutes of MVPA participation in a week) and low sedentary time (lowest quartile of sedentary time, 0-25%), 2) meeting or exceeding physical activity recommendations and high sedentary time (highest quartile of sedentary time, 75%-100%), 3) not meeting physical activity and low sedentary time (lowest quartile of sedentary time, 0-25%), and 4) not meeting physical activity recommendations and high sedentary time (highest quartile of sedentary time, 75%-100%).

Part 2: Examining the influence of an exercise enhancement intervention on the sedentary time of CR patients

The influence of exercise participation on sedentary time was re-examined among a sample of CR patients who were involved in a randomized controlled trial designed to enhance exercise participation. This study complements Part 1 by further verifying whether enhanced exercise participation in CR has spill over influences on sedentary behaviours.

Chapter 4: To explore and identify factors that can inform sedentary behaviour interventions for CR patients.

- Implementation considerations for future sedentary behaviour for CR patients were determined in three ways:
Part 1: The awareness and understanding of sedentary behaviour, together with the perceived facilitators and barriers to reducing sedentary behaviours from the perspectives of CR patients and staff

- A qualitative study was undertaken to understand the awareness and understanding of sedentary behaviour, as well as the perceived facilitators and barriers to reducing sedentary behaviours from the perspectives of CR patients, and from individuals working at the CR program involved in supporting patient self-management. Findings inform the development of sedentary behaviour reduction recommendations that inform CR practice, and the appropriate design, development, and feasibility of such recommendations.

Part 2: A comparison of the energy expenditure benefits of replacing sedentary time with varying intensities of physical activity

- Sedentary behaviour interventions reporting energy expenditure were examined by a systematic review and meta-analysis to compare and quantify the benefits (based on daily cumulative energy expenditure) of reallocating short periods of sedentary time to MVPA vs. longer periods of sedentary time to light-intensity physical activity (LIPA) alone vs. a combination of LIPA and MVPA. Findings inform the duration of sedentary time and intensity of physical activity required for an intervention strategy.

Part 3: Examining which individuals can derive the most clinical benefit from a sedentary behaviour intervention for CR patients

- The characteristics of a large sample of CR patients linked by administrative datasets was examined to determine those that derived the most and least clinical effectiveness from CR
based on their baseline risk and behavioural attrition (dropout risk) profiles. Findings inform the extent that patient profiles benefit from CR participation, and considerations for targeted sedentary behaviour interventions.
Chapter 2

2 Determining the Independent Association Between Sedentary Behaviour And Health Risks, And How These Risks Are Modified By Exercise Participation

A modified version of this study has been published in the *Annals of Internal Medicine* journal.


2.1 Abstract

It is unclear as to the effects of prolonged sedentary time independent of physical activity participation across a broad spectrum of outcomes. The purpose of this study was to quantify the association between sedentary time and hospitalizations, all-cause mortality, cardiovascular disease, type 2 diabetes and cancer in adults independent of physical activity. English-language studies in MEDLINE, PubMed, EMBASE, CINAHL, Cochrane Library, Web of Knowledge and Google Scholar databases were searched till August 2014 with back-searching of in-text citations and no publication date limitations. Studies assessing sedentary behaviour in adults, adjusted for physical activity and correlated to at least one outcome. Two reviewers performed data abstractions/quality assessments and confirmed by a third reviewer. Of 47 articles assessed for quality, meta-analyses were performed on outcomes of all-cause mortality (13 studies), cardiovascular disease and diabetes (15 studies) and cancer (14 studies). Prospective design used in all but three studies, while
sedentary time was assessed by self-report in all but one. Significant hazard ratio (HR) associations were found with all-cause mortality (HR 1.240 [95% CI 1.090, 1.410]), cardiovascular mortality (HR 1.179 [95% CI 1.106, 1.257]), cardiovascular incidence (HR 1.143, [95% CI 1.002, 1.303]), cancer mortality (HR 1.173, [95% CI 1.108, 1.242]), cancer incidence (HR 1.130, [95% CI 1.053, 1.213]) and type 2 diabetes (HR 1.909, [95% CI 1.642, 2.222]). Strongest associations were found between sedentary time and outcomes among those with little physical activity participation. Limitations of this study were heterogeneity from varying confounder adjustment and defining/measuring sedentary behaviour. Publication and language bias is possible despite comprehensive search. In conclusion, prolonged sedentary time is positively associated with deleterious health outcomes irrespective of physical activity participation.
2.2 Introduction

Adults are advised to accumulate at least 150 minutes of weekly physical activity in bouts of 10 minutes or more (Canadian Society for Exercise Physiology 2013). The intensity of such habitual physical activity has been found to be a key characteristic of primary and secondary health prevention, with an established preventive role in cardiovascular disease, type 2 diabetes, obesity and some cancers (Lee, Sesso et al. 2003, Katzmarzyk, Rhodes et al. 2007). Despite the health-enhancing benefits of being physically active, this alone may not be enough to reduce the risk of disease and illness. Population-based studies have found that more than half of an average individual’s waking day is spent being sedentary in activities ubiquitously associated with prolonged sitting such as watching the television and using the computer (Matthews, Chen et al. 2008). This lifestyle trend is particularly worrisome as studies suggest that long periods of sitting can have deleterious health effects independent of adults meeting physical activity guidelines (Hu, Leitzmann et al. 2001, Dunstan, Salmon et al. 2005, Hamilton, Hamilton et al. 2007). Moreover, physical activity and sedentary behaviours may be mutually exclusive. For example, some individuals who achieve their recommended physical activity targets may be highly sedentary throughout the remainder of their waking hours, while others who may not regularly participate in physical activity may be non-sedentary either because of their leisure time activities, workplace environments, or both (Craft, Zderic et al. 2012). While studies and subgroups of systematic reviews have explored the independent association between sedentary behaviours and outcomes after adjustment for physical activity, the magnitude and consistency of such associations and the manner by which such associations change according to the level of participation in physical

Accordingly, the objective of this meta-analysis was to quantitatively evaluate the association between sedentary time and health outcomes independent of physical activity participation among adult populations. We hypothesized that sedentary time would be independently associated with both cardiovascular and non-cardiovascular outcomes after adjusting for participation in physical activity, but that the relative hazards associated with sedentary times would be attenuated in those who participate in higher levels as compared with lower levels of physical activity (Salmon, Bauman et al. 2000).

2.3 Materials and Methods

Data Sources and Searches

The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines were followed when conducting and reporting this meta-analysis (Moher, Liberati et al. 2009). Published studies on the association between sedentary behaviour and various health outcomes were identified and cross-checked by two reviewers through a systematic search of the Ovid MEDLINE, PubMed, Ovid EMBASE, EBSCO CINAHL, Cochrane Library, Web of Knowledge and Google Scholar databases. These health outcomes included: all-cause mortality, cardiovascular disease incidence (including diabetes), cardiovascular mortality, cancer incidence, cancer mortality, and all-cause hospitalizations. Searching was restricted to English-language primary research articles up to August 2014 with no publication date limitations. The following key words were applied
to the search: (exercise OR physical activity OR habitual physical activity) AND (sedentar* OR inactivity OR television OR sitting) AND (survival OR morbidity OR mortality OR disease OR hospital* OR utilization). References from relevant publications and review articles were hand-searched to supplement the electronic searches. A broad and comprehensive search strategy was chosen to encompass the range of outcomes associated with sedentary behaviour among different populations/settings and variations in the operational definition of leisure-time sedentary behaviour.

**Study Selection**

The inclusion criteria were primary research studies that assessed sedentary behaviour in adult human subjects as a distinct predictor variable, independent from physical activity and correlated to at least one health outcome. We broadly defined sedentary behaviour as a distinct class of waking behaviours characterized by little physical movement and low-energy expenditure (≤1.5 metabolic equivalents, METs) including sitting, television watching and reclined posture (Tremblay, Colley et al. 2010). We allowed for studies that assessed the effects of varying intensities of physical activity, provided that they also correlated a measure of sedentary behaviour with an outcome. We excluded studies that assessed non-adult populations (e.g. children and youth); those that did not adjust for physical activity in their statistical regression models or only assessed sedentary behaviour as a reference category to the effects of physical activity, and those that measured sedentary behaviour as the lowest category of daily/weekly physical activity.
Data Extraction and Quality Assessment

Data was extracted from all articles that met selection criteria and deemed appropriate for detailed review by three authors. Where multiple articles of the same study were found, data was extracted from the most recently published article. Details of individual studies were collected and characterized based on: 1) authors/year of publication, 2) study design, 3) sample size/characteristics (age and gender), 4) data collection methods, 5) study outcomes, 6) study limitations, and 7) hazard ratios, odds ratios or relative risk ratios (and their associated confidence intervals or standard errors). We restricted studies reporting health outcomes to those with direct associations with mortality (i.e. death), disease incidence (i.e. risk of being diagnosed with a disease given a period of time) and health service utilization (i.e. change in health service use) outcomes. This led to the exclusion of studies reporting indirect surrogate outcomes with inconsistent clinical endpoints and cut-offs (e.g. insulin sensitivity, quality of life, activities of daily living, metabolic biomarkers, metabolic syndrome and weight gain). Our study’s primary exposure was overall sedentary or sitting time (hours per week or hours per day). Studies reporting information on total screen time (television and/or computer screen use), television viewing time and MET (metabolic equivalents)-hour/week were also abstracted when information on the primary exposure was unavailable.

We assessed articles for quality based on methods used by Proper et al. (2011) (Proper, Singh et al. 2011). Their quality assessment tool had been previously validated (face and content) and evaluated to limit the risk of bias from study participation, study attrition, measurement of prognostic factors, measurement of and controlling for confounding
variables, measurement of outcomes and analysis approaches (Hoogendoorn, van Poppel et al. 2000, Singh, Mulder et al. 2008). Each study was evaluated according to a standardized set of predefined criteria consisting of 15 items (Table 1) (Hayden, Côté et al. 2006). The use of the original quality assessment tool was expanded to permit and score non-prospective studies. The items of the tool assessed study quality within the domains of 1) study population, 2) study attrition, 3) data collection and 4) data analysis. Each quality criterion was rated as positive; negative; or unknown. As with other meta-analyses, we required positive quality criteria of eight items or more in order to be included in our study (Koeneman, Verheijden et al. 2011, Proper, Singh et al. 2011). Two reviewers independently scored each article for quality. Any scoring inconsistencies were discussed with an additional reviewer (Alter). Scores from each reviewer were averaged to attain a final quality score assessment and verified by a single reviewer. If available from each study, we also considered whether the effects of prolonged bouts of sedentary time were modified by the highest or lowest reported participation in physical activity (herein termed “joint-effects”).

**Data Synthesis and Analysis**

All meta-analyses were performed using Comprehensive Meta-analysis, version 2 (Biostat, Englewood NJ) and the metafor package of the R statistical software (Borenstein M 2005, Viechtbauer 2010). Odds ratios, relative risk ratios and hazard ratios with associated 95% confidence intervals were collected from studies for each outcome, where available. We considered relative risk ratios to be equivalent to hazard ratios (HR) and when only odds ratios were provided, these were approximated to relative risk ratios in which we employed
the assumption of rare events using methods described and demonstrated elsewhere (Zhang and Kai 1998, Wilmot, Edwardson et al. 2012). When studies presented multiple statistical risk-adjustment models, we only considered relative risk ratios associated with the statistical models that contained the fewest number of additional covariates beyond physical activity to enhance comparability across studies. Adjusting for physical activity (rather than moderate-vigorous physical activity) allowed for a broader range of studies, of which some may not have specified the intensity of physical activity in regression models. Knapp-Hartung small sample estimation was used to pool the analysis of the overall effect size for each outcome. Studies that separately presented results for men and women were combined using a fixed-effects model. We received a 79% response rate from authors we had contacted to provide additional statistical information for our meta-analysis (11 out of 14).

Potential modifying effects of physical activity on sedentary time were examined by comparing the statistical effect sizes of any studies that reported the longest period of sedentary time with the highest and lowest duration and intensity of physical activity. Statistical heterogeneity was assessed using Cochran’s Q statistic and the I² statistic of the proportion of total variation due to heterogeneity (Higgins and Thompson 2002). When substantial heterogeneity was observed, a Knapp-Hartung-modified random-effects model was considered (Knapp and Hartung 2003). For the summary estimate, a $P$ value < 0.05 was considered statistically significant. The potential for small study effects such as publication bias was explored graphically using funnel plots through Egger’s test of asymmetry and quantitatively by Egger’s linear regression method (Egger, Smith et al. 1997). Last, we performed a sensitivity analysis on the impact of individual studies on the pooled meta-
analysis results of each outcome. The exclusion of each individual study and the corresponding changes on effect size allowed for the determination of whether any particular study was influencing the pooled point estimate and confidence interval.

2.4 Results

Literature Search Results


**Study Characteristics**

The characteristics of the studies assessed for quality in our meta-analysis are summarized in Table 1. No study was excluded exclusively because of low quality scores of <8 (<50%). No randomized controlled trials met our selection criteria. Most studies used prospective cohort study designs, while three studies used cross-sectional and case-control study designs. All but one study used self-reported methods to measure patterns of sedentary behaviour and physical activity and these were collected either by trained staff or directly from the individuals being observed. Definitions for sedentary time varied considerably across studies while a diverse range of criteria was used to collect information on sedentary time from self-report questionnaires (Table 2).

**Publication Bias and Heterogeneity**

There was statistical evidence of publication bias among studies reporting all-cause mortality (Egger’s regression intercept, 2.63 \([P=0.015]\)) and cancer incidence (Egger’s regression intercept, 1.870 \([P=0.046]\)), but no statistical evidence of publication bias for cardiovascular disease mortality (Egger’s regression intercept, 1.51 \([P=0.160]\)) and cancer
mortality (Egger’s regression intercept, 0.957 [$P=0.156$]). Publication bias was not assessed for cardiovascular disease incidence and type 2 diabetes incidence as the relatively few studies may overestimate the effects of bias.

Figure 2 summarizes the degree of heterogeneity across studies. As per Higgins and Thompson’s (2002) classification, there may be high heterogeneity within studies reporting all-cause mortality and cardiovascular disease incidence as outcomes (Higgins, Thompson et al. 2003). Heterogeneity was found to be low for cardiovascular disease mortality, cancer mortality, cancer incidence and type 2 diabetes incidence.

**Independent Effects of Sedentary Time on Health Outcomes**

Greater sedentary time was found to be positively associated with an increased risk for all-cause mortality, cardiovascular disease mortality, cancer mortality, cardiovascular disease incidence, cancer incidence and type 2 diabetes incidence (Figure 2). The largest statistical effect was associated with the risk of developing type 2 diabetes (pooled HR, 1.910 [95% CI 1.642 to 2.222]). Among studies assessing cancer mortality and incidence, statistically significant associations were specifically found with breast, colon, colorectal, endometrial and epithelial ovarian cancers (Higgins and Thompson 2002, Higgins, Thompson et al. 2003, Lee, Sesso et al. 2003, Proper, Singh et al. 2011, Hildebrand, Gapstur et al. 2013). The only study that evaluated associations with all-cause hospitalization was a prospective study that examined whether sedentary behaviour (among other modifiable health behaviours) was correlated with potentially modifiable hospitalization (defined as avoidable or ambulatory care sensitive hospitalizations) (Tran, Falster et al. 2014). Conducted among a large cohort
of men and women aged ≥45 years in Australia, the study found that participants self-reporting <8 hours of sitting time per day had a 14% lower risk for potentially preventable hospitalization (HR, 0.86 [95% CI 0.83 to 0.89]). The multivariate regression model was adjusted for age, sex, education, marital status, income, geographical remoteness of residence, language spoken at home, health insurance, chronic disease history, prior admission for potentially preventable hospitalization, moderate-vigorous physical activity and other health behaviours.

**Joint-Effects between Physical Activity, Sedentary Time and Health-Outcomes**

Ten studies reported joint-effects between sedentary times, physical activity, and health outcomes (Krishnan, Rosenberg et al. 2009, Patel, Bernstein et al. 2010, Matthews, George et al. 2012, Pavey, Peeters et al. 2012, van der Ploeg, Chey et al. 2012, Chomistek, Manson et al. 2013, Kim, Wilkens et al. 2013, Seguin, Buchner et al. 2014). The relative hazards associated with sedentary times on outcomes varied according to physical activity levels, and were generally more pronounced at lower than at higher levels of physical activity (Table 3). However, given the limited number of studies available, our meta-analysis examining the joint-effects between physical activity and exercise was restricted to all-cause mortality. Sedentary time was associated with a 30% lower relative risk for all-cause mortality among those who participated in high-levels of physical activity (pooled HR, 1.16 [95% CI 0.84 to 1.59]) as compared to those participating in low-levels of physical activity (pooled HR, 1.46 [95% CI 1.22 to 1.75]) (Figure 3).
Sensitivity Analysis

The pooled effect estimates for the associations between sedentary time and risk for all-cause mortality, cardiovascular disease mortality, cancer mortality, cancer incidence and diabetes did not change substantively with the exclusion of any individual study. The exclusion of non-prospective studies as well as applying the DerSimonian and Laird random effects estimator did not affect the statistical significance of outcomes.

2.5 Discussion

Our study demonstrated that after statistical adjustment for physical activity, sedentary time, assessed as either daily overall sedentary time, sitting time, television/screen time or leisure time spent sitting, was independently associated with a higher risk of all-cause mortality, cardiovascular disease incidence/mortality, cancer incidence/mortality (breast, colon, colorectal, endometrial and epithelial ovarian) and the development of type 2 diabetes in adults. However, the deleterious outcome effects associated with sedentary time generally decreased in magnitude among those who participated in higher as compared with lower levels of physical activity.

Our study builds on the previous body of literature examining the associated effects of sedentary time on various health outcomes. Prior to this review, an OVID Medline search up to August 2014 found two meta-analyses that positively associated increasing sedentary time with an independent risk for cardiovascular disease incidence (including diabetes) and cardiovascular disease-, all-cause mortality as well as certain cancers (Wilmot, Edwardson et al. 2012, Schmid and Leitzmann 2014). However, unlike our systematic meta-analysis
which has focused exclusively on studies that adjusted for physical activity, only a minority of studies included in these two prior meta-analyses adjusted for physical activity, and did so only among a limited subgroup of available studies. Consequently, previous studies lacked precision in the estimated independent effect sizes of sedentary time-outcome associations. Moreover, previous meta-analyses were not designed to examine the extent to which different levels of physical activity might potentially modify sedentary time-outcome associations. The consistency in the magnitude of effects associated with sedentary time across a host of cardiovascular and non-cardiovascular outcomes after adjustment for physical activity underscores the validity and strength of association, and provides confidence that such associations may indeed be causally linked. While more research is required to better understand how changes in physical activity may modify the deleterious effects of prolonged sedentary time, our study does suggest that these associations may vary according to the level of physical activity undertaken and become less pronounced as participation in physical activity increases.

Our study has also shed greater insight on the various sources of heterogeneity than previously published systematic reviews. Statistical heterogeneity was highest for those studies examining all-cause mortality and cardiovascular disease incidence. Moreover, the sources of such heterogeneity were multifactorial. First, there were marked variations in methodological quality and design across studies. Second, there were multiple operational definitions and/or quantitative cut-offs when categorizing sedentary time and physical activity. Third, self-reported measures were predominantly used to assess physical activity exposure which are more vulnerable to biased estimates than those ascertained through more
objective measurement techniques (e.g. accelerometry) (Colley, Garriguet et al. 2011, Atkin, Gorely et al. 2012). Last, there were large variations in the comprehensiveness of risk-adjustment methodology across studies, with some studies adjusting for covariates which may overlap or lie within the same causal-pathways as those that are thought to mediate the adverse effects from sedentary behaviours themselves (e.g. adiposity). Future studies must address such sources of heterogeneity to improve the interpretation, comparability, and implications of physical activity-behavioural outcomes research.

Until recently, the implications of sedentary behaviour on public health programs and policies have primarily focused on the promotion of physical activity. Health promotion messaging advocating for a reduction in sedentary time is far less common and faces many challenges. Comprehensive clinical outpatient programs such as cardiac rehabilitation have demonstrated effectiveness in helping patients recover from and manage their risk for cardiovascular disease and other chronic diseases, but have done so by focusing predominantly on exercise and lifestyle modification rather than the avoidance of sedentary behaviour per se (Taylor, Brown et al. 2004, Armstrong 2006). Less is known about optimal prescribing methods for reducing sedentary time, as strategies have remained highly variable (Sørensen, Skovgaard et al. 2006, Wisse, Rookhuizen et al. 2010). Moreover, such strategies may necessitate different integrative approaches across populations to align with demographic and sociocultural norms (Ainsworth and Macera 2012, Dunstan, Kingwell et al. 2012).

Several limitations must be considered when interpreting these findings. Our search strategy
was limited to English-only studies, which may have resulted in a language or cultural bias. Nonetheless, our expansive search across multiple databases has incorporated numerous studies conducted outside of the English-speaking world. We also acknowledge the presence of publication bias with the possibility that selective reporting may have further undermined the generalizability of our findings. Furthermore, the examination of joint-effects between sedentary time, physical activity levels, and outcomes did yield overlapping confidence intervals. Accordingly, more studies will be required to confirm and better quantify how associations between sedentary time and outcomes attenuate at higher levels of physical activity. Finally, we did not have access to individual-level data. While we did attempt to contact individual authors to confirm statistical effects and accordingly, received a good response-rate in so doing, we were ostensibly reliant on the quality of individual studies provided and the statistical effect sizes reported.

In conclusion, our findings suggest that prolonged sedentary time, independent from physical activity, is positively associated with a variety of deleterious health outcomes. These results and others reaffirm the need for greater public awareness regarding the hazards associated with sedentary behaviours, and justify further research to explore the effectiveness of interventions designed to target sedentary times independently from, and in addition to physical activity.
### 2.6 Tables

#### Table 1

Criteria list for the assessment of quality of prospective and non-prospective studies

<table>
<thead>
<tr>
<th>Criteria</th>
<th>I, V/P</th>
<th>Prospective studies meeting criteria #/total (%)</th>
<th>Non-prospective studies meeting criteria #/total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Study population and participation (baseline)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Adequate (sufficient information to be able to repeat the study) description of the source population</td>
<td>I</td>
<td>32/38 (84)</td>
<td>7/9 (78)</td>
</tr>
<tr>
<td>2. Adequate (sufficient information to be able to repeat the study) description of sampling frame, recruitment methods, period of recruitment, and place of recruitment (setting and geographic location)</td>
<td>V/P</td>
<td>33/38 (94)</td>
<td>9/9 (100)</td>
</tr>
<tr>
<td>3. Participation rate at baseline at least 80% or if the nonresponse was not selective (show that baseline study sample does not significantly differ from population of eligible subjects)</td>
<td>I</td>
<td>17/38 (49)</td>
<td>6/9 (67)</td>
</tr>
<tr>
<td>4. Adequate description of baseline study sample (i.e. individuals entering the study) for key characteristics (n, age, gender, sedentary behaviour, and health outcome)</td>
<td>I</td>
<td>32/38 (84)</td>
<td>8/9 (89)</td>
</tr>
<tr>
<td><strong>Study attrition</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Provision of the exact n at each follow-up measurement</td>
<td>I</td>
<td>19/38 (50)</td>
<td>0/9 (0)</td>
</tr>
<tr>
<td>6. Provision of the exact information on follow-up duration</td>
<td>V/P</td>
<td>24/38 (63)</td>
<td>0/9 (0)</td>
</tr>
<tr>
<td>7. Response at short-term follow-up (up to 12 months) was at least 80% of the n at baseline and response at long-term follow-up was at least 70% of the n at baseline</td>
<td>V/P</td>
<td>20/38 (53)</td>
<td>0/9 (0)</td>
</tr>
<tr>
<td>8. Information on not selective nonresponse during follow-up measurement(s)</td>
<td>V/P</td>
<td>6/38 (17)</td>
<td>0/9 (0)</td>
</tr>
<tr>
<td><strong>Data collection</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>9. Adequate measurement of sedentary behaviour: done by objective measures (i.e., accelerometry, heart rate monitoring, observation) and not by self-report (self-report = -; no/insufficient information = ?)</td>
<td>V/P</td>
<td>5/38 (16)</td>
<td>2/9 (22)</td>
</tr>
</tbody>
</table>
10. Sedentary behaviour was assessed at a time prior to the measurement of the health outcome

| V/P | 38/38 (100) | 9/9 (100) |

11. Adequate measurement of the health outcome: objective measurement of the health outcome done by trained personnel by means of standardized protocol(s) of acceptable quality and not by self-report (self-report = –; no/insufficient information = ?)

| V/P | 27/38 (71) | 5/9 (56) |

**Data analyses**

12. The statistical model was appropriate

| V/P | 38/38 (100) | 9/9 (100) |

13. The number of cases was at least 10 times the number of independent variables

| V/P | 33/38 (87) | 8/9 (88) |

14. Presentation of point estimates and measures of variability (confidence interval or standard error)

| I   | 38/38 (100) | 9/9 (100) |

15. No selective reporting of results

| V/P | 29/38 (76) | 8/9 (89) |

---

*a* Rating of criteria: + = yes; - = no; ? = unknown.

*b* + given only if adequate information is given on all items.

*c* + given only if non-selective dropout on key characteristics (age, gender, sedentary behaviour, health outcomes) is reported in the text or tables.

*d* + given only if a multivariate regression model was used.

I, informativeness; V/P, criterion on validity/precision.
Table 2
Characteristics and potential risk of bias of studies included in meta-analysis reporting associations between sedentary behaviour and disease incidence and mortality outcomes

<table>
<thead>
<tr>
<th>First author (year)</th>
<th>Study design</th>
<th>Country; sample characteristics</th>
<th>Sedentary behaviour definition</th>
<th>Method of sedentary behaviour assessment; criteria</th>
<th>Primary outcome; cases/N</th>
<th>Follow-up duration; completeness</th>
<th>Adjusted covariates</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-cause mortality</td>
<td>Seguin (2014)</td>
<td>Prospective US; Women’s Health Initiative Observational Study; women; 50-79 years</td>
<td>Overall daily hours spent sitting during day/night</td>
<td>Self-report questionnaire; ≤ 4, &gt;4-8, &gt;8-11, ≥11 hours/day</td>
<td>All-cause mortality; 3073/20187</td>
<td>12 years; 98.5%</td>
<td>Age, sex, physical activities and physical function</td>
</tr>
<tr>
<td>Katzmarzyk (2009)</td>
<td>Prospective Canada; 1981 Canada Fitness Survey; both sexes, men and women; 18-90 years</td>
<td>‘Sedentary almost all the time’</td>
<td>Time spent sitting during work, school and housework 1) almost none of the time, 2) approximately one fourth of the time, 3) approximately half of the time, 4) approximately three fourths</td>
<td>Self-report questionnaire; Time spent sitting during work, school and housework 1) almost none of the time, 2) approximately one fourth of the time, 3) approximately half of the time, 4) approximately three fourths</td>
<td>All-cause mortality; both: 159/822, men: 83/370, women: 76/452</td>
<td>12 years; not specified</td>
<td>Age, sex, smoking, alcohol use, leisure time physical activity and physical activity readiness</td>
</tr>
<tr>
<td>Study</td>
<td>Methodology</td>
<td>Location</td>
<td>Sample Size</td>
<td>Outcome</td>
<td>Follow-up</td>
<td>Adjusted Factors</td>
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<tr>
<td>George (2013)</td>
<td>Prospective</td>
<td>US; Healthy Eating, Activity and Lifestyle (HEAL); breast cancer surviving women; 18-64 years</td>
<td>Television watching time of the time, or 5) almost all of the time</td>
<td>All-cause mortality; 41/217</td>
<td>7 years; 73%</td>
<td>Age, moderate-vigorous physical activity</td>
<td></td>
</tr>
<tr>
<td>Matthews (2012)</td>
<td>Prospective</td>
<td>US; NIH-AARP Diet and Health Study; both sexes; 50-71 years</td>
<td>Overall sitting time</td>
<td>All-cause mortality; 1492/240819</td>
<td>8.5 years; 59%</td>
<td>Age, sex, race, education, smoking status, diet quality, moderate-vigorous physical activity</td>
<td></td>
</tr>
<tr>
<td>Patel (2010)</td>
<td>Prospective</td>
<td>US; CPS-II Nutrition Cohort; men and women; 50-74 years</td>
<td>Sitting time</td>
<td>All-cause mortality; men: 1864/53440, women: 1104/69776</td>
<td>14 years; 67%</td>
<td>Age, race, marital status, education, smoking status, BMI, alcohol use, total caloric intake, comorbidities score; physical activity</td>
<td></td>
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<tr>
<td>Pavey (2012)</td>
<td>Prospective</td>
<td>Australia; Australian Longitudinal</td>
<td>Sitting time</td>
<td>All-cause mortality; 136/273</td>
<td>9 years; 83%</td>
<td>Age, education, marital status, area, smoking</td>
<td></td>
</tr>
<tr>
<td>Study on Women’s Health; women; 76-81 years</td>
<td>sitting while doing things like visiting friends, driving, reading, watching television, or working at a desk or computer on (a) usual week-day and (b) usual weekend-day”. 0–4, 4 to &lt;8, 8 to &lt;11 and ≥11 hours/day</td>
<td>status, alcohol use, BMI, physical activity</td>
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<tr>
<td>Dunstan (2010) Prospective Australia; Australian Diabetes, Obesity and Lifestyle Study; both sexes; ≥ 25 years</td>
<td>Television viewing time</td>
<td>Television viewing time, &lt;2, 2 to 4, and &gt;4 hours/day</td>
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<tr>
<td></td>
<td>All-cause mortality; 54/672</td>
<td>6.6 years; 43%</td>
<td>Age, sex, smoking status, education, total energy intake, alcohol use, diet quality, waist circumference, hypertension, total plasma cholesterol, lipid lowering medication use, glucose tolerance status, exercise</td>
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<tr>
<td>Study</td>
<td>Type</td>
<td>Location</td>
<td>Participants</td>
<td>Sedentary activities</td>
<td>Mortality Measures</td>
<td>Follow-up</td>
<td>Mortality Rate</td>
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<tr>
<td>Inoue (2008)</td>
<td>Prospective</td>
<td>Japan; Japan Public Health Centre-based Prospective Study; men and women; 45-74 years</td>
<td>Sedentary activities: Self-report questionnaire; Average time spent in sedentary activity, &lt;3 h, 3–8 h, &gt;8 hours/day</td>
<td>All-cause mortality: men: 322/39183, women: 114/43851</td>
<td>5 years; 97.3%</td>
<td>Age, area, occupation, occupation, diabetes history, smoking status, alcohol use, BMI, total energy intake, leisure time physical exercise</td>
<td></td>
</tr>
<tr>
<td>Stamatakis (2011)</td>
<td>Prospective</td>
<td>Scotland; 2003 Scottish Health Survey; both; ≥35 years</td>
<td>Screen time: Self-report questionnaire; Weekly and weekday screen time, “how much time on average day do you spend watching TV or another type of screen such as a computer, or video game? Please do not include any time spent in front of a screen while at school, college or work”, &lt;2,</td>
<td>All-cause mortality: 115/1204</td>
<td>4.3 years; 71%</td>
<td>Age, sex, BMI, smoking status, marital status, race, social class, long-standing illness, occupational physical activity, diabetes diagnosis/hypertension, moderate-vigorous physical activity</td>
<td></td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Country and study cohorts</td>
<td>Measurement</td>
<td>Time Measure</td>
<td>All-cause mortality</td>
<td>Follow-up</td>
<td>Mortality</td>
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<tr>
<td>Koster (2012)</td>
<td>Prospective</td>
<td>US, National Health and Nutrition Examination Survey; both sexes; ≥ 50 years</td>
<td>Sedentary time 7-day accelerometry; Sedentary time defined as movements &lt;100 counts/minute, highest category: ≥10 hours/day</td>
<td>2 to &lt;4, ≥ 4 hours/day</td>
<td>All-cause mortality: 53/476</td>
<td>2.8 years; 98.2%</td>
<td>2.8 years; 98.2%</td>
</tr>
<tr>
<td>Kim (2013)</td>
<td>Prospective</td>
<td>US; Multiethnic Cohort Study (MEC); men and women; 45-75 years</td>
<td>Total sitting time Self-report questionnaire; Total sitting time as sum of midpoints of ‘never’, &lt;1, 1–2, 3–4 hours, 5–6, 7–10, ≥ 11 hours</td>
<td>All-cause mortality; men: 3116/61395, women: 2960/73201</td>
<td>13.7 years; 62.6%</td>
<td>13.7 years; 62.6%</td>
<td>13.7 years; 62.6%</td>
</tr>
<tr>
<td>van der Ploeg (2012)</td>
<td>Prospective</td>
<td>Australia; 45 and Up Study; both sexes, men and women; ≥ 45 years</td>
<td>Sitting time Self-report questionnaire; “About how many hours in each 24-hour day do you usually spend sitting?”, 0 to ≥ 11 hours</td>
<td>All-cause mortality; both: 649/222497, men: 401/105855, women: 248/116642</td>
<td>4 years; 98.7%</td>
<td>4 years; 98.7%</td>
<td>4 years; 98.7%</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Country</td>
<td>Sex/Age</td>
<td>Measures</td>
<td>Outcome</td>
<td>Follow-up</td>
<td>Risk Factors</td>
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<tr>
<td>Leon-Munoz (2013)</td>
<td>Prospective</td>
<td>Spain; both sexes; ≥ 60 years</td>
<td>Sitting time</td>
<td>Self-report questionnaire; “About how much time do you spend sitting down on weekdays? Consistently sedentary, newly sedentary, formerly sedentary, consistently non-sedentary</td>
<td>All-cause mortality; 203/567</td>
<td>2 years; 80.9%</td>
<td>Sex, age, education, smoking status, alcohol use, heart disease, stroke, diabetes, osteomuscular disease, cancer, physical function, physical activity, mobility and agility</td>
</tr>
</tbody>
</table>

**Type 2 diabetes**
<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Country</th>
<th>Sex/Age</th>
<th>Measures</th>
<th>Outcome</th>
<th>Follow-up</th>
<th>Risk Factors</th>
<th>Additional Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dunstan (2005)</td>
<td>Cross-sectional</td>
<td>Australia; Australian Diabetes, Obesity and Lifestyle Study; both sexes; ≥ 25 years</td>
<td>Television watching time</td>
<td>Self-report questionnaire; television time, 0–7, 7.01–14 and &gt;14 hours per week</td>
<td>Type 2 diabetes; 1103/20187</td>
<td>1 year; 55%</td>
<td>Age, education, diabetes history, smoking status, diet, physical activity</td>
<td></td>
</tr>
<tr>
<td>Hu (2003)</td>
<td>Prospective</td>
<td>US; Nurses’ Health Study; women; 35-55 years</td>
<td>Television watching time</td>
<td>Self-report questionnaire; Average weekly TV watching time</td>
<td>Type 2 diabetes; 51/1464</td>
<td>6 years; 56.3%</td>
<td>Age, hormone use, alcohol use, smoking, diabetes history; physical activity</td>
<td></td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Country/Study</td>
<td>Study Population</td>
<td>Television Watching Time</td>
<td>Outcome</td>
<td>Follow-up</td>
<td>Controls</td>
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<tr>
<td>Krishnan (2009)</td>
<td>Prospective</td>
<td>US; Black Women’s Health Study; black women; 21-69 years</td>
<td>Television watching time (hours/week), 0-1, 2-5, 6-29, 21-40, &gt;40 Self-report questionnaire; Hours spent watching TV per day, 0, &lt;1, 1-2, 3-4, and &gt;5 hours per day.</td>
<td>Type 2 diabetes; 712/2928</td>
<td>10 years; 80%</td>
<td>Age, time period, diabetes history; education; family income; marital status, smoking status, energy intake, coffee intake; vigorous activity, TV watching, walking</td>
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<tr>
<td>Ford (2010)</td>
<td>Prospective</td>
<td>Germany; European Prospective Investigation in Cancer and Nutrition (EPIC) - Potsdam Study; men 35-65 years, women 40-65 years</td>
<td>Television watching time Self-report questionnaire; “On average, how many hours/day did you watch television during the last 12 months?” &lt;1, 1-&lt;2, 2-&lt;3, 3-&lt;4, 4+</td>
<td>Type 2 diabetes; both; 131/1935</td>
<td>7.8 years; 90%</td>
<td>Age, sex, education, occupational activity, smoking status, alcohol intake, physical activity</td>
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</tr>
<tr>
<td>Hu (2001)</td>
<td>Prospective</td>
<td>US; Health Professional’s Follow-up study (HPFS); men; 45-75 years</td>
<td>Television watching time Self-report questionnaire; Average weekly television watching time (hours/week),</td>
<td>Type 2 diabetes; 12/186</td>
<td>10 years; 73.6%</td>
<td>Age, smoking status, diabetes, diabetes history, alcohol intake, diet, physical activity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Location</td>
<td>Participants</td>
<td>Health Status</td>
<td>Sedentary Time Description</td>
<td>Cardiovascular Disease Mortality</td>
<td>Duration</td>
<td>Other Variables</td>
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<tr>
<td>Seguin (2014)</td>
<td>Prospective</td>
<td>US; Women’s Health Initiative Observational Study; women; 50-79 years</td>
<td>Sedentary time: Self-report questionnaire; Overall daily hours spent sitting during day/night, ( \leq 4 ), ( &gt;4-8 ), ( &gt;8-11 ), ( \geq 11 )</td>
<td>Cardiovascular disease mortality; 895/20187 Coronary heart disease mortality; 418/20187</td>
<td>12 years; 98.5%</td>
<td>Age, sex, physical activities and physical function</td>
<td></td>
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<tr>
<td>Katzmarzyk (2009)</td>
<td>Prospective</td>
<td>Canada; 1981 Canada Fitness Survey; both sexes, men and women; 18-90 years</td>
<td>‘Sedentary almost all the time’: Self-report questionnaire; Time spent sitting during work, school and housework 1) almost none of the time, 2) approximately one fourth of the time, 3) approximately half of the time, 4) approximately three fourths of the time, or 5) almost all of the time</td>
<td>Cardiovascular disease mortality; both: 67/822, men: 34/370, women: 33/452</td>
<td>12 years; not specified</td>
<td>Age, sex, smoking, alcohol use, leisure time physical activity and physical activity readiness</td>
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</tr>
<tr>
<td>Matthews (2012)</td>
<td>Prospective</td>
<td>US; NIH-AARP Diet and Health</td>
<td>Overall sitting time: Self-report questionnaire;</td>
<td>Cardiovascular disease</td>
<td>8.5 years; 59%</td>
<td>Age, sex, race, education,</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Patel (2010) Prospective US; CPS-II Nutrition Cohort; men and women; 50-74 years Sitting time in 24-hour period, <3, 3–4, 5–6, 7–8, or 9+ hours/day Self-report questionnaire; Hours spent sitting per day, none, <3, 3–5, 6–8, >8 Cardiovascular disease mortality; men: 685/53440, women: 331/69776 14 years; 67% smoking status, diet quality, moderate-vigorous physical activity Age, race, marital status, education, smoking status, BMI, alcohol use, total caloric intake, comorbidities score; physical activity

Dunstan (2010) Prospective Australia; Australian Diabetes, Obesity and Lifestyle Study; both sexes; ≥ 25 years Television viewing time; Self-report questionnaire; Television viewing time, <2, 2 to 4, and >4 hours/day Cardiovascular disease mortality; 22/672 6.6 years; 43% Age, sex, smoking status, education, total energy intake, alcohol use, diet quality, waist circumference, medication, glucose tolerance status, exercise time

Stamatakis (2011) Prospective Scotland; 2003 Scottish Health Survey; both sexes; ≥ 35 years Screen time; Self-report questionnaire; Weekly and weekday screen time, “how much” Cardiovascular disease event; 65/1072 4.3 years; 71% Age, sex, BMI, smoking status, marital status, race, social class, long-standing illness,
| Kim (2013) | Prospective | US; Multiethnic Cohort Study (MEC); men and women; 45-75 years | Total sitting time | Cardiovascular disease mortality; men: 1104/61395, women: 1002/73201 | 13.7 years; 62.6% | Age, education, ethnicity, smoking history, history of hypertension/diabetes, alcohol use, energy intake, physical activity | occupational physical activity, diabetes diagnosis/hypertension, moderate-vigorous physical activity |}

The question asks about the average time spent watching TV or another type of screen such as a computer, or video game. The instruction is to not include any time spent in front of a screen while at school, college or work.
<table>
<thead>
<tr>
<th>Study</th>
<th>Study Type</th>
<th>Population</th>
<th>Outcome Measure</th>
<th>Follow-up Duration</th>
<th>Percent Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wijndaele (2011)</td>
<td>Prospective</td>
<td>UK. EPIC Norfolk Study; both sexes; 45-79 years</td>
<td>Television viewing time</td>
<td>4.3 years</td>
<td>61.6%</td>
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<tr>
<td></td>
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<td></td>
<td>Self-report questionnaire. Hours/day spent watching TV before and after 6 pm on weekdays and weekends, Lowest: &lt;2.5, middle: 2.5–3.6, highest: &gt;3.6 hours/day</td>
<td></td>
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<tr>
<td></td>
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<td></td>
<td>Any cardiovascular disease event; 2620/12608</td>
<td></td>
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</tr>
<tr>
<td>Chomistek (2013)</td>
<td>Prospective</td>
<td>US; Women’s Health Initiative Observational Study; women; 50-79 years</td>
<td>Sitting time</td>
<td>12.2 years</td>
<td>75.8%</td>
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<td></td>
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<td>Self-report questionnaire; “During a usual day and night, about how many hours do you spend sitting? Be sure to include the time you spend sitting at work, sitting at the table eating, driving or riding a car or bus, and sitting up watching TV or talking.”</td>
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<td>Coronary heart disease event; 490/17374, Total cardiovascualar disease (nonfatal myocardial infarction, fatal coronary heart disease, nonfatal and fatal stroke); 849/17374</td>
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<td></td>
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<td></td>
<td>Total cardiovascular (nonfatal myocardial infarction, fatal coronary heart disease, nonfatal and fatal stroke); 849/17374</td>
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<td>Age, sex, education, smoking status, medication, diabetes status, family history of CVD, sleep duration, total physical activity energy expenditure</td>
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<td>Age, physical activity, race, education, income, marital status, smoking, family history of MI, depression, alcohol intake, hours of sleep, calorie intake, hypertension, diabetes/high cholesterol at baseline</td>
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</tr>
<tr>
<td><strong>Cancer-related incidence and mortality</strong></td>
<td><strong>Seguin (2014)</strong></td>
<td>US; Women’s Health Initiative Observational Study; women; 50-79 years</td>
<td>Sedentary time</td>
<td>Self-report questionnaire. Overall daily hours spent sitting during day/night, (\leq 4, &gt;4-8, &gt;8-11, \geq 11) hours/day.</td>
<td>Cancer mortality; 1103/20187</td>
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</tr>
<tr>
<td><strong>Campbell (2013)</strong></td>
<td>US; CPS-II Nutrition Cohort; both;</td>
<td>Leisure time spent sitting</td>
<td>Self-report questionnaire; Daily time in the past year spent driving or sitting in a car, sitting on a bus, or sitting on a train; sitting and watching television; and sitting at home reading, (&lt; 3, 3-&lt;6, \geq 6) hours/day</td>
<td>Colorectal cancer mortality; 40/2293</td>
<td>16.1 years; 74%</td>
</tr>
<tr>
<td><strong>Katzmarzyk (2009)</strong></td>
<td>Canada; 1981 Canada Fitness Survey; both sexes, men and women; 18-90</td>
<td>‘Sedentary almost all the time’</td>
<td>Self-report questionnaire; Time spent sitting during work, school</td>
<td>Cancer mortality; both: 36/822; men: 21/370; women:</td>
<td>12 years; not specified</td>
</tr>
<tr>
<td>Study</td>
<td>Type</td>
<td>Country</td>
<td>Age, race, education, smoking status, BMI, alcohol use, total caloric intake, comorbidities score</td>
<td>Physical activity</td>
<td>Overall sitting time</td>
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<tr>
<td>Patel (2010)</td>
<td>Prospective</td>
<td>US; CPS-II Nutrition Cohort; men and women; 50-74 years</td>
<td>Age, race, marital status, education, smoking status, BMI, alcohol use, total caloric intake, comorbidities score</td>
<td>Physical activity</td>
<td>Sitting time</td>
</tr>
<tr>
<td>Matthews (2012)</td>
<td>Prospective</td>
<td>US; NIH-AARP Diet and Health Study; both sexes; 50-71 years</td>
<td>Age, sex, race, education, smoking status, diet quality, moderate-vigorous physical activity</td>
<td>Physical activity</td>
<td>Overall sitting time</td>
</tr>
<tr>
<td>Friberg</td>
<td>Prospective</td>
<td>Sweden;</td>
<td></td>
<td></td>
<td>Leisure time</td>
</tr>
<tr>
<td>Year</td>
<td>Study Type</td>
<td>Country</td>
<td>Study Details</td>
<td>Questionnaire Details</td>
<td>Cancer Incidence</td>
</tr>
<tr>
<td>----------</td>
<td>-----------------</td>
<td>---------</td>
<td>-------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>2006</td>
<td>Swedish Mammography Cohort</td>
<td>Sweden</td>
<td>50-83 years inactivity (watching television/sitting)</td>
<td>Time spent per day watching television/sitting (inactive leisure time &lt;1 hour daily to &gt;6 hours daily)</td>
<td>24/33723</td>
</tr>
<tr>
<td>2010</td>
<td>Dunstan</td>
<td>Australia</td>
<td>Prospective Australia; Australian Diabetes, Obesity and Lifestyle Study; both sexes; ≥ 25 years</td>
<td>Television viewing time</td>
<td>Self-report questionnaire; Television viewing time, &lt;2, 2 to 4, and &gt;4 hours/days</td>
</tr>
<tr>
<td>2008</td>
<td>Howard</td>
<td>US</td>
<td>Prospective US; NIH-AARP Diet and Health Study; men and women; 50-71 years</td>
<td>Sitting time</td>
<td>Self-report questionnaire; Average number of hours per day currently spent watching television or videos, and average number of hours per day spent sitting, &lt;</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Country</td>
<td>Cohort Details</td>
<td>Outcome Measures</td>
<td>Follow-up Time</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>------------</td>
<td>---------</td>
<td>----------------------------------</td>
<td>------------------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Kim (2013)</td>
<td>Prospective</td>
<td>US; Multi-ethnic Cohort Study (MEC); men and women; 45-75 years</td>
<td>Total sitting time</td>
<td>Cancer mortality; men: 1053/61395, women: 1018/73201</td>
<td>13.7 years; 62.6%</td>
</tr>
<tr>
<td>George (2010)</td>
<td>Prospective</td>
<td>US; NIH-AARP Diet and Health Study; women; 50-71 years</td>
<td>Sitting time</td>
<td>Invasive breast cancer incidence; 224/48594</td>
<td>6.9 years; 73%</td>
</tr>
<tr>
<td>Hildebrand (2013)</td>
<td>Prospective</td>
<td>US; CPS-II Nutrition Cohort; women; 50-74 years</td>
<td>Leisure time sitting</td>
<td>Breast cancer incidence; 572/73615</td>
<td>14.2 years; 88%</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Country</td>
<td>Age Range</td>
<td>Measures of Sitting Time</td>
<td>Outcomes</td>
</tr>
<tr>
<td>------------------------------</td>
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<td>-------------------------------------------</td>
</tr>
<tr>
<td>Teras (2012)</td>
<td>Prospective</td>
<td>US; CPS-II Nutrition Cohort; men and women; 50-74 years</td>
<td>Sitting time</td>
<td>Self-report questionnaire; Hours spent sitting per day</td>
<td>Non-Hodgkin lymphoid neoplasm incidence; men: 69849, 151, women: 99/77001</td>
</tr>
<tr>
<td>Peplonska (2008)</td>
<td>Case-control</td>
<td>Poland; women; 20-74 years</td>
<td>Sitting time</td>
<td>Self-report questionnaire; Hours spent sitting per day converted to MET hours/week of Lifetime</td>
<td>Breast cancer incidence;</td>
</tr>
<tr>
<td>Zhang (2004)</td>
<td>Case-control</td>
<td>China; hospital-based; women; &lt;75 years</td>
<td>Total sitting duration</td>
<td>Self-report questionnaire; 5 years ago, how many</td>
<td>Epithelial ovarian cancer; 75/205</td>
</tr>
</tbody>
</table>
hours on average in a day did you spend sitting (1) at work, (2) while watching television, (3) in car or bus, (4) at meals, and (5) in other activities (such as reading, playing cards, and sewing)? <4, 4-10, >10.

smoking, alcohol use, tea drinking, physical activity, marital status, menopausal status, parity, oral contraceptive use, tubal ligation, hormone replacement therapy, ovarian cancer in first degree relatives, total energy intake

[Rating criteria for risk of bias: low, moderate, high.]

BMI, body mass index; CVD, cardiovascular disease; CHD, coronary heart disease; CHF, coronary heart failure.
Table 3
Joint association between longest sedentary time and highest and lowest levels of physical activity reported in studies

<table>
<thead>
<tr>
<th>Outcome, Study</th>
<th>Sedentary time</th>
<th>Highest PA</th>
<th>HR (95% CI)</th>
<th>Lowest PA</th>
<th>HR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All-cause mortality</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seguin (2014)</td>
<td>≥11 h/day total sedentary time</td>
<td>≥19.75 MET h/week</td>
<td>0.94 (0.80, 1.11)</td>
<td>0-3 MET h/week</td>
<td>1.22 (1.08, 1.38)</td>
</tr>
<tr>
<td>Patel (2010)</td>
<td>≥6 h/day sitting time</td>
<td>≥52.5 MET h/week</td>
<td>M: 1.07 (0.97, 1.18)</td>
<td>&lt;24.5 MET h/week</td>
<td>M: 1.48 (1.33, 1.65)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>W: 1.25 (1.07, 1.45)</td>
<td>&lt;24.5 MET h/week</td>
<td>W: 1.94 (1.70, 2.20)</td>
</tr>
<tr>
<td>Pavey (2012)</td>
<td>≥6 h/day sitting time</td>
<td>Meeting PA guidelines</td>
<td>0.50 (0.25, 1.00)</td>
<td>Not meeting PA guidelines</td>
<td>1.52 (1.17, 1.98)</td>
</tr>
<tr>
<td>Kim (2013)</td>
<td>≥5 h/d watching TV</td>
<td>≥33.4 MET h/week</td>
<td>M: 1.12 (0.98, 1.28)</td>
<td>&lt;33.4 MET h/week</td>
<td>M: 1.22 (1.11, 1.36)</td>
</tr>
<tr>
<td></td>
<td>≥5 h/d watching TV</td>
<td>≥20 MET h/week</td>
<td>W: 1.23 (1.06, 1.41)</td>
<td>&lt;20 MET h/week</td>
<td>W: 1.39 (1.24, 1.55)</td>
</tr>
<tr>
<td>van der Ploeg (2012)</td>
<td>≥11 h/d sitting time</td>
<td>≥300 min/week PA</td>
<td>1.57 (1.28, 1.93)</td>
<td>0 min/week PA</td>
<td>1.36 (1.26, 1.92)</td>
</tr>
<tr>
<td>Matthews (2012)</td>
<td>≥7 h/d watching TV</td>
<td>&gt;7 h/week MVPA</td>
<td>1.47 (1.20, 1.79)</td>
<td>1-3 h/week MVPA</td>
<td>1.95 (1.63, 2.35)</td>
</tr>
<tr>
<td><strong>CVD incidence/mortality</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seguin (2014)</td>
<td>≥11 h/day total sedentary time</td>
<td>≥19.75 MET h/week</td>
<td>0.89 (0.66, 1.22)</td>
<td>0-3 MET h/week</td>
<td>1.20 (0.95, 1.51)</td>
</tr>
<tr>
<td>Matthews (2012)</td>
<td>≥7 h/d watching TV</td>
<td>&gt;7 h/week MVPA</td>
<td>2.00 (1.33, 3.00)</td>
<td>1-3 h/week MVPA</td>
<td>2.63 (1.81, 3.84)</td>
</tr>
<tr>
<td>Chomistek (2013)</td>
<td>≥10 h/day sitting time</td>
<td>≥20 MET h/week</td>
<td>1.05 (0.83, 1.32)</td>
<td>≤1.8 MET h/week</td>
<td>1.63 (1.39, 1.90)</td>
</tr>
<tr>
<td><strong>Cancer mortality</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seguin (2014)</td>
<td>≥11 h/day total sedentary time</td>
<td>≥19.75 MET h/week</td>
<td>1.30 (1.00, 1.68)</td>
<td>0-3 MET h/week</td>
<td>1.21 (0.97, 1.50)</td>
</tr>
<tr>
<td><strong>Diabetes incidence</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Krishnan (2009)</td>
<td>≥5 h/d watching TV</td>
<td>&gt;3 h/week MVPA</td>
<td>2.03 (no CI provided)</td>
<td>&lt; 1 h/week MVPA</td>
<td>3.64 (no CI provided)</td>
</tr>
</tbody>
</table>

HR, hazard ratio; CI, confidence interval; M, male sample; W, female sample; h/d or h/w, hours per day or hours per week; MET, metabolic equivalents; PA, physical activity; MVPA, moderate-vigorous physical activity
2.7 Figures

Figure 1

Summary of evidence search and selection

20,980 records identified through database searching

25 additional records identified through other sources

15,749 records after duplicates removed

65 records excluded due to sampling of non-adults; failure to adjust for physical activity in regression models; prevalence studies without definitive outcomes; sedentary behaviour defined as low physical activity, lack of statistical reporting in results.

108 records screened for eligibility

47 full-text articles included in qualitative synthesis

6 studies excluded due to unclear presentation of statistical effect sizes

41 studies included in quantitative synthesis (meta-analysis)

All-cause mortality (13)
Cardiovascular disease related incidence and mortality (9)
Cancer-related incidence and mortality (14)
Type 2 diabetes incidence (5)
Figure 2

Association between high sedentary time and health outcomes, adjusted for physical activity

An HR > 1 suggests that high sedentary time is harmful. Diamonds indicate overall HRs with associated 95% CIs. CVD = cardiovascular disease; HR = hazard ratio.
### Figure 3

Pooled associations between high sedentary time and health outcomes and modifying effects of physical activity

<table>
<thead>
<tr>
<th>Outcome (number of studies)</th>
<th>Study Statistics</th>
<th>Hazard ratio and 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hazard ratio</td>
<td>Lower limit</td>
</tr>
<tr>
<td>Pooled effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All-cause mortality (13)</td>
<td>1.240</td>
<td>1.090</td>
</tr>
<tr>
<td>Cardiovascular mortality (6)</td>
<td>1.179</td>
<td>1.106</td>
</tr>
<tr>
<td>Cardiovascular incidence (3)</td>
<td>1.143</td>
<td>1.002</td>
</tr>
<tr>
<td>Cancer mortality (7)</td>
<td>1.173</td>
<td>1.108</td>
</tr>
<tr>
<td>Cancer incidence (7)</td>
<td>1.130</td>
<td>1.053</td>
</tr>
<tr>
<td>Diabetes (5)</td>
<td>1.910</td>
<td>1.642</td>
</tr>
<tr>
<td>Knapp-Hartung Estimator</td>
<td>1.26</td>
<td>1.03</td>
</tr>
<tr>
<td>Heterogeneity ($I^2 = 92.62, P &lt; 0.001, Q = 40.234$)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Modifying effects of physical activity on risk of all-cause mortality

*High physical activity: high sedentary time*

<table>
<thead>
<tr>
<th>Study</th>
<th>Hazard ratio</th>
<th>Lower limit</th>
<th>Upper limit</th>
<th>Z-Value</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seguin (2014)</td>
<td>0.940</td>
<td>0.798</td>
<td>1.107</td>
<td>-0.741</td>
<td>0.459</td>
</tr>
<tr>
<td>Patel (2010)</td>
<td>1.120</td>
<td>1.031</td>
<td>1.216</td>
<td>2.692</td>
<td>0.007</td>
</tr>
<tr>
<td>Pavey (2012)</td>
<td>0.500</td>
<td>0.250</td>
<td>1.000</td>
<td>-1.660</td>
<td>0.050</td>
</tr>
<tr>
<td>Kim (2013)</td>
<td>1.170</td>
<td>1.061</td>
<td>1.290</td>
<td>3.149</td>
<td>0.002</td>
</tr>
<tr>
<td>van der Ploeg (2012)</td>
<td>1.570</td>
<td>1.279</td>
<td>1.928</td>
<td>4.306</td>
<td>0.000</td>
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<tr>
<td>Matthews (2012)</td>
<td>1.470</td>
<td>1.204</td>
<td>1.795</td>
<td>3.777</td>
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<tr>
<td>Knapp-Hartung Estimator</td>
<td>1.16</td>
<td>0.84</td>
<td>1.59</td>
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</tr>
<tr>
<td>Heterogeneity ($I^2 = 90.06, P &lt; 0.001, Q = 26.487$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Low physical activity: high sedentary time*

<table>
<thead>
<tr>
<th>Study</th>
<th>Hazard ratio</th>
<th>Lower limit</th>
<th>Upper limit</th>
<th>Z-Value</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seguin (2014)</td>
<td>1.220</td>
<td>1.079</td>
<td>1.379</td>
<td>3.180</td>
<td>0.001</td>
</tr>
<tr>
<td>Patel (2010)</td>
<td>1.649</td>
<td>1.517</td>
<td>1.793</td>
<td>11.729</td>
<td>0.000</td>
</tr>
<tr>
<td>Pavey (2012)</td>
<td>1.520</td>
<td>1.168</td>
<td>1.977</td>
<td>3.120</td>
<td>0.002</td>
</tr>
<tr>
<td>Kim (2013)</td>
<td>1.288</td>
<td>1.198</td>
<td>1.384</td>
<td>6.879</td>
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<tr>
<td>van der Ploeg (2012)</td>
<td>1.360</td>
<td>1.260</td>
<td>1.468</td>
<td>7.891</td>
<td>0.000</td>
</tr>
<tr>
<td>Matthews (2012)</td>
<td>1.950</td>
<td>1.624</td>
<td>2.341</td>
<td>7.156</td>
<td>0.000</td>
</tr>
<tr>
<td>Knapp-Hartung Estimator</td>
<td>1.46</td>
<td>1.22</td>
<td>1.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heterogeneity ($I^2 = 89.83, P &lt; 0.001, Q = 38.126$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

An HR>1 suggests that high sedentary time is harmful. Diamonds indicate overall HRs with associated 95% CIs. CVD=cardiovascular disease; HR=hazard ratio.
Chapter 3

3 Examining The Relationship Between Exercise Participation And Sedentary Behaviour During CR Participation

3.1 Part 1: Examining The Influence Of Exercise Participation On The Sedentary Time Of CR Patients

A modified version of this study has been submitted for publication in the Clinical Rehabilitation journal.

3.1.1 Abstract

Prolonged sedentary time is recognized as a distinct health risk, and mortality risks are expected to be greatest for individuals with low physical activity levels. It is unknown whether participation in exercise-based cardiac rehabilitation (CR) influences sedentary time particularly among those expected to be at greatest mortality risk. This study examined the influence of CR participation on sedentary time and identified the proportion and characteristics (socio-demographic and clinical) of patients who are highly sedentary and not meeting physical activity recommendations. A prospective study was conducted among patients of an exercise-based outpatient CR program in Canada and assessments were conducted at baseline and 3 months. Physical activity and sedentary behaviour information were collected by self-report, and convergent validity was examined on an accelerometer-wearing subsample. 130 participants were recruited,
with an average sedentary time of 8 hours/day. Sedentary time remained consistent at follow-up (relative change= -2.4%, P=0.07) notwithstanding a greater proportion meeting physical activity recommendations (relative change= 57.4%). 19.2% of participants were classified as highly sedentary and did not meet physical activity recommendations at baseline. No significant differences were found between the characteristics of these high-risk individuals and lower risk subgroups. Findings were consistent among the accelerometer-derived subgroup and the overall sample despite poor convergent measurement validity. These results suggest that the physical activity-focus of CR does not reduce patient sedentary behaviour. Future studies are needed to determine whether sedentary behaviour reduction strategies are more effective than physical activity-based strategies and lead to meaningful improvements in clinical outcomes.
3.1.2 Introduction

The average adult in North America spends the majority of their waking day expending little energy (≤1.5 resting metabolic equivalents) in sedentary behaviours such as sitting, lying down, watching television and using the computer (Matthews, Chen et al. 2008, Colley, Garriguet et al. 2011). This lifestyle trend is particularly worrying as mounting evidence suggests that prolonged sedentary time is associated with an increased risk for cardiovascular disease and all-cause mortality, independent of physical activity (Wilmot, Edwardson et al. 2012). These risks are expected to be highest among the highly sedentary individuals who are also not meeting minimum physical activity recommendations of 150 minutes of moderate to vigorous physical activity (MVPA) a week (Wilmot, Edwardson et al. 2012, Biswas, Oh et al. 2015).

Cardiac rehabilitation (CR) programs are an integral part of the standard of care for individuals recovering from a cardiovascular event (Stone and Arthur 2005, Heran, Chen et al. 2011). These exercise-based secondary prevention programs are highly effective at reducing mortality rates and improving the quality of life of patients by emphasising exercise training, patient education, psychosocial counselling, and risk factor modification (Heran, Chen et al. 2011, Lawler, Filion et al. 2011). Yet, exercise-based interventions have largely been shown to be unsuccessful in reducing sedentary time (Martin, Fitzsimons et al. 2015). Understanding the influence of CR participation on patient sedentary behaviours can inform the need for additional strategies targeted towards sedentary behaviour reduction. Furthermore, identifying the socio-demographic and clinical characteristics of patients (age, sex, sociodemographic factors,
cardiopulmonary fitness, comorbid conditions and psychosocial health) who are highly sedentary and do not meet physical activity guidelines can facilitate sedentary behaviour reduction strategies targeted towards these individuals at highest mortality risk (Biswas, Oh et al. 2016). While Prince and others found a cross-section of individuals to be highly sedentary upon graduating from CR, and associating their sedentary time with various negative cardio-metabolic markers, to the best of our knowledge, no study has examined the influence of CR participation on the potential change in sedentary behaviours of patients, with a particular focus on individuals who might be at highest mortality risk. The objectives of this study were to examine the extent to which CR participation influences the sedentary behaviour of patients, and to identify the proportion and characteristics (if any) of patients who do not meet physical activity recommendations and are highly sedentary.

3.1.3 Methods

This prospective study was conducted among patients of an exercise-based, 6-month outpatient CR program in Toronto, Canada. Assessments were conducted at baseline and after 3 months (program midpoint). This follow-up period is considered a critical period in which to examine adherence to physical activity recommendations and the uptake of healthy lifestyles (Lane, Carroll et al. 2001). The research ethics boards of the University Health Network and the University of Toronto approved the study protocol, and written informed consent was obtained from all participants.
Program Delivery

Participants were enrolled in the University Health Network-Toronto Rehabilitation Institute’s Cardiac Prevention and Rehabilitation program. The publicly-funded, outpatient CR program is among the largest in North America, accommodating as many as 1,800 patients per week (Grace, Bennett et al. 2014). Patients are referred to the program by a physician or after discharge from a hospital if they had a recent cardiovascular hospitalization or were assessed to be at risk for cardiovascular disease.

The service delivery model follows established clinical guidelines for traditional outpatient programs (CACR 2009), and the core components include patient assessments, risk stratification, health behaviour interventions, risk factor modification, psychosocial counselling, exercise training, and patient education. At program intake, patients undergo a medical assessment and graded exercise stress testing to determine their suitability for exercise training, and to facilitate the development of an individualized exercise prescription. Once approved for exercise training, patients participate in supervised, group-based exercise classes, typically held once or twice per week over a 6-month period with the expectation that patients will continue to exercise unsupervised. Exercise training consists of MVPA with the goal of reaching at least 60% of their peak aerobic exercise testing threshold, and strength (resistance) training. While moderate physical exertion in leisure time activities is routinely promoted, information and recommendations specifically for reducing sedentary behaviour are not part of program guidelines. Patients repeat medical assessments and graded exercise stress testing after 3 months (midpoint) and at the conclusion of the program to examine their cardiovascular health status and renew their exercise prescription.
Sampling and Participant Recruitment

Participants were selected by non-random, convenience sampling from consecutive CR intake classes during August 2015 to January 2016. Newly enrolled patients were approached with information about the study and invited to consent if they had completed their initial medical assessment/exercise stress testing and had not begun supervised exercise training. A sample size analysis for cross-sectional surveys using the z-test indicated that at least 130 patients would need to be sampled. This was based on an expected population proportion of highly sedentary patients with similar age-sex characteristics ($p=0.3$) (Harvey, Chastin et al. 2013), 80% power, a marginal error of $d=1/4p$, and a two-tailed alpha of 0.05.

Measurement of Sedentary Behaviour and MVPA

Participants were asked to self-report the time they typically spend in sedentary behaviours and MVPA. Self-reported questionnaires were used to minimize participant burden (Lee and Shiroma 2014). Participants provided their baseline assessment at study enrolment, and were followed-up within two weeks after their second medical assessment/exercise stress test (approximately 3 months from their baseline assessment). Clinical characteristics were extracted from medical assessment data and patient records, including anthropometry (height, weight, waist and hip circumference), medical history (referral indication, existing and prior disease history and risk factors), depressive
symptoms using the Centre for Epidemiological Studies – Depression Scale (Orme, Reis et al. 1986), and indicators of cardio-metabolic health from graded exercise stress testing.

Self-reported sedentary behaviour information was collected using the Sedentary Behaviour Questionnaire (SBQ) (Rosenberg, Norman et al. 2010). The SBQ has been validated as an approximate measure of overall and domain-specific sedentary time among adults (Rosenberg, Norman et al. 2010), has a low participant burden, can be implemented on a large scale, and provides context on the nature of activities undertaken (Healy, Clark et al. 2011, Atkin, Gorely et al. 2012). The SBQ assesses sedentary time across 9 behaviours (watching television, playing computer/video games, sitting while listening to music, sitting and talking on the phone, doing paperwork or office work, sitting and reading, playing a musical instrument, doing arts and crafts, sitting and driving/riding in a car, bus or train). Time spent in each activity was converted into hours (e.g. a response of 15 minutes recorded as .25 hours). For total scores, hours per day for each activity were summed separately for weekday and weekend days. Weekday hours were multiplied by 5 and weekend hours multiplied by 2 and summed for an estimate of total hours/week. MVPA information such as the typical MVPA activities undertaken, duration and frequency was available from the self-reported exercise component of the in-program medical health assessment. While not known as a validated measure of physical activity, the MVPA measure is readily available from the program and was chosen to lower the overall assessment burden for participants.
Assessment of Validity

A convenience-sampled subgroup of participants wore an ActiGraph GT3X+ triaxial accelerometer device on their hip (attached by an elastic belt) (ActiGraph, Pensacola, FL, USA) to assess concurrent validity with the self-reported measures of physical activity and sedentary behaviour. While there is no universally accepted ‘gold standard’ measure of physical activity and sedentary behaviour in free-living adults, accelerometer-determined physical activity and sedentary behaviour have been commonly used as a comparator in a number of studies using self-reported measures (Matthew 2005, Healy, Clark et al. 2011, Clemes, David et al. 2012). 50% of all participants were targeted to wear accelerometer devices by convenience sampling. This was to ensure that a minimum of 20 to 30 participants typically sampled in accelerometer validity studies were included (Reilly, Penpraze et al. 2008, Hutto, Howard et al. 2013). Participants selected to wear an accelerometer began wearing the device upon receiving the SBQ survey. While this method may have introduced measurement discordance, it maximized the opportunity to collect SBQ data. Participants were asked to wear the accelerometer during their waking hours (except during water-based activities) continuously for seven days, and to record their device wear time in a written log. Accelerometer output was processed using the manufacturer’s software (ActiLife version 6, ActiGraph, Pensacola, FL, USA) with reference to wear time logs to determine the precise times (approximately coinciding with accelerometer wear and removal periods) that movement ceased or began. Sleep time and non-wear periods were excluded from the scoring of physical activity and sedentary behaviour data. An automatic sleep scoring algorithm was used to estimate sleep time if participants did not return their written log or if they were deemed inaccurate (Cole,
Kripke et al. 1992). A 60 second sampling epoch was used when processing raw data and converted into counts per minute. This threshold is most commonly used for ActiGraph accelerometer-studies among older and less physically active adults (Gorman, Hanson et al. 2013). Thresholds of counts per minute (a reflection of the frequency and intensity of the raw acceleration values, summed based on epochs (i.e. ‘chunks’ of time)) were applied to calculate daily time spent in MVPA (≥1952 counts per minute), light-intensity physical activity (100 to 1951 counts per minute), and sedentary (<150 counts per minute) (Freedson, Melanson et al. 1998). In the absence of validated threshold cut-offs for cardiovascular patient populations, this threshold was chosen over others because of its lower cut off for moderate-intensity physical activity, which was deemed more attainable for older and clinical populations. Prolonged sedentary behaviour (sedentary time accumulated in bouts of 30 minutes or more) and non-prolonged sedentary behaviour (sedentary time accumulated in bouts < 30 minutes) were calculated separately (Healy, Winkler et al. 2015). Sedentary breaks were considered to be any count that interrupted a bout of sedentary time (<150 counts per minute). Examining the time accumulated in ≥10 minute bouts assessed participants who met physical activity guidelines. Total time was calculated as the sum of time spent in all activities (prolonged sedentary, non-prolonged sedentary, light-intensity physical activity, and MVPA). Data were considered valid if a participant wore their accelerometer for 10 or more hours in a day, with 4 or more valid days of data included for analyses. In the event that a whole week of accelerometer data was unavailable, then weekly MVPA and sedentary time was extrapolated from daily values. Consistent with other studies, extreme outlier values (>2 standard deviations from the mean, given normally distributed data) were removed to
ensure that plausible, non-erroneous data were analyzed (Uswatte, Foo et al. 2005, Colley and Tremblay 2011).

**Data Analysis**

Descriptive data were reported using means, standard deviation, frequencies and percentages. Relative change and paired t-tests were used to examine pre-post differences between baseline and follow-up data for the mean time spent in MVPA and sedentary behaviour. Using cut off parameters reported in other studies (Ford, Kohl et al. 2005, Touvier, Bertrais et al. 2010, Jefferis, Sartini et al. 2014), participants (based on self-reported data only) were classified into four sedentary behaviour risk categories: 1) meeting or exceeding physical activity recommendations (150 minutes of MVPA participation in a week) and low sedentary time (lowest quartile of sedentary time, 0-25%), 2) meeting or exceeding physical activity recommendations and high sedentary time (highest quartile of sedentary time, 75%-100%), 3) not meeting physical activity recommendations (less than 150 minutes of MVPA in a week) and low sedentary time (lowest quartile of sedentary time, 0-25%), and 4) not meeting physical activity recommendations and high sedentary time (highest quartile of sedentary time, 75%-100%). Participant characteristics within these categories were examined for differences using paired t-tests. Participant characteristics based on accelerometer data were not compared, as the available sample size was considered too small to make reasonable conclusions. Wilcoxon Signed Rank-Sum tests were used to compare baseline characteristics of the overall participant sample and the subsample that provided additional accelerometer data. Scatterplots, Pearson product-moment correlation
coefficients and Intra-Class Correlation Coefficients were examined to assess the convergent validity and the linear association (strength and direction) between the subjective and accelerometer-derived MVPA time and sedentary time. Statistical analyses were conducted using the R statistical software package, version 3.2 (R Development Core Team 2012). Significance was set at \( P<0.05 \) (two-tailed).

### 3.1.4 Results

Of the 468 CR patients approached (mean age: 62.0 years, 70% male), the study recruited the expected sample size of 130 participants. Follow-up information was available from 108 participants (83% follow-up). Participants were lost to follow-up due to the following reasons: they prematurely dropped out of the CR program or were unable to continue; were unreachable for 3 weeks after their second medical assessment; or declined their follow-up assessment. On average, participants attended 72% of their prescheduled CR classes from baseline to follow-up.

Table 1 outlines the socio-demographic, clinical and physical activity/sedentary behaviour characteristics of all participants at baseline. The majority were male, Caucasian, lived with a spouse or partner, were retired or close to retirement age, had a university education, had comorbid conditions, had a high body mass index, and were able to move independently without the use of walking aids. Participant characteristics were similar to the general population of referred CR patients with the exception of a lower prevalence of diabetics, and a greater prevalence of comorbidities (Grace, Russell et al. 2011). On average, participants reported spending 8 hours in sedentary behaviours
at baseline. Watching the television (mean 3.2 hours ± 1.2) was the most commonly reported sedentary behaviour followed by office work (mean 2.4 hours ± 1.1).

The mean sedentary time for participants at follow-up was relatively unchanged from baseline (relative change= -2.4%, P=0.07) despite a greater proportion meeting their physical activity recommendations (relative change= 57.4%), and increasing their MVPA (relative change= 42.2%, P=<0.001) (Table 2). These proportions were found ot be stable at follow-up. The proportions of participants across categories were comparable at baseline and follow-up. 19.2% of participants were found to be within the pre-identified, high-risk category of not meeting physical activity recommendations and having high sedentary behaviour, and at follow-up, this proportion was 8.8% (P=0.11) (Figure 1). No significant differences were found between the characteristics of these high-risk individuals, and those in lower risk subgroups (who met physical activity recommendations and/or had low sedentary behaviour) (Table 3).

A subsample of 63 participants wore an accelerometer, of which 35 had valid accelerometer wear data (75% or 47 participants had >4 valid days of data, but subsequent losses occurred after data cleaning), and 30 were followed-up. Questionnaire responses were found to be moderately concordant with accelerometer measurements for MVPA ($r=0.49$, 95% CI: 0.11-0.75, $P=0.01$) and poorly concordant with sedentary behaviour ($r=0.21$, 95% CI: -0.16 to 0.53, $P=0.26$) (Table 4). On average, participant questionnaire responses over-reported daily sedentary time (~8.1 hours vs. 4.6 hours) and underreported weekly MVPA time (111.0 minutes vs. 121.1 minutes). Irrespective of
these differences, findings from the subgroup had a consistent trend to those of the overall sample, where total sedentary time remained unchanged during CR participation between baseline and follow-up (relative change= -3.6%, \( P=0.43 \)) and MVPA increased (relative change= 52%, \( P=<0.001 \)). Similar to the subjectively assessed overall participant sample, the accelerometer-assessed subgroup showed no significant differences in the characteristics of high-risk individuals who did not meet physical activity recommendations and were highly sedentary to individuals with other profiles of physical activity and sedentary behaviour.

### 3.1.5 Discussion

This study found that patients participating in CR were highly sedentary at the start of the program, and this remained unchanged after 3 months of participation, despite some meeting physical activity recommendations. Approximately 19% of patients at baseline were classified as being at high mortality risk as they did not meet physical activity recommendations and were highly sedentary. However, we found no characteristics that distinguished these individuals from patients who met physical activity recommendations and/or had lower levels of sedentary behaviour.

Previous research had found that CR patients spend an average of 50% to 70% of their waking day in sedentary pursuits at CR, and post-CR (Buijs, Ramadi et al. 2015, Prince, Blanchard et al. 2015). While these studies postulated that the physical activity-focus of CR programs might not be effective at reducing sedentary behaviours, their inferences were limited to a single, cross-sectional time point. As the first study to prospectively
examine the sedentary behaviours of patients during CR participation, our findings reaffirm the emerging knowledge that CR programs may be less effective at modifying patient sedentary behaviours as compared to increasing physical activity. This agrees with evidence suggesting that interventions focused on promoting physical activity-alone may be more effective in helping individuals increase higher intensity physical activity over a short period of time in a day rather than reducing sedentary behaviours over the rest of the day (Martin, Fitzsimons et al. 2015). Future studies are needed to determine whether strategies focused on reducing sedentary behaviour or in combination with the present physical activity-focus of CR programs can help patients reduce their sedentary behaviour, and effectively improve overall clinical outcomes.

We found no significant distinguishing characteristics of highly sedentary individuals who did not meet physical activity recommendations. This contrasts the existing literature suggesting that certain individuals such as older males, those employed, and having physical impairments are expected to be more prone to being sedentary and not participating in exercise (Van Dyck, Cardon et al. 2011, Seguin, Buchner et al. 2014, O’Donoghue, Perchoux et al. 2016). Such a finding is perhaps unsurprising given that CR patients generally typify these characteristics and exhibit a range of risk factors associated with unhealthy behaviours, as well as physical and psychological limitations (Evenson and Fleury 2000, Forhan, Zagorski et al. 2013). Furthermore, it is well established that CR patients are poorly adherent to exercise-based programs (Martin, Hauer et al. 2012, Karmali, Davies et al. 2014). Thus there is a strong possibility that a substantial proportion of CR patients are already at greater mortality risk for prolonged
sedentary behaviour, particularly if they continue or revert to a physically inactive and sedentary lifestyle. While beyond the scope of this study, it also remains to be seen whether physically inactive and highly sedentary patients can be differentiated by psychological, social or environmental factors (Owen, Sugiyama et al. 2011). For example, these individuals may have a lower self-efficacy and behavioural motivation to participate in healthy behaviours. Accordingly, future research is needed to determine whether these additional factors characterise patients likely to be physically inactive and highly sedentary, while involving larger participant sample sizes to better elucidate any potential characteristics of patients associated with high physical inactivity and sedentary behaviour.

This study has important clinical and research implications. A meta-analysis examining the risks of prolonged sedentary time had determined that increases in physical activity can lead to a decreased mortality risk among highly sedentary individuals as compared to those with lower levels of physical activity (Biswas, Oh et al. 2015). Accordingly, sedentary behaviour reduction strategies that promote increased daily movements might not only address the risks of sedentary behaviour among the overall CR patient population but also at least partly alleviate mortality risks for those with patients who are likely to be non-adherent to their exercise training program and/or have physical limitations that already restrict their engagement in higher intensity physical activities. This further supports the incorporation of sedentary reduction strategies as part of CR delivery models and guidelines. Further research is needed to confirm, if as expected, that
sedentary behaviour reductions among CR patients and other exercise-engaged populations leads to significant improvements in clinical outcomes.

This study includes several limitations that warrant mention. First, misclassification bias from self-reported measures of sedentary behaviour and physical activity was a possibility. While we compared self-reported questionnaire measures with objectively measured accelerometer data, concordance with sedentary behaviour was found to be poor. This may be a result of the accuracy of the measures used in this study, or potential discordance by sex or clinical status between the overall sample and the accelerometer-wearing subsample of participants. Nonetheless, both measures showed consistent trends and patterns, suggesting that they are likely to realistically reflect the actual routine of patients. Given the lack of accepted consensus on a ‘gold-standard’ for sedentary behaviour measurement (Atkin, Gorely et al. 2012), the development of more precise methods to assess sedentary behaviour should be prioritised before larger-scale studies are conducted. Second, this study did not evaluate participants by the frequency of breaks in sedentary time and physical activity. While such information would have elucidated the manner in which daily movements are accumulated (Healy, Dunstan et al. 2008, Swartz, Squires et al. 2011), these might be challenging for participants to recall by self-reported methods. Future studies are needed to examine the consistency of our findings when breaks and bouts are also considered. Third, the weekly minutes of MVPA were reported to be higher in this study than other studies conducted among CR patients (Gayda, Juneau et al. 2006, Prince, Blanchard et al. 2015). While the participant sample closely matched the general referred CR patient population, it is possible that there may
be a greater proportion of less physically active patients among those who declined to participate. Fourth, discordance between SBQ and accelerometer data is possible as selected participants returned their accelerometer device a week after completing the SBQ. Nonetheless, we do not envision too much variation in physical activity and sedentary behaviour among participants in the span of a week. Lastly, the generalizability of our findings may be limited given that they are from a single CR center. However, we believe our findings can still resonate with other CR programs that follow similar delivery models and guidelines and serving populations with similar characteristics.

In conclusion, this study demonstrated that patients are highly sedentary and are likely to remain so during CR participation, irrespective of whether or not physical activity recommendations are met. Furthermore, a significant proportion of individuals did not meet physical activity recommendations and were highly sedentary, and accordingly, were at higher risk for sedentary behaviour-associated mortality. These results suggest that the existing physical activity-focus of CR programs may be insufficient in reducing sedentary behaviours, and future studies are needed to examine the feasibility and clinical effectiveness of sedentary behaviour reduction strategies tailored towards CR patients.
### 3.1.6 Tables

#### Table 1
Baseline characteristics of study participants and overall CR population

<table>
<thead>
<tr>
<th></th>
<th>All participants (n=130)</th>
<th>Subsample wearing accelerometer (n=30)</th>
<th>P value between samples</th>
<th>Overall population referred to CR * (n=2,635)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sociodemographic factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, mean years, (SD)</td>
<td>64.3 (10.6)</td>
<td>66.9 (10.5)</td>
<td>0.21</td>
<td>65.0 (11.2)</td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>78 (60%)</td>
<td>13 (43%)</td>
<td>0.15</td>
<td>1928 (73%)</td>
</tr>
<tr>
<td><strong>Support structure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lives with spouse or partner, n (%)</td>
<td>89 (69%)</td>
<td>20 (67%)</td>
<td>0.84</td>
<td>1915 (74%)</td>
</tr>
<tr>
<td>Lives alone, n (%)</td>
<td>24 (18%)</td>
<td>4 (13%)</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td><strong>Employment status</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retired, n (%)</td>
<td>54 (42%)</td>
<td>14 (47%)</td>
<td>0.77</td>
<td>1253 (50%)</td>
</tr>
<tr>
<td>Working full-time or part-time, n (%)</td>
<td>49 (38%)</td>
<td>6 (20%)</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White/Caucasian, n (%)</td>
<td>89 (68%)</td>
<td>23 (77%)</td>
<td>0.84</td>
<td>2040 (82%)</td>
</tr>
<tr>
<td><strong>Highest level of education attained</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University, n (%)</td>
<td>72 (55%)</td>
<td>14 (47%)</td>
<td></td>
<td>1850 (73%)</td>
</tr>
<tr>
<td>College/trades certificate or diploma, n (%)</td>
<td>32 (25%)</td>
<td>7 (23%)</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>High school or less, n (%)</td>
<td>26 (20%)</td>
<td>7 (23%)</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td><strong>Clinical and anthropometric factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoker, n (%)</td>
<td>3 (2%)</td>
<td>1 (3%)</td>
<td>0.73</td>
<td>204 (8%)</td>
</tr>
<tr>
<td>Type II diabetes, n (%)</td>
<td>20 (15%)</td>
<td>3 (10%)</td>
<td>0.49</td>
<td>827 (35%)</td>
</tr>
<tr>
<td>Depression/anxiety (existing or past), n (%)</td>
<td>33 (26%)</td>
<td>8 (27%)</td>
<td>0.80</td>
<td>NA</td>
</tr>
<tr>
<td>Comorbidities present</td>
<td>118 (90%)</td>
<td>24 (80%)</td>
<td>0.81</td>
<td>1621 (68%)</td>
</tr>
<tr>
<td>Can move independently</td>
<td>119 (92%)</td>
<td>24 (80%)</td>
<td>0.37</td>
<td>NA</td>
</tr>
<tr>
<td>Cardiopulmonary fitness VO₂ peak (ml/kg/min), mean, (SD)</td>
<td>21.7 (6.9)</td>
<td>21.6 (6.6)</td>
<td>0.91</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>Mean (SD) 1</td>
<td>Mean (SD) 2</td>
<td>T-Value</td>
<td>p-Value</td>
</tr>
<tr>
<td>------------------------------</td>
<td>-------------</td>
<td>-------------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td><strong>Body mass index, mean, (SD)</strong></td>
<td>28.2 (4.9)</td>
<td>28.0 (4.5)</td>
<td>0.89</td>
<td>NA</td>
</tr>
<tr>
<td><strong>CES-D score, mean, (SD)</strong></td>
<td>13 (9.2)</td>
<td>11.4 (5.9)</td>
<td>0.67</td>
<td>NA</td>
</tr>
</tbody>
</table>

**Sedentary behaviour and MVPA**

<table>
<thead>
<tr>
<th></th>
<th>Mean (SD) 1</th>
<th>Mean (SD) 2</th>
<th>T-Value</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-reported weekday sedentary time (hours), mean (SD)</td>
<td>8.1 (3.5)</td>
<td>7.8 (3.4)</td>
<td>0.58</td>
<td>NA</td>
</tr>
<tr>
<td>Self-reported weekend sedentary time (hours), mean (SD)</td>
<td>8.0 (3.6)</td>
<td>8.1 (4.0)</td>
<td>0.98</td>
<td>NA</td>
</tr>
<tr>
<td>Self-reported weekly MVPA time (minutes), mean (SD)</td>
<td>110.98 (124.1)</td>
<td>82.3 (47.5)</td>
<td>0.017</td>
<td>NA</td>
</tr>
<tr>
<td>Objective daily sedentary time (hours), mean (SD)</td>
<td>NA</td>
<td>4.6 (2.7)</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>Objective weekly MVPA time (minutes), mean (SD)</td>
<td>NA</td>
<td>273 (163.5)</td>
<td></td>
<td>NA</td>
</tr>
</tbody>
</table>

*Table includes all participants who completed baseline on-site clinical assessments, self-report and objective (accelerometer) movement measurements.*

* Characteristics of cardiac inpatients from 11 Ontario (Canada) hospitals enrolled in the Cardiac Rehabilitation Care Continuity through Automatic Referral Evaluation study (Grace, Russell et al. 2011).

CR, cardiac rehabilitation; SD, standard deviation; MVPA, moderate-to-vigorous intensity physical activity; NA, data not available/not applicable.
Table 2
Change in sedentary behaviour and MVPA determined from self-reported measures at baseline and 3-month follow-up a.

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Follow-up</th>
<th>Relative Change</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All participants with follow-up assessment (n=108)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sedentary behaviour</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekly sedentary time, hours</td>
<td>57.6 (23.0)</td>
<td>56.2 (22.2)</td>
<td>-2.4%</td>
<td>0.07</td>
</tr>
<tr>
<td>Weekday, hours/day</td>
<td>8.3 (3.5)</td>
<td>8.1 (3.4)</td>
<td>-2.4%</td>
<td>0.06</td>
</tr>
<tr>
<td>Weekend, hours/day</td>
<td>8.1 (3.4)</td>
<td>7.9 (3.4)</td>
<td>-2.5%</td>
<td>0.07</td>
</tr>
<tr>
<td><strong>MVPA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekly MVPA, minutes</td>
<td>105.1 (104.1)</td>
<td>149.5 (80.6)</td>
<td>42.2%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Physically active, n (%)</td>
<td>35 (32%)</td>
<td>55 (51%)</td>
<td>57.4%</td>
<td></td>
</tr>
</tbody>
</table>

a Mean values (standard deviation) unless otherwise specified.
CR, cardiac rehabilitation; MVPA, moderate-to-vigorous intensity physical activity.
P-value determined by paired t-test.
Table 3
Common characteristics of participants categorized as meeting or unable to meet physical activity recommendations (≥150 minutes of moderate to vigorous intensity physical activity per week), and low (lowest quartile of total sedentary time, 0-25%) and high (highest quartile of total sedentary time, 75-100%) sedentary behaviour, as assessed by self-reported measures at baseline, and 3 month follow-up. Participants within the second (25-50%) and third (50-75%) quartiles of sedentary behaviour are not shown. N=130.

<table>
<thead>
<tr>
<th>Low Sedentary Behaviour</th>
<th>High Sedentary Behaviour</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Physically Active</td>
<td>Physically Inactive</td>
</tr>
<tr>
<td><strong>Baseline</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>10</td>
<td>21</td>
</tr>
<tr>
<td>Mean age (SD)</td>
<td>59.9 (11.1)</td>
<td>67.5 (13.8)</td>
</tr>
<tr>
<td>Sex (%)</td>
<td>Male (63%)</td>
<td>Male (57%)</td>
</tr>
<tr>
<td>Mean BMI (SD)</td>
<td>23.9 (4.3)</td>
<td>27.5 (5.0)</td>
</tr>
<tr>
<td>Social support (%)</td>
<td>Married (100%)</td>
<td>Married (62%)</td>
</tr>
<tr>
<td>Education (%)</td>
<td>University (50%)</td>
<td>University (43%)</td>
</tr>
<tr>
<td>Mean CES-D score (SD)</td>
<td>14.4 (6.3)</td>
<td>10.3 (6.9)</td>
</tr>
<tr>
<td>Mean fitness, VO₂ (SD)</td>
<td>26.7 (9.3)</td>
<td>19.7 (6.2)</td>
</tr>
<tr>
<td>Comorbidities (%)</td>
<td>2 or more (63%)</td>
<td>2 or more (57%)</td>
</tr>
<tr>
<td><strong>Follow up</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean age (SD)</td>
<td>67.8 (10.2)</td>
<td>67.1 (13.1)</td>
</tr>
<tr>
<td>Sex (%)</td>
<td>Male (75%)</td>
<td>Both (50%)</td>
</tr>
<tr>
<td>Mean BMI (SD)</td>
<td>28.6 (5.1)</td>
<td>25.3 (2.7)</td>
</tr>
<tr>
<td>Social support (%)</td>
<td>Married (75%)</td>
<td>Married (50%)</td>
</tr>
<tr>
<td>Employment (%)</td>
<td>Retired/not in workforce (88%)</td>
<td>Retired/not in workforce (70%)</td>
</tr>
<tr>
<td>Education (%)</td>
<td>Colleges/trades (38%)</td>
<td>University (60%)</td>
</tr>
<tr>
<td>Mean CES-D score (SD)</td>
<td>8.2 (6.3)</td>
<td>8.9 (6.6)</td>
</tr>
<tr>
<td>Mean fitness, VO$_2$ (SD)</td>
<td>27.7 (8.2)</td>
<td>24.5 (9.7)</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Comorbidities</td>
<td>2 or more (63%)</td>
<td>Equal spread</td>
</tr>
</tbody>
</table>

MVPA, moderate to vigorous intensity physical activity; SD, standard deviation; BMI, body mass index; CES-D, Center for Epidemiological Studies Depression scale.
Physically Active, met physical activity guidelines of 150 minutes of moderate to vigorous intensity physical activity per week; Physically Inactive, did not meet physical activity guidelines of 150 minutes of moderate to vigorous intensity physical activity per week; Low Sedentary Behaviour, between 0-25% percentile of sedentary behaviour; High Sedentary Behaviour, between 75-100% percentile of sedentary behaviour.
P-value determined by paired t-test.
Table 4

Change in sedentary behaviour and MVPA determined from accelerometer-derived measures at baseline and 3-month follow-up a.

<table>
<thead>
<tr>
<th>Sub-sample with follow-up assessment (n=30)</th>
<th>Baseline</th>
<th>Follow-up</th>
<th>Relative Change</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sedentary behaviour</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekly sedentary time, hours</td>
<td>39.1 (15.2)</td>
<td>40.8 (9.4)</td>
<td>4.3%</td>
<td>0.43</td>
</tr>
<tr>
<td>Daily sedentary time, hours</td>
<td>5.6 (2.2)</td>
<td>5.4 (1.8)</td>
<td>-3.6%</td>
<td>0.43</td>
</tr>
<tr>
<td>Daily sedentary bouts, number/day</td>
<td>13.7 (4.1)</td>
<td>13.4 (4.1)</td>
<td>-2.2%</td>
<td>0.53</td>
</tr>
<tr>
<td>Daily sedentary breaks, breaks/day</td>
<td>13.5 (4.2)</td>
<td>13.2 (4.1)</td>
<td>-2.2%</td>
<td>0.54</td>
</tr>
<tr>
<td><strong>MVPA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekly MVPA, minutes</td>
<td>84.5 (56.1)</td>
<td>128.1 (52.3)</td>
<td>51.6%</td>
<td>0.04</td>
</tr>
<tr>
<td>Participants meeting MVPA guidelines, n (%)</td>
<td>10 (33.3%)</td>
<td>12 (40%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Questionnaire measures</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sedentary behaviour</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekly sedentary time, hours</td>
<td>54.1 (24.1)</td>
<td>52.0 (19.7)</td>
<td>-3.9%</td>
<td>0.55</td>
</tr>
<tr>
<td>Weekday, hours/day</td>
<td>7.8 (3.6)</td>
<td>8.8 (5.7)</td>
<td>12.8%</td>
<td>0.36</td>
</tr>
<tr>
<td>Weekend, hours/day</td>
<td>7.7 (3.7)</td>
<td>7.8 (3.2)</td>
<td>1.3%</td>
<td>0.81</td>
</tr>
<tr>
<td><strong>MVPA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekly MVPA, minutes</td>
<td>81.3 (46.2)</td>
<td>149.4 (89.3)</td>
<td>83.7%</td>
<td>0.006</td>
</tr>
<tr>
<td>Participants meeting MVPA guidelines, n (%)</td>
<td>32.4 (32%)</td>
<td>56.1 (51%)</td>
<td>73.1%</td>
<td></td>
</tr>
</tbody>
</table>

a Mean values (standard deviation) unless otherwise specified.

CR, cardiac rehabilitation; MVPA, moderate-to-vigorous intensity physical activity.
3.1.7 Figures

Figure 1

The proportion of participants categorized as meeting or not meeting physical activity recommendations (≥150 minutes of moderate to vigorous intensity physical activity per week), and associated sedentary time at baseline, and 3-month follow-up. Sedentary times are shown in increasing quartiles (Q1 is the lowest sedentary time, 0-25%, and Q4 is the highest sedentary time, 75-100%).

(a) Baseline

(b) Follow-up
3.2 **Part 2: Examining The Influence Of An Exercise Enhancement Intervention On The Sedentary Time Of CR Patients**

A modified version of this study has been published in the *General Internal Medicine and Clinical Innovations* journal.


**3.2.1 Abstract**

The extent to which exercise-based interventions influence the daily sedentary time of individuals is unclear. The objective of this study was to explore whether an integrative exercise-based intervention that had previously shown efficacy in increasing time in moderate-vigorous physical activity (MVPA) impacts the sedentary time of patients engaged in a cardiac rehabilitation (CR) program. We examined a 12-week randomized controlled trial intervention that featured music playlists enhanced with rhythmic auditory stimulation (RAS) as compared to usual care of CR only, on the duration of MVPA time and sedentary time. Accelerometer-derived and self-reported MVPA time and sedentary time were used to examine the duration spent in each. The relationship between MVPA time and sedentary time was determined using Pearson’s Correlation Coefficient. Changes in MVPA time and sedentary time over the 12-weeks were determined using mixed effects repeated measures ANOVA tests. The RAS-enhanced music intervention arm showed the highest duration of weekly MVPA time across groups but irrespective of intervention exposure, all participants were highly sedentary over the 12-weeks No
correlation was found between sedentary time and MVPA time of all participants derived by accelerometer ($r = -0.08, P=0.812$) and self-report ($r=-0.24, P=<0.001$). Self-report resulted in an overestimation of sedentary time and an underestimation of MVPA time as compared to accelerometer-derived data. The majority of participants in an integrative intervention were successful at meeting MVPA recommendations but otherwise were highly sedentary. Therefore it was found that increasing MVPA does not result in a compensatory decrease in sedentary time. Accordingly, our findings reaffirm the needs for the need for separate strategies that focus on reducing overall daily sedentary time and promote regular MVPA.
3.2.2 Introduction

Prolonged sedentary time is increasingly abundant in modern societies and independently associated with cardiovascular and non-cardiovascular mortality (Colley, Garriguet et al. 2011, Matthews, George et al. 2012). Intervention strategies targeted at sedentary time have typically been designed to reallocate an individual’s sedentary time to physical activity (Owen, Sugiyama et al. 2011). While evidence has established the efficacy of exercise-based interventions for increasing moderate-vigorous physical activity (MVPA), it is unclear whether these interventions have spillover effects on the daily sedentary time of individuals.

The objective of this study was to explore the extent to which an integrative exercise-based intervention impacts the sedentary time of individuals. This study utilized data obtained from a novel intervention that combined enhanced music playlists with exercise. The intervention had previously demonstrated a significant increase in participants’ weekly adherence to MVPA-specific and total physical activity using music audio playlists enhanced with rhythmic auditory stimulation (RAS) as compared with a usual-care of participating in a structured exercise-based cardiac rehabilitation program. Considering its efficacy in influencing overall physical activity (irrespective of intensity), we hypothesized that the integrative exercise-based intervention effectively replaces daily sedentary time with physical activity (MVPA and otherwise).
3.2.3 Methods

Intervention Design and Primary Outcome Findings

The Music Activity INTervention for Adherence Improvement (MAINTAIN) study was a randomized controlled trial designed to examine the incremental effects of personalized music playlists on the time that CR patient participants spent in total and intensity-specific physical activity (Alter, O'Sullivan et al. 2015). A total of 34 participants were initially recruited and met inclusion criteria, of which 1 participant dropped out. 33 participants completed the study; with 11 participants included in the usual-care control arm (no music intervention), and 22 participants received a music playlist intervention featuring two arms: (1) listening to a personalized music playlist while engaging in physical activity; (2) listening to a personalized music playlist enhanced with RAS while engaging in physical activity. All participants enrolled in the trial received CR as their minimum standard of care irrespective of treatment arm. Participants were recruited during their third class (3 weeks from intake) in the CR program, and were followed over the 12-week study duration (baseline to program midpoint). The study was reviewed and approved by the University Health Network-Toronto Rehabilitation Institute research ethics board. The trial was registered with ClinicalTrials.gov I.D. (NCT01752595).

The primary outcome findings of the trial (with details on the intervention, sample size estimation and methods) are published elsewhere (Alter, O’Sullivan et al. 2015). Briefly, the weekly average duration of total physical activity and MVPA were found to be higher among participants randomized to the RAS-enhanced music playlist intervention arm as compared to both the non-RAS music playlist arm and the non-music, usual-care control...
arm. These findings demonstrated that the integrative intervention of RAS combined with music playlists was feasible and effective at improving participation time and adherence to total and intensity-specific physical activity within a structured exercise-based cardiac rehabilitation program.

Participants

Participants were patients enrolled in the Cardiac Prevention and Rehabilitation Program of the University Health Network-Toronto Rehabilitation Institute in Toronto, Canada. The outpatient CR program is one of the largest in North America by patient volume, accommodating up to 1,800 patients a year and servicing a territory that encompasses 2.2 million mostly urban dwelling individuals. The program is publicly funded and services are provided free of charge as part of Canada’s universal healthcare system. All of the patients enrolled in this study had a recent cardiovascular hospitalization. Patients were referred to the program through automated referrals at the time of hospital discharge, or by their cardiologist during ambulatory care follow-up. Waiting-time from point of referral to CR intake generally took place within 8 weeks following their cardiovascular hospitalization. Patients take part in individualized weekly exercise sessions, one-on-one counselling, education and peer-to-peer support (Hamm and Kavanagh 2000, Franklin, Whaley et al. 2013) and were expected to attend one on-site visit per week over the 24-week duration of the program.
Data Collection

Patient characteristics were obtained from clinical records collected at baseline for age, sex, body mass index (by measured weight and height), cardiopulmonary fitness (peak VO$_2$, assessed through cardiopulmonary exercise testing), referral indication, cardiovascular risk factors, comorbidities, and prior disease history. Depressive symptoms were assessed using the Centre for Epidemiological Studies – Depression Scale, and cardiac self-efficacy was assessed using the Cardiac Self Efficacy Scale (Orme, Reis et al. 1986, Sullivan, LaCroix et al. 1998).

All participants wore a triaxial accelerometer device (Personal Activity Monitor, P.A.M., model AM300, PAM BV, Doorwerth, the Netherlands) on their waist (belt, edge of pants/skirt) during their waking days to objectively measure their weekly minutes spent performing light-intensity physical activity (2 to 3 metabolic equivalents), moderate-intensity physical activity (3 to 6.9 metabolic equivalents) and vigorous-intensity physical activity (≥7 metabolic equivalents). The P.A.M. accelerometer device is low-cost, shown to have little participant burden, capable of storing data continuously for over three months, and previously validated for the estimation of daily physical activity among adults and clinical populations (Slootmaker, Paw et al. 2009, Vooijs, Alpay et al. 2014). Weekly recordings of moderate and vigorous intensity physical activity time were summed to estimate the MVPA for participants. MVPA time was compared to the Physical Activity Guidelines for Adults (aged 18-64 years and 65 years and older) of accumulating at least 150 minutes of MVPA per week to achieve health benefits and improve functional abilities. We derived daily estimates of sedentary time using
accelerometer-measured physical activity time and self-reported sleep time, which is herein referred to as the accelerometer-derived measure. While semi-objective, this composite measure of sedentary time was expected to partially correct and minimize the possible measurement errors and recall bias from using self-reported sedentary time alone (Atkin, Gorely et al. 2012, Matthews, Moore et al. 2012).

Along with accelerometer-derived data, participants were asked to self-report their daily time spent sleeping, being sedentary during their waking day, and participating in MVPA throughout the 12-week duration of the MAINTAIN trial. The short-recall interval of the self-reported assessment was designed to limit the scope of allowable reporting errors. These individual participant logs were then summed into weekly totals. Weekly patient data were considered valid if non-zero values for sleeping time and sedentary time were reported for at least 5 days of the week. Excluded from calculations were sleeping and sedentary time that were reported with a zero value or left blank.

**Statistical Analysis**

Statistical analyses were performed using the R statistical software, version 3.2 (R Development Core Team 2012) and statistical significance was established at $P<0.05$. Participants in the intervention and control arms were examined separately and together for weekly differences in MVPA time and sedentary time using one-way ANOVA and Kruskal-Wallis tests. Scatterplots and Pearson product-moment correlation coefficients were examined to assess the strength and direction of the linear association between accelerometer-derived and self-reported sedentary and MVPA time of all participants.
One-way mixed effects analyses of repeated measures ANOVA tests were conducted to compare the longitudinal effect of study duration on sedentary and MVPA time. Convergent validity between the self-reported and accelerometer-derived MVPA and sedentary time were examined by Pearson correlation coefficients. Among those who provided self-reported time, one participant’s accelerometer-derived data was unavailable for any of the 12 weeks and subsequently removed from the validity analysis.

### 3.2.4 Results

The baseline characteristics of all participants are detailed in Table 1. The clinical and socio-demographic characteristics of the sample was found to be generalizable to the CR patient population in the region (Shanmugasegaram, Oh et al. 2013). The average age was 63 years, and the majority male, married, with at least 1-2 comorbidities and confident in their abilities to self-manage cardiovascular disease and exercise. Poor concurrent validity was found for all participants between accelerometer-derived and self-reported sedentary time ($r=0.327$, $P=0.300$) and MVPA time ($r=-0.209$, $P=0.516$). Self-reported time ranged from 0 to 356 minutes of MVPA per week and 1 to 17 hours spent sedentary. Accelerometer-derived MVPA ranged from 0 to 507 minutes of MVPA per week, and sedentary time ranged from 10 to 21 hours per day.

**Association between MVPA and Sedentary Time**

The RAS-enhanced music intervention arm showed the highest duration of weekly MVPA time across groups. Irrespective of intervention exposure, all participants were highly sedentary over the 12-weeks (Figure 1). We found that the association between
MVPA time and sedentary time did not change between the intervention and control arms based on accelerometer-derived and self-reported data (Table 2). Among all participants, there was poor correlation between sedentary and MVPA time for both accelerometer-derived \((r= -0.08, P=0.812)\) and self-reported measurements \((r= -0.24, P<0.001)\).

Participants underestimated their sedentary time (mean difference of 4 hours per day) and overestimated their MVPA time (mean difference of 62 minutes per week) when compared to accelerometer-derived data. Sedentary time \((F\text{-value}=1.19, P=0.3)\) and MVPA time \((F\text{-value}=1.623, P=0.093)\) did not change significantly over the 12-week duration of the trial for the RAS-enhanced music intervention group.

### 3.2.5 Discussion

This study examined whether an integrative intervention combining music playlists with RAS was more efficacious at improving sedentary times than usual care among patients participating in a structured exercise-based cardiac rehabilitation program. While MVPA was increased by RAS, the integrative intervention did not influence sedentary time. This is in line with earlier work that suggests that interventions designed to increase MVPA do not elicit as meaningful of a reduction in sedentary time as those interventions focused specifically on reducing sedentary behaviours (Prince, Saunders et al. 2014, Prince, Blanchard et al. 2015).

To the best of our knowledge, this study is the first to examine the effect of an integrative intervention that combines a multicomponent lifestyle program such as CR with RAS-enhanced music playlists on displacing sedentary time. Second, we know of no other
study to have examined the relationship between MVPA and sedentary time among a
clinical population engaged in a structured exercise and lifestyle program. The 12-week
study duration of the intervention represents the midpoint of 6-month CR and other
integrative lifestyle programs, and has been shown to be a critical period in which to
examine the adherence to physical activity and the uptake of healthy lifestyles (Lane,
Carroll et al. 2001). The consistency in sedentary and MVPA time over this period
suggests that behavioural patterns of physical activity are likely to be stable up to this
point. Our finding that participants underestimated their sedentary time and overestimated
their MVPA time also suggests that exercise-engaged populations seem to be no better at
perceiving their activity patterns than general populations (Klesges, Eck et al. 1990).
Self-reported measurement is wrought with inaccuracy related to social desirability and
recall bias. While the pairing of accelerometer measurement is expected to increase
precision, accuracy and to validate self-reported measures, these devices have been
shown to misclassify sedentary behaviours (Atkin, Gorely et al. 2012). Despite the
limitations of our methods of measurement, both show consistent trends and patterns,
which suggests that they are likely to realistically reflect the actual routine of patients.
Future studies incorporating inclinometer devices that show promise in differentiating
between postures may serve to better elucidate the risks of physical inactivity and
sedentary behaviour (Ryan, Grant et al. 2006).

Available evidence suggests that the risks associated with prolonged sedentary time are
highly dependent on MVPA. For example, a previous meta-analysis from our group
suggested that adverse event rates associated with prolonged sedentary time were
significantly less among those engaged in MVPA (Biswas, Oh et al. 2015). Moreover, participation in MVPA results in increasing cardiopulmonary fitness levels, which itself, is an important independent predictor of long-term outcomes over and beyond reductions in sitting times (Myers 2003, Warburton, Nicol et al. 2006). Accordingly, strategies that aim to displace sedentary time with longer durations of light-intensity physical activity may not approach the prognostic health benefits associated with shorter durations of higher-intensity physical activity, irrespective of total caloric expenditures. That said, the behavioural patterns of sedentary behaviour and MVPA may be mutually exclusive for many individuals, as those who participate in MVPA may also remain sedentary during the rest of their waking day (Colley, Garriguet et al. 2011, Owen, Sugiyama et al. 2011). This may explain why studies have demonstrated only modest or negligible efficacy associated with MVPA interventions at reducing sedentary time (Prince, Saunders et al. 2014, Martin, Fitzsimons et al. 2015). In this study, the majority of patients who were participating in exercise-based CR and received an integrative co-intervention of personalized music playlists with RAS achieved minimal acceptable MVPA targets despite sedentary times approaching and/or exceeding 10 hours per day. As such, interventions targeting MVPA and sedentary time may necessitate separate and distinctive behavioural strategies in order for participants to sufficiently adhere to them.

This study’s focus on patients participating in an integrative intervention designed to increase MVPA provides an ideal situation in which to determine the longitudinal co-occurrence of MVPA and sedentary behaviour. Nonetheless, our study has limitations which merit discussion. We acknowledge that our study participants may be more
compliant and adherent with prescribed physical activity than those not enrolling in such studies (Alter, Oh et al. 2009, Bjarnason-Wehrens, McGee et al. 2010). With this considered, the consistently long duration of sedentary time observed across trial arms and for the entire sample reinforces the expectation that there is a high burden of sedentary behaviour even among exercise-engaged populations. Furthermore, a small sample size and a single center were additional limitations of this study. Accordingly, our findings are preliminary and might require further testing and replication among larger sample sizes to confirm the significance of our findings.

In conclusion, the majority of participants in an integrative intervention were successful at meeting MVPA recommendations but otherwise were highly sedentary. Accordingly, while the deleterious health risks associated with prolonged sedentary time may be lower for exercise-engaged populations; the results of this study and others reaffirm the need for personalized strategies that focus on reducing overall daily sedentary time in addition to those promoting regular MVPA.
### 3.2.6 Tables

#### Table 1

Baseline characteristics of the study sample

<table>
<thead>
<tr>
<th>Population a (N=944)</th>
<th>Sample (n=31)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sociodemographic factors</strong></td>
<td></td>
</tr>
<tr>
<td>Mean age, years (SD)</td>
<td>64.1 (9.8)</td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>739 (78.3)</td>
</tr>
<tr>
<td>Married, n (%)</td>
<td>775 (82.8)</td>
</tr>
<tr>
<td><strong>Clinical factors</strong></td>
<td></td>
</tr>
<tr>
<td>Past or current smoker, n (%)</td>
<td></td>
</tr>
<tr>
<td>Mean body mass index, kg/m² (SD)</td>
<td></td>
</tr>
<tr>
<td>Mean baseline VO₂ peak, ml/kg/min (SD)</td>
<td></td>
</tr>
<tr>
<td>Referral diagnosis</td>
<td></td>
</tr>
<tr>
<td>Coronary artery bypass graft, n (%)</td>
<td></td>
</tr>
<tr>
<td>Percutaneous transluminal coronary angioplasty stent, n (%)</td>
<td></td>
</tr>
<tr>
<td><strong>Number of comorbidities</strong></td>
<td></td>
</tr>
<tr>
<td>None, n (%)</td>
<td></td>
</tr>
<tr>
<td>1-2, n (%)</td>
<td></td>
</tr>
<tr>
<td>3-4, n (%)</td>
<td></td>
</tr>
<tr>
<td><strong>Behavioural factors</strong></td>
<td></td>
</tr>
<tr>
<td>Mean CES-D score (SD)</td>
<td></td>
</tr>
<tr>
<td>Mean Stanford self-efficacy score (SD)</td>
<td></td>
</tr>
<tr>
<td>Mean Cardiac self-efficacy score (SD)</td>
<td></td>
</tr>
</tbody>
</table>

a Characteristics of cardiac inpatients from 11 Ontario hospitals enrolled in the Cardiac Rehabilitation Care Continuity through Automatic Referral Evaluation study (1807 of 2635 recruited patients were enrolled, 944 patients have participated in CR) (17)

SD, standard deviation; CES-D, Centre for Epidemiological Studies – Depression scale
Table 2

The average weekly moderate-vigorous physical activity (MVPA) time and sedentary time of participants randomized to the trial arms of the primary randomized control trial study (Alter, O'Sullivan et al. 2015)

<table>
<thead>
<tr>
<th></th>
<th>Control arm (no music, usual CR care) (n=11)</th>
<th>Intervention arm (usual CR care with RAS) (n=10)</th>
<th>Intervention arm (usual CR care without RAS) (n=10)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekly accelerometer-derived volume of total MVPA, mean minutes (SD)</td>
<td>370.2 (332.5)</td>
<td>631.3 (473.8)</td>
<td>320 (355.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Weekly self-reported volume of total MVPA, mean minutes (SD)</td>
<td>510.3 (421.3)</td>
<td>550.5 (373.7)</td>
<td>407.5 (307.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Daily accelerometer-derived volume of total sedentary time, mean hours (SD)</td>
<td>13.7 (2.2)</td>
<td>14.7 (1.2)</td>
<td>13.6 (2.4)</td>
<td>0.061</td>
</tr>
<tr>
<td>Daily self-reported volume of total sedentary time, mean hours (SD)</td>
<td>10.8 (1.2)</td>
<td>7.8 (2.3)</td>
<td>8.6 (2.3)</td>
<td>0.122</td>
</tr>
</tbody>
</table>

SD, standard deviation; CR, cardiac rehabilitation; RAS, rhythmic auditory stimulation.
3.2.7 Figures

Figure 1

The moderate-vigorous intensity physical activity (MVPA) time and sedentary time of participants in an integrative intervention featuring cardiac rehabilitation (CR) with the addition of 1) music playlists enhanced with rhythmic auditory stimulation (playlist plus RAS) (n=10); 2) music playlists without RAS (playlist) (n=10), or 3) a control group with usual-care CR only (n=11). Error bars represent the standard error of the means. N=31.
Chapter 4

4 Identifying And Exploring Factors To Inform Sedentary Behaviour Interventions For CR Patients

4.1 Part 1: The Awareness And Understanding Of Sedentary Behaviour, Together With The Perceived Facilitators And Barriers To Reducing Sedentary Behaviours From The Perspectives Of CR Patients And Staff

A modified version of this study has been submitted for publication in the *Disability and Rehabilitation* journal.

4.1.1 Abstract

It is important to understand why individuals engage in sedentary behaviour, irrespective of their participation in physical activity, in order to develop effective intervention efforts that encourage reduced sedentary behaviours. This study sought to understand the awareness and understanding of sedentary behaviour, as well as the perceived facilitators and barriers to reducing sedentary behaviours from the perspectives of individuals undertaking an exercise-based cardiac rehabilitation (CR) program, and from staff involved in supporting the self-management of these individuals. A descriptive qualitative approach was used. Guided by an ecological framework for sedentary behaviour, semi-structured interviews were conducted with 15 patients, and two focus
groups with 6 staff of a large outpatient CR program in Canada. Data were analysed using thematic analysis. Patients did not place much importance on reducing their sedentary behaviour as they were unconvinced of the health benefits, did not perceive themselves to be sedentary, or associated such behaviours with enjoyment and relaxation. Staff were aware of sedentary behaviour risks but many saw them as less critical than other healthy lifestyle behaviours. Intrapersonal factors (physical and psychosocial health) and environment factors (the information environment, socio-cultural factors, the natural environment) within the behaviour setting contexts of leisure time, the home, and work were common themes identified as influencing patient sedentary behaviour. CR programs should modify their education and delivery components to increase awareness of the independent health benefits of reducing sedentary behaviour, utilizing existing behaviour change strategies such as self-monitoring and goal-setting, and use a participatory approach to tailor strategies to individual patients.
4.1.2 Introduction

The inverse relationship between physical activity participation and the risk of cardiovascular disease, hospitalization, and mortality is well established (Sattelmair, Pertman et al. 2011). Thus, the benefits of promoting regular moderate-to-vigorous intensity physical activity as an essential part of primary and secondary chronic disease prevention strategies is widely accepted (Myers 2003, Whaley, Brubaker et al. 2006). However, epidemiological surveillance studies have shown that adults also typically spend over half of their waking day in sedentary states of seated and/or reclined activity with little energy expenditure (Matthews, Chen et al. 2008, Colley, Garriguet et al. 2011). This lifestyle trend is particularly worrying, as evidence suggests that prolonged periods in sedentary behaviours can affect cardiovascular and all-cause mortality risk independent of physical activity participation (Hamilton, Healy et al. 2008, Wilmot, Edwardson et al. 2012). Hence, it is important to understand why individuals engage (or do not) in sedentary behaviour, irrespective of their participation in physical activity. This is vital for developing intervention efforts that encourage more active lifestyles.

Existing strategies to reduce sedentary time in adults have largely focused on promoting physical activity alone or breaking up sedentary bouts with light-intensity physical activities (Pate, O'Neill et al. 2008, Owen, Sugiyama et al. 2011). However, the mixed effectiveness of these strategies (Martin, Fitzsimons et al. 2015) may be explained by individual, social, and environment differences (Owen, Leslie et al. 2000). For example, Deliens et al. (2015) found that engaging in physical activity and sedentary behaviour among university students was influenced by similar factors at the individual level (such as time and convenience), and
in terms of social support, the physical environment, and exposure to information (such as media and advertising) (Deliens, Deforche et al. 2015). In contrast, Chastin et al. (2014) examined the perspectives of older women and found that while some barriers to reducing sedentary behaviour were identical to those affecting physical activity (self-efficacy, functional limitations, ageist stereotyping), others appeared to be specific to sedentary behaviour ( locus of control, pain) (Harvey, Chastin et al. 2013). Mcewan et al. (2015) also noted that older individuals associated the term “sedentary” with negative health consequences but also knowingly engaged in many sedentary activities that they perceived positively (Mcewan, Tam-Seto et al. 2016). Furthermore, Rhodes et al. (2012) suggested that the sedentary behaviour research domain is complex and cannot be considered simply as the absence of physical activity, with the need to explore the distinct environmental and cognitive correlates to better understand sedentary behaviour (Rhodes, Mark et al. 2012).

Cardiac rehabilitation (CR) programs are ideal settings to examine sedentary behaviour among individuals already engaged in physical activity. These evidence-based, clinical programs have proven survival benefits among individuals with established cardiovascular disease through a multifaceted lifestyle modification intervention which includes education, self-monitoring, goal-setting, and individualized one-on-one counselling (Whaley, Brubaker et al. 2006). Central to the success of these programs is their focus on prescribing a structured, individualized program of physical activity and exercise. However, while current CR participants and those who had graduated from the program are more active than non-participants, their sedentary time remains high (Prince, Blanchard et al. 2015). Furthermore, current CR clinical guidelines also do not include recommendations to address the sedentary
behaviours of patients. Expanding CR programming to include strategies that reduce sedentary behaviours seems intuitively correct and could utilize behaviour change approaches already being operationalized. Accordingly, to inform the development of sedentary behaviour recommendations for integration into CR practice, it is important to engage individuals attending the program and staff involved in program delivery as to the appropriate design, development, and feasibility of such recommendations.

The objectives of this study were to understand the awareness and understanding of sedentary behaviour, as well as the perceived facilitators and barriers to reducing sedentary behaviours from the perspectives of individuals with a recent cardiovascular event who are undertaking a CR program, and from those individuals involved in supporting the self-management of these individuals. To the best of our knowledge, this is the first study to understand such perspectives among a population already engaged in a structured program of physical activity and from those responsible for delivering the program.

4.1.3 Methods

Conceptual Framework

The conduct and analysis of this study was guided by an ecological framework for sedentary behaviour which outlines multiple levels of influencers of sedentary behaviour in specific settings (Owen, Sugiyama et al. 2011). Adopted from a model applied to physical activity, the ecological framework suggests that sedentary behaviours are context and environment-specific with manifold determinants including individual, social, organizational/community, environmental, and policy. Of particular importance is to understand the behaviour setting,
which emphasizes the physical and social context in which sedentary behaviours occur. Furthermore, the ecological model is closely tied to social cognitive theory (Bandura 1991) which is a prominent behaviour change theory that has been used extensively to design physical activity programs for older adults and clinical populations (Booth, Owen et al. 2000, Lee, Arthur et al. 2008, Ashford, Edmunds et al. 2010). The premise of social cognitive theory is that individuals learn not only through their own experiences, but also by observing the actions of others and the results of those actions. The key constructs of the theory emphasize observational learning, reinforcement, self-control and confidence (self-efficacy) as relevant to health behaviour change interventions. These tenets paired with the ecological framework informed this study’s inquiry into understanding the barriers and facilitators to reducing sedentary behaviours and identifying implications for intervention development.

**Design and Approach**

This study used a descriptive, qualitative inquiry approach to allow for the exploration of the unique perspectives and experiences of individuals in relation to sedentary behaviour and daily lifestyles (Cresswell 1998). Such an approach is well-accepted for researching topics about which little is known and yielding practical answers of relevance to policy makers and health care practitioners (Sandelowski 2004). Given the important role of CR staff in the self-management of individuals with chronic disease, perspectives from both individuals participating in CR and the staff helping their self-management were included. The University Health Network-Toronto Rehabilitation Institute and the University of Toronto granted ethics approval for this study.
Participants

Participant recruitment was undertaken at the University Health Network-Toronto Rehabilitation Institute’s Cardiac Rehabilitation Program in Canada. The 24-week outpatient CR program is a publicly funded, lifestyle and chronic disease management intervention that provides services free of charge as part of Canada’s universal healthcare system. Patients typically attend the program once a week for on-site exercise (aerobic exercise and resistance training) and complete 4 other exercise sessions at home, and in addition participate in a standardized protocol of medical assessments, exercise stress testing, psychosocial counselling, education and peer-to-peer support (Hamm and Kavanagh 2000, Franklin, Whaley et al. 2013). Patients were sampled from a study that examined the influence of CR participation on sedentary behaviour and physical activity. The results of this study (not published as yet) found participants were highly sedentary at the start of the program (average of 8 hours daily sedentary time), and their sedentary time did not change significantly after three months of CR participation, whether or not they met physical activity recommendations (≥150 minutes of exercise per week). These participants, were in general, actively engaged in physical activity or were motivated to do so. Both patients and staff participants were recruited by purposive sampling (Patton 1990) based on their availability by direct personal interactions with the first author (AB) at various points during scheduled CR classes. The criteria for purposive sampling included patients who were 1) 18 years of age or older; 2) had a recent cardiovascular procedure/event, or were deemed to be at high risk for a future cardiovascular disease-related event; 3) could comfortably communicate in English; and, 4) had attended at least a month of their weekly scheduled CR classes. Staff were selected if they were directly involved in patient care or in the design and
delivery of the CR program. All participants provided informed consent prior to being interviewed.

**Data Collection**

The socio-demographic and clinical characteristics of patient participants were retrieved from medical records available at the CR program. Interviews with patients and staff were conducted and facilitated by the first author (AB) in a private meeting room during regular program participation/working hours between January and March 2016. Interviews with patients were held on a one-to-one basis, while two focus groups of 3 participants were conducted with staff. Interviews lasted for approximately 45 minutes to an hour in duration. The ecological framework for sedentary behaviour, such as the behavioural contexts, intrapersonal factors, and environmental determinants that conceivably affect an individual reducing their sedentary behaviours informed the development of themes for the open-ended, semi-structured interview guides, and were considered by the first author when reflexively interviewing participants. For patients, the facilitator asked questions about their current knowledge and views of physical activity and sedentary behaviour and the importance they place on them in the context of other health behaviours; their daily routine and perceived influences on daily sedentary behaviour; thoughts on reducing sedentary behaviour and how to incentivize and maintain such a change; and how they perceive that a CR program can assist them in maintaining a less sedentary daily routine.

Staff were asked to share their views on the sedentary behaviour of patients and how they perceive its importance to patients in context of other health behaviours; their opinions as to why patients may be sedentary in their daily routine; thoughts on strategies to help patients
be less sedentary and how to incentivize and maintain such a change; and how they perceive themselves and the resources of the CR program can help patients be less sedentary. The interview guides are available on request from the first author (AB). Probes or recursive questioning were used during interviews to explore issues in greater depth and verify the interviewer’s understanding of the information being collected (Cresswell 2003). Recruitment ceased as the study approached the point of data saturation, when successive interviews became repetitive and no new responses or themes emerged (Marshall 1996). Audio from the interview discussions were digitally recorded and transcribed verbatim by the first author (AB).

Analysis

Participants were contacted via telephone call or direct interaction to ascertain whether transcribed responses were true and reliable reflections of their opinions. Inductive thematic analysis was performed on the transcribed responses in consideration of the criteria described by Braun and Clark (2013) (Braun and Clarke 2013). This analytical approach is a data-driven method for identifying, analysing, and reporting patterned responses or meaning (themes) from participant responses. Interview transcripts and notes were read repeatedly before coding by the first author (AB) to familiarize himself with the depth and breadth of the content. The first author initially coded the interview transcripts, giving full attention to all data, and then codes were sorted into potential themes. The first author held a critical realist, constructivist position when actively identifying patterns/themes that reflected the experiences, meanings and the reality of participants. The formation of codes and themes were guided by the ecological framework for sedentary behaviour (Owen, Sugiyama et al.
2011) and social cognitive theory (Bandura 1991). Regular discussions took place between the first author (AB) and second author (GEF), who acted as a critical friend in exploring emerging themes and challenging the interpretations of the first author (Morehouse 1994).

4.1.4 Results

Individual interviews were held with 15 patients and two focus groups with 6 staff. The demographic and clinical characteristics of the patients are described in Table 1. Men and women were equally represented, with the majority Caucasian, retired, living with a spouse or partner, having a recent myocardial infarction event, 3 to 4 comorbid conditions, and a high body mass index. These socio-demographic and clinical characteristics are consistent with those of referred CR patients in the region in which the study was conducted (Grace, Russell et al. 2011). Staff had 2 to 30 years of CR-related experience and comprised of four program supervisors (who conduct and supervise patient education and exercise classes), a program manager (who oversees program resource allocation and staffing), and a nurse (performs clinical assessments and intake coordination).

The next section will first describe participants’ awareness and understanding of sedentary behaviour as a potential health risk. Second, the facilitators and barriers perceived to be most important to reducing sedentary behaviour in accordance with the ecological framework for sedentary behaviour will be presented. Intrapersonal factors (biological, psychological, and family situation), and environmental factors (behaviour settings, the information environment, social-cultural factors, natural environment) were perceived as facilitators and barriers to reducing sedentary behaviour among CR patients and staff. Figure
I summarizes the relationship between these factors. Participant quotes are attributed to non-identifiable pseudonyms to protect anonymity.

**Awareness and Importance**

Patients were generally aware of the terms, “sedentary” and/or “sedentary behaviour” and commonly associated them to be detrimental to health, with a lack of motivation and laziness, and others more positively with relaxation and as part of the time they spend with friends and family. In contrast, all patients were aware that physical activity was important to their health, and considered themselves to be physically active or trying to be. The majority of patients also did not feel that reducing their sedentary behaviour was a priority for them, even when several had mentioned that they were attempting to increase their daily movements as part of their physically active lifestyle:

*My new perspective of active is somebody who gets up every hour, or every couple of hours and does something to move his body, maybe stretches, maybe some light exercise so probably a combination of this and exercise to be an active person.* (“Don”, a 60 year old man, who is unmarried and employed)

A prominent reason for the lower priority placed on addressing sedentary behaviours was the association with activities of relaxation and enjoyment. An elderly patient was reluctant to reduce her reading time as it gave her enjoyment, even if she was seemingly aware of the risks:
I like to read fiction as an escape. I read up to 2:00 AM sometimes. I know it’s bad for me but it’s what I enjoy and I don’t want to change it. (“Clara”, a 72 year old woman, who is divorced and retired)

Some patients were also unsure whether the relaxation they got from being sedentary had any negative health consequences:

*When I’m feeling that I need a break, I just sit down, and I don’t think it’s bad. I don’t see if as it as negative. I don’t.* (“Fernando”, a 58 year old man, who is married and employed)

Several patients were also uninterested in reducing their sedentary behaviour, as they did not perceive themselves as leading a sedentary lifestyle:

*I don’t think it’ll change very much as I don’t think I am very sedentary to start with.* (“John”, a 63 year old man, who is married and retired)

Patients also prioritized other health issues that were more important to them than reducing their sedentary behaviour:

*When it comes to priority, that’s [reducing sedentary behaviour] probably down the list for a lot of people. It’s sleep, it’s exercise, it’s nutrition, and it’s dealing with other chronic issues. I don’t think it’s hot on a lot of people’s priorities right now.* (“Don”, a 60 year old man, who is unmarried and employed)
Right now, I'm really just focusing on improving my mental health and getting in my exercise. Once I can deal with that, I could probably start to think about being less sedentary. (“Alice”, a 53 year old woman, who is divorced and employed)

**Behaviour Settings**

Patients typically participated in sedentary behaviours within the physical and social context of their leisure time, their household, and at work. Common sedentary behaviours among retired patients were socializing with friends and family, reading books, watching television, and engaging in hobbies. Those employed often reported their workplace as the setting in which they were most sedentary, followed by watching television, and spending time with family at home. While transportation was occasionally mentioned, it was not considered a major contributor to sedentary behaviour.

**Intrapersonal Factors**

Health was frequently mentioned by patients as an important barrier to reducing sedentary behaviour, and was not limited to physical health but also psychological health. A patient described the physical pain she regularly experiences as a non-modifiable barrier to her ability to reduce sedentary behaviour:

*Some of my sitting time during the day is moving from pain to less pain.*

*With the heat and the medications, I don’t think you can do much there.*

(“Margaret”, a 89 year old woman, who is a widow and retired)
Another patient also explained how her depression adversely affects her vigour:

*I’m tired a lot. It’s a part of having depression and being on the medications that I’m on now. When anyone asks me how I’m doing, I say I’m tired, very tired. There are times that when left to my own devices I could sleep twenty hours a day.* (“Sarah”, a 45 year old woman, who is unmarried and employed)

Another patient found that anxiety from a family situation might contribute to her sedentary and inactive lifestyle:

*I’ve gone through a divorce and it really affected me. I went through a phase where I said I don’t have to do it anymore and I just stopped. So I did the opposite. I just stopped being motivated to be active. I just sat.* (“Jane”, a 62 year old woman, who is divorced and employed)

Better health was viewed as a strong motivator for health behaviour change. A patient who had previously been hospitalized after a stroke illustrated this point:

*I don’t want another stroke. I don’t want that. I am willing to follow any advice that will make me healthy.* (“Mandy”, 57 years old woman, married and employed)
Staff identified the elderly and those with musculoskeletal disabilities as likely to be less motivated to perform non-sedentary tasks as a result of physical limitations and pain, which may restrict their motivation to decrease sedentary behaviour.

**Perceived Environment**

Many patients were receptive to making a lifestyle change but perceived reducing their sedentary behaviour as difficult to achieve. Patients who were sedentary at their workplace, found that sitting for long periods of time was an obligatory aspect of their work:

> All the things that I do requires that I be sitting, and that must be same with 80% of office people. (“Ray”, a 57 year old man, who is married and employed)

Another patient was opposed to reducing sedentary behaviour at work as he felt that it might affect his productivity:

> I wouldn’t consider it [reducing sedentary behaviour at work]. I don’t know where to incorporate it at work. I can’t be on my computer and walk at the same time and give it the same degree of focus. (“Fernando”, a 58 year old man, who is married and employed)

A retired patient also did not feel that she would be able to influence her rigid routine:

> I’m interested in reducing my sitting time because it’s on my mind, but I just don’t think anyone can do anything to influence how much I’m sitting as I’m
pretty set in my ways. ("Jenny", a 61 year old woman, who is married and retired)

In addition, patients were reluctant to reduce their sedentary behaviour if it was inconvenient for them or imposed on their enjoyment or relaxation (such as when reading, watching the television and spending time with family):

*I’m only interested in changing my sedentary time at work. I sit at home because I want to relax and I don’t want to change that.* ("Gerald", a 52 year old man, who is married and employed)

A patient felt that reducing her sedentary behaviour would not be possible without reducing activities she finds enjoyable and satisfying:

*I don’t know what I would do in my life to be less sedentary. For example, the things I do in my life now, I enjoy doing. I’m not an expert on this obviously, but I don’t know anyway to do it.* ("Claudia", a 81 year old woman, who is married and retired)

A patient was hesitant to incorporate standing breaks as a strategy to reduce her sedentary behaviour as it might be uncomfortable for her:

*I would only take standing breaks if it were comfortable. I already don’t think that would work for me.* ("Sarah", a 45 year old woman, who is unmarried and employed)
Staff suggested that older individuals living alone may not have a daily routine that would inherently allow for moments to break up sedentary behaviours such as preparing meals for family members. Single, middle-aged men and diabetics were also identified as difficult to motivate as some of these individuals were likely to be set in their ways and were typical patients who did not follow through with staff advice:

There’s also a number of young to middle age men who live alone, diabetics, who love to eat out a lot, don’t have many friends, eat at home, watch TV all the time. They don’t really take care of themselves, have no reason to, and are set in their ways. They’re hard to motivate. (“Jackie”, program supervisor)

**Information Environment**

Individuals who perceived sedentary behaviours as detrimental to health had learned of the risks from friends and family, intuition, their own life experiences, and from staff during classes at the CR program.

Many patients suggested that more information about sedentary behaviour would be important to them, even among those who already perceived that prolonged sedentary behaviours were detrimental to health. When probed further, these patients suggested that once convinced of the risks, they could be motivated to alter their daily routine:

I kind of need the information first to make up my mind. If you could demonstrate to me what would happen if I reduced my sitting time and what
the health benefits were, that would motivate me. That would certainly open my eyes. (“Kyle”, a 66 year old man, who is married and retired)

Another patient suggested that a formalized program would draw this attention to the seriousness of the health risks, and a CR program might be an ideal repository for this information:

A formalized workshop or program might make me seriously believe in the risks. This (CR) is also a great place to get all that information. (“John”, a 63 year old man, who is married and retired)

Staff agreed that sedentary behaviour posed a negative health risk to patients. This was a consequence of their exposure to information from the media, from interactions with patients, and from being made aware from their experiences working at the CR program. It was suggested that the CR program could support patients to reduce their sedentary behaviour by supplementing existing educational lectures that already focused on physical activity. However, some staff also felt that existing educational messaging already incorporated information to help patients reduce their sedentary behaviour:

We have a handout specifically for this [the risks of sedentary behaviour] and we incorporate it into a talk on active living, so we think about not just about getting up every 30 minutes but that you need to get out there. We talk about hobbies, getting back into recreational activities. Not just getting up for the sake of getting up but getting up and doing something they enjoy. (“Linda”, program supervisor)
Other staff suggested sedentary behaviour might be seen as a less critical risk factor to address than other health behaviours, and could overburden patients already attempting to modify other aspects of their lifestyle:

*You don’t want it [messaging] to be so onerous as they will have other barriers to overcome such as their diet and stress management. If you overburden them, then they’ll just shut down completely.* (“Vanessa”, program manager)

Some staff suggested the incorporation of a broad message of increasing daily overall movement into educational lectures that is consistent with the existing messaging of increasing physical activity. Others believed patients needed specific instructions and messaging (“take the stairs instead of the escalator” or “stand up every 30 minutes”) in order to directly act on the advice they receive.

Patients spoke favourably of tracking their lifestyle as a way to facilitate long-term behaviour change. These individuals believed that this would help them to internalize their routine, provide accountability, and reflect on their lifestyle. A patient felt that the existing diaries utilized in the CR program to track physical activity could be extended to also track their sedentary behaviours:

*The journal I’m doing as part of the cardiac program has helped a lot.*

*Writing a record of all the exercises that I’ve done – I can see how I’ve improved, and how I can improve more. Perhaps you can add a new section*
to this diary specifically for sedentary behaviour. (“Jenny”, a 61 year old woman, who is married and retired)

A few patients were more receptive towards using smartphone applications and other technologies (such as activity tracking wrist bands) for self-monitoring and tracking as they provided tangible goals (such as alarms, or monitoring step counts or level of cardiovascular fitness). Two patients had reservations about self-tracking as they already felt overburdened by the existing diaries required by the CR program and felt the time spent completing them was a burden.

Those tracking things help me. If you ask me to do that, I will do that. But you can’t also burden someone with so much tracking. You can’t track every hour of the day. People won’t do it. It’s overwhelming! . (“Fernando”, a 58 year old man, who is married and employed)

Some staff strongly believed that the regular tracking of activity and sedentary behaviour might help patients to work towards goals and targets. Reinforcement by repetition was felt to be necessary for facilitating behaviour change and strategies for reinforcement included: following up with patients to assess their experience with incorporating a less sedentary lifestyle either during the program or after their graduation, incorporating messaging on sedentary behaviour strategies at multiple instances in the CR program, and strategically placing educational materials and signage across well-attended areas of the program facility such as at the entrance.
Socio-Cultural and Natural Environment

Some patients felt that a strategy to reduce their sedentary behaviour might not be socially normative, and unacceptable to friends and family. For example, a male patient described an experience where his wife was uncomfortable when he chose to stand while watching television and how this affected his motivation to continue:

*So, this week, one day I was standing and watching TV.... I did it for half an hour, and then afterwards, I sat down again. My wife found it strange. She was uncomfortable and found it strange so I did that for only one day and after that I didn’t do it again.* ("Ray", a 57 year old man, who is married and employed)

Another patient believed that her family would support any strategy that was important for her health and well-being:

*You would get over it. They would get over it [how her family would view her taking regular standing breaks]. Especially when it’s anything for your health, right? If you say it’s for your health, it’s not odd, it’s not on a whim, it’s not some new fad, and it’s actually for your health.* ("Jenny", a 61 year old woman, who is married and retired)

Some patients felt that support from staff was a positive motivator to behaviour change as they were in regular contact with them and trusted their advice. Several patients also believed that ongoing follow-up by staff during or after their CR participation would keep them motivated to continue and give them a sense of accountability. For example, a female
patient trusted the advice of the CR program as she recognized that it was positively impacting her lifestyle and health:

*I really believe in this program. It has helped me so much already…they’ve got the education; I believe in them. I’m going to follow their advice. It’s a medical program I trust.* (“Alison”, a 74 year old woman, who is divorced and retired)

Another patient believed that the formalized CR program, and peer-support were helpful to him, and wanted these to be part of a sedentary behaviour reduction strategy:

*I would love to still be part of the program through follow-up if that was part of a potential strategy, and have the opportunity to keep in touch with my group after I leave the program. I think it’s important to keep being part of some external structure too.* (“Kyle”, a 66 year old man, who is married and retired)

Based on her experience incorporating a routine of physical activity, a patient felt that she was more sedentary when there are shorter periods of sunlight in the winter months, and this might also demotivate her to reduce sedentary behaviour:

*When it’s five o’clock and it’s dark [during winter months], then I don’t feel like I can get my walk in. I feel like I’m already more sedentary in that time because of that. In the summer I’m at the cottage, I garden a lot, you cut grass and you’re out talking to neighbours, you’re just out more.* (“Kathy”, a 61 year old woman, who is married and a homemaker)
Other patients similarly perceived that they might be seasonally demotivated to reduce their sedentary behaviour, though some also believed that they could reduce their sedentary behaviour through indoor-based activities unaffected by light and weather conditions.

4.1.5 Discussion

This study used a descriptive, qualitative approach to understand the awareness and understanding of sedentary behaviour, as well as the facilitators and barriers to reducing sedentary behaviour among patients participating in an exercise-based CR program and, to the best of our knowledge, is the first study to amalgamate the perspectives of patients and the staff responsible for delivering the program. We found that patients and staff did not give as much importance to reducing their sedentary behaviour as compared to increasing their physical activity. Consistent with the ecological framework that guided this study, intrapersonal factors and environmental factors (the information environment, social-cultural factors, the natural environment) within the behaviour setting contexts of leisure time, the home, and work were perceived as influencing the sedentary behaviours of patients. Physical and psychological health, social unacceptability, lack of information, and associating sedentary activities with enjoyment/relaxation were found to be important barriers to reducing sedentary behaviours. Getting healthier and being supported/motivated by their CR program were seen as important facilitators for patients to reducing sedentary behaviour. Staff most commonly identified patient health and more information as the most important factors. Furthermore, some insight was gained in identifying how CR programs may need to support patients through the provision of information to convince them of the
health benefits of reducing their sedentary behaviour, and facilitating self-monitoring and goal-setting.

Previous studies to have examined the perspectives of adults in reducing their sedentary behaviours were largely undertaken among individuals who also experienced barriers to physical activity (Chastin, Fitzpatrick et al. 2014, Martínez-Ramos, Martín-Borràs et al. 2015, Mcewan, Tam-Seto et al. 2016). While the services available from CR motivated patients to engage in physical activity, the majority did not feel confident in their ability to reduce their sedentary behaviour, or were hesitant to substitute sedentary moments associated with work, routine, and relaxation with activity. Similar findings have been reported elsewhere (Hamilton, Healy et al. 2008, Straker, Dunstan et al. 2016), and may be a consequence of the perceived benefits of sedentary activities such as relaxation, relief from pain, increased social interaction and mental stimulation that are common among older and medically impaired populations. Patients also felt that implementing a strategy to reduce their sedentary behaviour (such as taking standing or walking breaks) was socially unacceptable, and felt unsupported by their friends or family. Accordingly, patients might find it challenging to reduce their sedentary behaviour if they are unwilling or have low confidence to do so. Given that improving one’s health was found to be a strong motivator for many patients, CR programs and future interventions should prioritize the communication of a “move more, sit less” message and the associated health benefits, to compliment the present focus on promoting physical activity.
This study found that a singular approach to reducing sedentary behaviour might not be effective for CR patients, as has also been shown in other populations (Gilson, Burton et al. 2011, Hadgraft, Brakenridge et al. 2016, Mcewan, Tam-Seto et al. 2016). Staff perceived that certain patients such as middle-aged men, diabetics, and the elderly could be challenging to motivate as they may be set in their ways or have physical limitations. Furthermore, patients held different views on whether various intervention strategies were feasible for them. Social cognitive theory suggests that these barriers to greater self-efficacy can be overcome by evaluating a patient’s emotional and physical state, increasing their experience of success by setting achievable targets, providing constructive feedback, and helping individuals vicariously observe others perform the same strategy (Strecher, DeVellis et al. 1986, Bandura 1991). A participatory approach involving both patients and those implementing the strategy may be needed for these recommendations to be operationalized and be sustainable for patients in the long-term (McAllister, Green et al. 2003). This could be achieved by discussing the feasibility of prospective interventions with a patient, and accordingly, setting achievable targets, and providing supporting feedback after assessing progress. In addition, incorporating supportive peers/friends or ideal role models who might share experience in reducing sedentary behaviour could also help build confidence.

The perceived facilitators and barriers to reducing sedentary behaviour include factors operating at the individual, social, and environmental levels, supporting an ecological framework of sedentary behaviour (Owen, Sugiyama et al. 2011). This highlights the importance of interventional approaches that address multiple, interrelated levels of influence on behaviour. Exercise-based CR programs already utilize such approaches
(Sniehotta, Scholz et al. 2005, Ferrier, Blanchard et al. 2011), which suggests the existing resources offered by these programs can be extended to positively influence the daily sedentary behaviour of individuals. For example, the self-monitoring of physical activity/exercise could be extended to include daily movement, while ongoing support and follow-up by staff on health behaviours should include an interest on patient sedentary behaviours. Future interventions should examine the extent that the behaviour change strategies and resources implemented in CR programs can reduce the sedentary behaviour of CR patients, as well as for other clinical and exercise-engaged populations. Furthermore, this study was purposely kept broad to serve as the foundation for more detailed, stratified analysis, and future work is needed to examine facilitators and barriers to reducing sedentary behaviour among particular subgroups e.g. older vs. younger patients, men vs. women, employed vs. retired individuals etc.

A strength of this study is its capture of the perspectives of CR patients and staff to provide a well-rounded understanding of not only the enablers and barriers to reducing sedentary behaviours, but also the feasibility of implementing such strategies into practice. This study also has limitations that must be considered. First, the patient sample consisted of those already actively engaged in a CR program and may be healthier or possess a greater motivation for behaviour change than patients who declined to participate. While our purposive sampling strategy allowed for us to determine the influence of CR on the perceptions of active patients, sampling at different stages of their CR program may have yielded more diverse responses particularly among less behaviourally motivated patients. Unmotivated individuals could also be more responsive to reducing sedentary behaviour if
perceived to be less demanding than increasing physical activity. Second, our sample was limited to a single CR centre in Canada, where services are provided free of charge as part of the country’s universal healthcare system. This may limit the generalizability of our findings to CR programs of similar size and modes of program delivery. Lastly, the perspectives of CR staff may be underrepresented in this study as only two focus groups were conducted. While greater staff participation may have provided additional perspectives, the study prioritized the opinions of patients in order to better explore the factors that may influence their sedentary behaviour.

In conclusion, this study identified the awareness, as well as the facilitators and barriers to reducing sedentary behaviours among CR patients already engaged in physical activity, and the staff supporting their self-management. It was found that the present CR delivery model might not be effective in reducing sedentary behaviours unless existing strategies are also targeted towards sedentary behaviour. Strategies informed by this study should consider increasing the awareness of individuals on the importance of increasing their daily movements to compliment a message of regular physical activity. Increasing a patient’s self-efficacy to interrupt their sedentary behaviour needs further development and testing. Furthermore, CR programs and future exercise- and lifestyle-based interventions should consider participatory approaches involving patients and staff to ensure that a sedentary behaviour reduction strategy is feasible at the individual-level and can be maintained for the long-term.
4.1.6 Tables

Table 1

Study sample characteristics of patient participants in one-on-one interviews.

<table>
<thead>
<tr>
<th>Sample (n=15)</th>
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<tbody>
<tr>
<td>Mean age (SD)</td>
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<tr>
<td>Male, n (%)</td>
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<tr>
<td>Ethnicity</td>
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<tr>
<td>White / Caucasian, n (%)</td>
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<tr>
<td>South Asian, n (%)</td>
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<tr>
<td>Chinese, n (%)</td>
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<tr>
<td>Highest level of education attained</td>
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<tr>
<td>High school, n (%)</td>
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<tr>
<td>College / trades, n (%)</td>
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<tr>
<td>University, n (%)</td>
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<tr>
<td>Employment status</td>
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<tr>
<td>Retired / not in the paid workforce, n (%)</td>
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<tr>
<td>Works full-time, n (%)</td>
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<tr>
<td>Works part-time, n (%)</td>
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<tr>
<td>Support structure</td>
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<tr>
<td>Lives with spouse / partner, n (%)</td>
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<tr>
<td>Lives with friends and/or other family, n (%)</td>
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<tr>
<td>Lives alone, n (%)</td>
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<tr>
<td>Mean body mass index [kg/m^2], (SD)</td>
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<tr>
<td>Mean CES-D Score, (SD)</td>
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<tr>
<td>Clinical diagnosis for cardiac rehabilitation referral</td>
</tr>
<tr>
<td>Myocardial infarction, n (%)</td>
</tr>
<tr>
<td>Cardiomyopathy, n (%)</td>
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<tr>
<td>Coronary bypass, n (%)</td>
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<tr>
<td>Hypertension, n (%)</td>
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<tr>
<td>PTCA / stent, n (%)</td>
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<tr>
<td>Mean peak cardiopulmonary fitness [peak VO_2, ml/kg/min] (SD)</td>
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<tr>
<td>Number of pre-existing comorbid conditions</td>
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<td>1-2, n (%)</td>
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<td>3-4, n (%)</td>
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</table>
4.1.7 Figures

Figure 1

Ecological framework of the factors influencing and discouraging sedentary behaviours informed by cardiac rehabilitation (CR) patient and staff perspectives.
4.2 Part 2: A Comparison Of The Energy Expenditure Benefits Of Replacing Sedentary Time With Varying Intensities Of Physical Activity

A modified version of this study has been submitted for publication in the Journal of Public Health.

4.2.1 Abstract

It is unclear whether sedentary time reallocation into light intensity physical activity (LIPA), moderate-vigorous intensity physical activity (MVPA) and a combination of both (LIPA & MVPA) results in clinically meaningful changes in daily cumulative energy expenditure. We compared direct and daily cumulative energy expenditure differences associated with physical activity-based sedentary interventions in adults. English-language studies in PubMed, Medline, EMBASE, CINAHL, PsycINFO, Cochrane Central Register of Controlled Trials and the Cochrane Database of Systematic Reviews databases were searched from inception to June 2016 with hand-searching of in-text citations. Studies eligible for inclusion were randomized and non-randomized interventions in adult populations with sedentary time and a measure of energy expenditure as an outcome. 20 studies were included in the meta-analysis. LIPA, MVPA, and LIPA & MVPA interventions were associated with a positive direct increase in energy expenditure. Reallocating 6 to 9 hours of sedentary time to LIPA (pooled SMD, 2.501 [CI, 1.204 to 5.363] had lower cumulative daily energy expenditure than 6 to 9 hours of reallocated LIPA & MVPA (pooled SMD, 5.218 [CI, 3.822 to 6.613]. Reallocating to 1 hour of MVPA resulted in greater daily cumulative energy expenditure than reallocation to 3 to 5 hours of LIPA & MVPA, but less than 6 to 9 hours of LIPA & MVPA. Comparable energy expenditures can be achieved
by different strategies, and a singular focus on promoting MVPA might be effective for those individuals where a combined co-intervention has proven to be a challenge.
4.2.2 Introduction

The average adult in North America spends the majority of their waking day expending little energy (≤1.5 resting metabolic equivalents) in sedentary behaviours such as sitting, lying down, watching television and using the computer (Matthews, Chen et al. 2008, Colley, Garriguet et al. 2011). The consequences can be severe, as mounting evidence suggests that greater amounts of time spent in sedentary activities can increase an adult’s risk for cardio-metabolic disorders and all-cause mortality independent of physical activity participation (Biswas, Oh et al. 2015). Strategies to increase cumulative energy expenditure have typically been designed to reallocate an individual’s sedentary time to light-intensity physical activities such as those associated with activities of daily living (LIPA), moderate-to-vigorous physical activity (MVPA) or both (LIPA & MVPA) (Owen, Sugiyama et al. 2011). However, it is still unclear from existing evidence whether one method of time-reallocation to increase cumulative caloric expenditures (e.g., sedentary time to LIPA) is superior to another (e.g., sedentary time to MVPA). The former would presumably require a longer time commitment consisting of lower workload intensity, while the latter may allow for shorter time commitments, but would require greater effort and higher workload intensities.

The objectives of this systematic review and meta-analysis were to first, compare the direct energy expenditure differences reported by interventions where sedentary time was reallocated to physical activity and second, to evaluate the daily cumulative energy expenditure differences (energy expenditure scaled and compared over a waking day) associated with these interventions. We hypothesized that LIPA-based interventions, by
reallocating a greater daily duration of sedentary time, will result in greater daily cumulative energy expenditures than those interventions reallocating to MVPA alone.

### 4.2.3 Methods

**Electronic Data Sources and Searches**

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed in the conduct and reporting of this review (Moher, Liberati et al. 2009). The literature search strategy was designed in Medline based upon the PICO method and utilized both subject headings and free text terms (see Supplemental Table 2). Adapting the subject headings as necessary, each of the following medical databases were searched from inception to June 15, 2016: Medline (Ovid), PubMed (excluding Medline records), Embase, CINAHL, PsycINFO, the Cochrane Central Register of Controlled Clinical Trials and the Cochrane Database of Systematic Reviews. Duplicate records were removed prior to applying the inclusion/exclusion criteria.

The aim of the search strategy was to extract articles reporting on physical activity interventions targeting sedentary behaviour with outcomes related to energy expenditure or metabolic health. Studies conducted in free-living or controlled conditions were both considered. No restrictions were placed on the search results with respect to geographic origin or language but minor publication types (newspaper articles, personal narratives, legal cases etc.) were excluded when possible. Reference lists from included materials and relevant reviews were manually examined to supplement the electronic searches.
Study Selection

Studies eligible for inclusion were randomized and non-randomized intervention investigations (trials and observational studies) that assessed adult populations (aged ≥18 years), with sedentary time and a measure of energy expenditure (and broadly as metabolic health) as an outcome. Two authors independently screened study titles and abstracts for inclusion. Both subjective and objective outcome measures were considered. We operationally distinguished sedentary behaviours as a distinct class of waking behaviours characterized by little physical movement and low-energy expenditure (≤1.5 metabolic equivalents, METs) (Pate, O’Neill et al. 2008) and excluded studies that defined sedentary behaviour as a category of physical activity or as inadequate physical activity (Tremblay, Colley et al. 2010). LIPA was predefined as activities such as standing and walking at a pace of 1.7 to 2.5 miles per hour; MVPA was predefined as activities such as calisthenics, bicycling, walking at a pace of 3 miles per hour or greater, or jogging (Ainsworth, Haskell et al. 2011).

Data Extraction and Quality Assessment

Data were extracted from all studies that met the pre-specified selection criteria and were deemed appropriate for detailed review by two authors. Details of individual studies were collected and characterized on the basis of authors and year of publication; study design; sample size and characteristics; data collection methods (exposure and outcome), follow-up length, attrition, and standardized mean differences. Included studies were assessed for risk of bias using the criteria outlined by the National Heart Lung and Blood Institute’s Controlled Intervention Studies and the Observational Cohort and Cross-
sectional Studies Quality Assessment Tools (NHLBI). These tools were selected over others given their ability to assess the internal validity of a range of observational and interventional study designs. Two authors independently assessed articles for quality and any scoring inconsistencies were discussed with an additional reviewer. The quality assessment tool evaluated studies for potential flaws in study methods or implementation including sources of bias (e.g., patient selection, performance, attrition, and detection), confounding, study power, the strength of causality in the association between interventions and outcomes, and other factors.

**Data Synthesis and Analysis**

All included studies were qualitatively analyzed to directly compare mean differences in equivalent energy expenditure associated with reallocating sedentary time to physical activity. Studies with comparable measures of energy expenditure were selected for quantitative analysis, of which, kilocalories per day, kilocalories per kg per day and kilocalories per hour were compared. Studies with comparable outcome data were quantitatively analyzed by meta-analysis, where standardized mean differences (SMD) were used to estimate pooled energy expenditure effect sizes. Efforts were made to contact study authors when suitable data were not reported or available. Statistical heterogeneity was assessed using Cochran’s Q statistic and the $I^2$ statistic of the proportion of total variation because of heterogeneity (Higgins and Thompson 2002). An $I^2$ value of 25% to 50% indicated a low degree of heterogeneity, 50% to 75% a moderate degree of heterogeneity and more than 75% a high degree of heterogeneity. If a small number of studies were available for meta-analysis or we saw substantial heterogeneity,
we considered a Knapp–Hartung modified random-effects model to yield more conservative effects (Knapp and Hartung 2003). For the summary estimate, we considered a $P$ value less than 0.05 as statistically significant. We graphically explored the potential for small study effects such as publication bias using Egger test of asymmetry of funnel plots and quantitatively by the Egger linear regression method (Egger, Smith et al. 1997). The meta-analyses and the generation of forest plots were conducted using Comprehensive Meta-analysis, version 2 (Biostat), and the R statistical software (R Foundation for Statistical Computing) (Borenstein M 2005, R Development Core Team 2012). For our second objective, we compared the energy expenditure of interventions by their daily duration of exertion (cumulative daily energy expenditure). We found several LIPA intervention studies were conducted over short trial periods to detect direct rather than energy expenditure accumulated over a day. In this case, we calculated projected estimations by extrapolating the direct energy expenditure (in kcal/h) over a 12-hour period (to standardize the typical duration of a waking day).

To assess the robustness of our findings, we examined the effect of individual studies on the pooled effect estimates. We also examined the feasibility of conducting a subgroup analysis of high methodological quality studies and associated pooled effect size estimates.

### 4.2.4 Results

A total of 32,988 studies were identified through database searching (PubMed: 2,170; Medline: 11,613; EMBASE: 13,331; CINAHL: 652; PsycINFO: 2,655;
the Cochrane Central Register of Controlled Trials: 2,397, and the Cochrane Database of Systematic Reviews databases: 170) and 52 were added after hand searching in-text citations (Figure 1). In total, 22 studies (817 participants) were qualitatively analyzed, of which, 20 studies (737 participants) were included in the meta-analysis.

**Study Characteristics**


Studies were all conducted in the high-income countries of the United States, Australia, New Zealand, United Kingdom, Canada, Spain and The Netherlands. The majority of studies utilized objective measurement methods to assess sedentary time and physical activity (by accelerometer and/or inclinometer devices) and objective methods to assess energy expenditure via indirect calorimetric and accelerometer estimates. Seventeen studies featured conditions where the focus was on limiting and/or replacing bouts of sedentary time with LIPA (LIPA interventions) (Levine and Miller 2007, Beers, Roemmich et al. 2008, Lopez-Fontana, Sanchez-Villegas et al. 2009, Cox, Guth et al. 2011, Speck and Schmitz 2011, Reiff, Marlatt et al. 2012, Steeves, Thompson et al. 2012, Buckley, Mellor et al. 2013, Duvivier, Schaper et al. 2013, Koepp, Manohar et al. 2013, Barwais and Cuddihy 2014, Blankenship, Granados et al. 2014, Carr, Maeda et al. 2014, Pedersen, Cooley et al. 2014, Carter, Jones et al. 2015, Creasy, Rogers et al. 2015, Fountaine, Johann et al. 2016); ten studies featured conditions where sedentary time was replaced with MVPA (MVPA interventions) (Dunn, Marcus et al. 1999, Levine and Miller 2007, Lopez-Fontana, Sanchez-Villegas et al. 2009, Swartz, Squires et al. 2011, Steeves, Thompson et al. 2012, Duvivier, Schaper et al. 2013, Koepp, Manohar et al. 2013, Blankenship, Granados et al. 2014, Carter, Jones et al. 2015, Fountaine, Johann et al. 2016); and four studies featured a combination of both (LIPA & MVPA interventions) (Duvivier, Schaper et al. 2013, Blankenship, Granados et al. 2014, Kozey Keadle, Lyden et al. 2014, Pedersen, Cooley et al. 2014). The majority of studies were conducted over a
short duration (< 1 week), with five studies conducted from 5 weeks to 24 months. Supplemental Table 1 provides an overview of the study characteristics.

**Publication Bias and Heterogeneity**

There was significant statistical evidence for publication bias among studies utilizing LIPA (Egger’s regression intercept, 7.29 \([P =0.019]\)) and MVPA (Egger’s regression intercept, 6.24 \([P =0.003]\)), while combined LIPA & MVPA studies were found to have non-significant, moderate publication bias (Egger’s regression intercept, 4.66 \([P =0.834]\)). Figure 2 summarizes the degree of heterogeneity across studies. As per Higgins and colleagues’ classification (Higgins and Thompson 2002), heterogeneity within LIPA, MVPA, and LIPA & MVPA interventions were found to be high.

**Effect of Sedentary Interventions on Energy Expenditure**

Figure 2 describes the quantified analysis of the direct energy expenditure associated with reallocating sedentary time to varying intensities of physical activity. As expected, LIPA, MVPA, and LIPA & MVPA interventions were all associated with a positive direct increase in energy expenditure. MVPA interventions were attributed to a larger increase in energy expenditure (pooled SMD, 3.13 [CI, 0.52 to 5.74]) than LIPA (pooled SMD, 2.50 [CI, 0.70 to 2.50]). Combined LIPA & MVPA interventions were associated with a lower and non-significant increase in energy expenditure (pooled SMD, 0.96 [CI, -0.38 to 2.31]) than LIPA and MVPA. The pooled energy expenditure estimates for the three intervention groups did not change substantially with the exclusion of any study. As there
were only 3 studies with a low risk of bias, the authors decided not to conduct a subgroup analysis among them based on the likelihood of high heterogeneity in the findings.

Table 2 outlines the daily cumulative energy expenditure associated with reallocating sedentary time to LIPA, MVPA and LIPA & MVPA. Reallocating 6 to 9 hours of sedentary time to LIPA (pooled SMD, 2.501 [CI, 1.204 to 5.363] had less than half of the cumulative daily energy expenditure than reallocating 6 to 9 hours of sedentary time to LIPA & MVPA (pooled SMD, 5.218 [CI, 3.822 to 6.613]. Reallocating one hour of sedentary time to MVPA resulted in greater daily cumulative energy expenditure than the reallocation of 3 to 5 hours of LIPA & MVPA, but less energy expenditure than 6 to 9 hours of LIPA & MVPA reallocation.

4.2.5 Discussion

This review found interventions that reallocate sedentary time to LIPA, MVPA, or LIPA & MVPA were positively associated with increased energy expenditure in adults. When examined by cumulative daily duration, interventions that focused on reallocating to LIPA required 6 to 9 hours of sedentary time to generate an equivalent cumulative daily energy expenditure of 1 hour of MVPA. While combined LIPA & MVPA interventions were expected to yield the greatest cumulative daily energy expenditure, reported yields were found to be similar to LIPA, which may be a result of the few studies available for comparison.
Previous reviews have largely evaluated sedentary interventions by their success in modifying the sedentary time of individuals (Prince, Saunders et al. 2014, Martin, Fitzsimons et al. 2015). However, sedentary time changes might reflect the motivation of study participants’ to engage in positive lifestyle behaviours. Furthermore, examining sedentary time alone provides little information on an individual’s daily activity patterns. Our study is unique in comparing the daily cumulative energy expenditure associated with interventions designed to reduce sedentary time, a useful measure to compare the effect of displacing sedentary time over a whole day.

This study serves to highlight the significance of focusing on increasing MVPA, particularly when transitioning between sedentary states and LIPA over the course of a day can be difficult to adhere to. While Prince and colleagues had found MVPA interventions to be less effective at reducing sedentary time than interventions focused specifically on sedentary time avoidance, they also found that MVPA was a more likely target for sedentary time reallocation (Prince, Saunders et al. 2014). This may be surprising given that LIPA reallocation for example, requires less physical and cognitive effort, and can be incorporated into everyday activities (Smith, Ekelund et al. 2015). However, as sedentary behaviours are largely created by habit and routine, consciously overcoming the many occasions in a day that individuals finds themselves sedentary can be more challenging than the intention needed to perform MVPA over a shorter time duration, even if requiring greater effort (Biddle 2011). The effort and burden required of participants to combine both spectrums of physical activity may partly explain the lower direct energy expenditure found in the few studies that evaluated combined LIPA &
MVPA interventions. As such, interventions seeking to reallocate time to MVPA or LIPA may necessitate separate and distinctive behavioural strategies in order for participants to sufficiently adhere to them.

This study has important clinical and research implications. Interventions replacing sedentary time with short periods of MVPA and frequent intervals of LIPA are expected to yield the greatest daily cumulative energy expenditure. However, such interventions are likely to be the most challenging to maintain given that increasing overall daily activity participation pose many barriers to adherence such as motivation, cost, time and a built environment that may not always be facilitative (Owen, Leslie et al. 2000). As such, successful interventions are likely to be those that are personalized to the individual. We found that similar energy expenditures can be achieved by different strategies, and a singular focus on promoting MVPA might be an effective strategy for those individuals where a combined co-intervention has proven to be a challenge. This may be the case for clinical populations already engaged in structured MVPA programs such as cardiac rehabilitation, where participants may be adherent to MVPA as a result of the program but sedentary otherwise (Prince, Blanchard et al. 2015). Furthermore, being adherent to MVPA alone confers important health status benefits, where cardiopulmonary fitness may be one of the most important modifiable prognostic determinants of health (Myers 2003, Warburton, Nicol et al. 2006). In contrast, older individuals and those with mobility limitations, who are among the most sedentary and physically inactive populations, may benefit greatly from the lower workload and effort required to perform LIPA. As research in this area continues to evolve, a focus on evaluating the feasibility of
implementing MVPA and LIPA co-interventions can be an important step in reducing the health risks of sedentary behaviour and physical inactivity among individuals. However, the controlled conditions in which the majority of the reviewed interventions have been designed (such as randomized controlled/crossover trials) may not suffice in determining the practicality of such interventions over an individual’s typical day and in the long-term. As such, interventions that determine the outcome benefits and behavioural preferences for individuals in their natural environment are necessary.

Some limitations should be considered when interpreting these findings. First, given the challenges of attributing changes in sedentary time with specific health outcomes, specific health outcomes were not assessed. Nonetheless, our findings are consistent with a recent harmonized meta-analysis attributing increases in MVPA with reduced mortality risk (Ekelund, Steene-Johannessen et al. 2016). As sedentary behaviour research expands, it remains to be seen whether the positive benefits of reduced sedentary behaviour are primarily driven by increases in energy expenditure that accompany the transition of sedentary time into physical activities, and/or differences in postural allocation. Second, different measures (direct and indirect) were used to derive energy expenditure, which may have affected comparability across studies. Third, we found several studies had examined energy expenditure within short follow-up durations. While it would be ideal to compare all interventions by their cumulative effects over a day or in natural conditions, protocol-driven and controlled assessments are likely to generalise hourly and cumulative energy expenditure as would as be the case if meta-regression estimation methods were applied (Thompson and Higgins 2002). Nonetheless, by examining actual and estimated
cumulative daily energy expenditure, it is likely the case that reallocating sedentary time to LIPA still requires far greater quantities of time than MVPA, which also has greater per minute gains in energy expenditure. Fourth, as other reviews have reported (Prince, Saunders et al. 2014, Martin, Fitzsimons et al. 2015, Shrestha, Kukkonen-Harjula et al. 2016), the large degree of study heterogeneity in the quantitative analysis may be attributed to the small sample sizes, poor-to-fair methodological quality, and study-by-study differences among the interventions reviewed. Such heterogeneity, while limiting interpretability, also reveals the need for better-designed interventional studies that clearly elucidate the effectiveness of interventions to reduce sedentary time. Lastly, we were unable to adjust for individual-level factors that can confound associations with energy expenditure such as average age, body mass index and pre-existing physical activity levels. Although we attempted to contact individual authors to confirm individual statistical effects and received a good response rate in so doing, we were ostensibly reliant on the quality of individual studies provided and the statistical effect sizes as they were reported.

In conclusion, while a combination of LIPA & MVPA are expected to produce the greatest daily cumulative energy expenditure benefits in adults, our systematic review suggests that similar energy expenditures can be achieved by reallocating sedentary time to MVPA over a shorter duration of time. These findings reaffirm the need for individualized interventions and provide reassurance that similar energy expenditures can be achieved through different intervention strategies.
### 4.2.6 Tables

**Table 1**

Criteria for the assessment of quality of included studies

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Studies meeting criteria n/N a</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Described as randomized</strong></td>
<td></td>
</tr>
<tr>
<td>1. Was the study described as randomized, a randomized trial, a randomized clinical trial, or an RCT?</td>
<td>11/22</td>
</tr>
<tr>
<td><strong>Treatment allocation</strong></td>
<td></td>
</tr>
<tr>
<td>2. Was the method of randomization adequate?</td>
<td>3/22</td>
</tr>
<tr>
<td>3. Was the treatment allocation concealed?</td>
<td>1/22</td>
</tr>
<tr>
<td><strong>Blinding</strong></td>
<td></td>
</tr>
<tr>
<td>4. Were the study participants and providers blinded to treatment group assignment?</td>
<td>1/22</td>
</tr>
<tr>
<td>5. Were the people assessing the outcomes blinded to the participants’ group assignments?</td>
<td>0/22</td>
</tr>
<tr>
<td><strong>Similarity of groups at baseline</strong></td>
<td></td>
</tr>
<tr>
<td>6. Were the groups similar at baseline on important characteristics that could affect outcomes (e.g., demographics, risk factors, co-morbid conditions)?</td>
<td>18/22</td>
</tr>
<tr>
<td><strong>Dropout</strong></td>
<td></td>
</tr>
<tr>
<td>7. Was the overall dropout rate from the study at endpoint 20% or lower of the number allocated to treatment?</td>
<td>20/22</td>
</tr>
<tr>
<td>8. Was the differential dropout rate (between treatment groups) at endpoint 15 percentage points or lower?</td>
<td>10/22</td>
</tr>
<tr>
<td><strong>Adherence</strong></td>
<td></td>
</tr>
<tr>
<td>9. Was there high adherence to the intervention protocols for each treatment group?</td>
<td>18/22</td>
</tr>
<tr>
<td><strong>Avoid other interventions</strong></td>
<td></td>
</tr>
<tr>
<td>10. Were other interventions avoided or similar in the groups (e.g., similar background treatments)?</td>
<td>10/22</td>
</tr>
<tr>
<td><strong>Outcome measures assessment</strong></td>
<td></td>
</tr>
<tr>
<td>11. Were outcomes assessed using valid and reliable measures, implemented consistently across all study participants?</td>
<td>14/22</td>
</tr>
<tr>
<td><strong>Power calculation</strong></td>
<td></td>
</tr>
<tr>
<td>12. Did the authors report that the sample size was sufficiently large to be able to detect a difference in the main outcome between groups with at least 80% power?</td>
<td>5/22</td>
</tr>
<tr>
<td><strong>Prespecified outcomes</strong></td>
<td></td>
</tr>
<tr>
<td>13. Were outcomes reported or subgroups analyzed prespecified (i.e., identified before analyses were conducted)?</td>
<td>21/22</td>
</tr>
<tr>
<td><strong>Intention-to-treat analysis</strong></td>
<td></td>
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</tbody>
</table>
14. Were all randomized participants analyzed in the group to which they were originally assigned, i.e., did they use an intention-to-treat analysis?  

| Studies rated to have a high risk of bias | 9/22 |
| Studies rated to have a moderate risk of bias | 10/22 |
| Studies rated to have a low risk of bias | 3/22 |

*a Rating of criteria: yes, no, or other (cannot determine; not applicable; not reported).
Table 2
Estimated cumulative energy expenditure associated with the reallocation of sedentary time into physical activity over a 12-hour waking day.

<table>
<thead>
<tr>
<th>Total duration of physical activity time</th>
<th>Pooled SMD (95% CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reallocating sedentary time to LIPA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-2 hours</td>
<td>1.124 (0.569, 0.3679)</td>
<td>0.01</td>
</tr>
<tr>
<td>3-5 hours</td>
<td>2.289 (0.250, 2.626)</td>
<td>0.09</td>
</tr>
<tr>
<td>6-9 hours</td>
<td>2.501 (1.204, 5.363)</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Reallocating sedentary time to LIPA &amp; MVPA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-2 hours</td>
<td>0.411 (-0.314, 1.136)</td>
<td>0.25</td>
</tr>
<tr>
<td>3-5 hours</td>
<td>0.795 (-0.055, 1.644)</td>
<td>0.73</td>
</tr>
<tr>
<td>6-9 hours</td>
<td>5.218 (3.822, 6.613)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Reallocating sedentary time to MVPA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 30 minutes</td>
<td>1.715 (-1.703, 5.133)</td>
<td>0.16</td>
</tr>
<tr>
<td>1 hour</td>
<td>3.753 (3.029, 10.536)</td>
<td>0.04</td>
</tr>
</tbody>
</table>

SMD, standardized mean difference of estimated cumulative energy expenditure.
<table>
<thead>
<tr>
<th>First Author (Year)</th>
<th>Country, Sample</th>
<th>Study Design, Sample Size</th>
<th>Intervention Type(s)</th>
<th>Intervention(s)</th>
<th>Control</th>
<th>Duration</th>
<th>Follow-up</th>
<th>Energy Expenditure Outcomes</th>
<th>Energy Expenditure Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barwais (2015)</td>
<td>Australia, men and women, average age: 29</td>
<td>Randomized controlled trial, n=24</td>
<td>LIPA intervention</td>
<td>Intervention to reduce SB and increase PA for sedentary adults using online physical activity monitor.</td>
<td>Baseline status</td>
<td>5 weeks</td>
<td>75%</td>
<td>Energy expenditure</td>
<td>Gruve online personal activity monitor</td>
</tr>
<tr>
<td>Beers (2008)</td>
<td>United States, men and women, sedentary, clerical workers, average age: 28</td>
<td>Crossover trial with three intervention conditions, n=24</td>
<td>LIPA intervention</td>
<td>1) Sitting on a therapy ball; 2) Standing.</td>
<td>Sitting in an office chair</td>
<td>20 minutes</td>
<td>100%</td>
<td>Energy expenditure</td>
<td>Indirect calorimetry</td>
</tr>
<tr>
<td>Ben-Ner (2014)</td>
<td>United States, men and women, sedentary office workers, average age: 42</td>
<td>Crossover trial with two conditions, n=40</td>
<td>LIPA intervention</td>
<td>Treadmill desk use at a maximum speed of 2 miles per hour</td>
<td>Seated at usual desk</td>
<td>12 months</td>
<td>100%</td>
<td>Energy expenditure</td>
<td>Indirect calorimetry</td>
</tr>
<tr>
<td>Blankenship (2014)</td>
<td>United States, men and women, sedentary, overweight/obese office workers, average age: 52</td>
<td>Crossover trial with three conditions, n=10</td>
<td>LIPA/ MVPA/LIPA &amp; MVPA intervention</td>
<td>1) FLB condition - sitting time limited to &lt;20min at a time. Sitting interrupted by standing or walking breaks; AGW - simulating typical office worker - spend 70% of workday sitting, 15%</td>
<td></td>
<td>7 days</td>
<td>100%</td>
<td>Energy expenditure, oxygen consumption</td>
<td>Indirect calorimetry</td>
</tr>
<tr>
<td>Study</td>
<td>Country</td>
<td>Gender and Age</td>
<td>Study Design</td>
<td>Intervention</td>
<td>Baseline Activity</td>
<td>Break Structure</td>
<td>Energy Expenditure Calculation</td>
<td></td>
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<tr>
<td>Buckley (2014)</td>
<td>United Kingdom, men and women, office workers, average age: not specified; 22-61 (men), 22-59 (women)</td>
<td>Repeated-measures study, n=10</td>
<td>LIPA intervention</td>
<td>Standing work at a sit-stand adjustable workstation</td>
<td>Sitting while at work</td>
<td>2 days</td>
<td>100% Heart rate and energy expenditure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carr (2014)</td>
<td>United States, men and women, office workers, average age: 43</td>
<td>Randomized crossover trial with three conditions, n=18</td>
<td>LIPA intervention</td>
<td>Use of a seated active workstation</td>
<td>Use of a traditional sedentary workstation</td>
<td>90 minutes</td>
<td>Not specified Energy expenditure, oxygen consumption, METs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carter (2015)</td>
<td>United Kingdom, men and women, average age: 24</td>
<td>Randomized crossover trial with four conditions, n=20</td>
<td>LIPA/MVPA intervention</td>
<td>Breaking up 30 minutes of sedentary time with 2 minutes of: 1) standing, 2) low-intensity walking, 3) low-intensity calisthenics.</td>
<td>Remaining seated for 30 minutes</td>
<td>30 minutes</td>
<td>Not specified One minute averages of VO$_2$ and RER were used to determine EE per minute of assessment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study (Year)</td>
<td>Participants</td>
<td>Country</td>
<td>Age</td>
<td>Study Design</td>
<td>Intervention</td>
<td>Duration</td>
<td>Energy Expenditure</td>
<td>Oxygen Consumption</td>
<td>Measurement</td>
</tr>
<tr>
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<tr>
<td>Cox (2011)</td>
<td>United States, men and women, average age: 37</td>
<td>Randomized crossover trial with three conditions, n=31</td>
<td>Standing still; 1) walking at 1.61 km/h</td>
<td>Sitting</td>
<td>60 minutes</td>
<td>100%</td>
<td>Oxygen consumption (VO₂)</td>
<td>Metabolic measurement system (energy expenditure)</td>
<td></td>
</tr>
<tr>
<td>Dunn (1999)</td>
<td>United States, men and women, healthy sedentary, average age: 46</td>
<td>Randomized controlled trial, n=235</td>
<td>Behaviourally-based lifestyle physical activity intervention</td>
<td>Structured fitness centre-based exercise program</td>
<td>24 months</td>
<td>Not specified</td>
<td>Total energy expenditure, cardiopulmonary fitness</td>
<td>Automated cardiorespiratory monitoring techniques (VO₂) activPAL inclinometer (energy expenditure and METs)</td>
<td></td>
</tr>
<tr>
<td>Duvivier (2013)</td>
<td>The Netherlands, men and women, average age: 21</td>
<td>Randomized crossover trial with three intervention conditions, n=20</td>
<td>1) 1 hour of sitting was replaced by 1 hour vigorous supervised bicycling per day, the rest of the day was spent similarly as during the sitting regime; 2) Subjects were instructed to replace 6 hour of sitting with 4 hour of walking at a leisure pace</td>
<td>4 days</td>
<td>90%</td>
<td>Energy expenditure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study</td>
<td>Location</td>
<td>Participants</td>
<td>Methodology</td>
<td>Intervention Details</td>
<td>Setting</td>
<td>Duration</td>
<td>Activity</td>
<td>Energy Expenditure</td>
<td>Measurement Methods</td>
</tr>
<tr>
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</tr>
<tr>
<td>Fountaine (2016)</td>
<td>United States, men and women, college students, average age: 23</td>
<td>Non-randomized crossover trial with three conditions, n=18</td>
<td>LIPA/ MVPA intervention</td>
<td>1) Standing-in-place, and 2) sitting/stepping protocol in which participants perform 1 min of stepping in place at 90 beats per minute, sat for 9 min, then repeating the stepping/sitting sequence once more.</td>
<td>Seated in a standard office chair</td>
<td>20 minutes</td>
<td>Not specified</td>
<td>Energy expenditure</td>
<td>Indirect calorimetry</td>
</tr>
<tr>
<td>Koeppe (2015)</td>
<td>United States, men and women, sedentary office workers, average age: 42</td>
<td>Crossover trial with two conditions, n=36</td>
<td>LIPA/ MVPA intervention</td>
<td>Treadmill desk Working normally, seated at office desk</td>
<td>12 months</td>
<td>100%</td>
<td>Energy expenditure</td>
<td>Indirect calorimetry</td>
<td></td>
</tr>
<tr>
<td>Kozy Keadle (2014)</td>
<td>United States, men and women, inactive, overweight/obese, average age: 44</td>
<td>Randomized crossover trial with four conditions, n=70</td>
<td>LIPA/ MVPA/LIPA &amp; MVPA intervention</td>
<td>1) Exercise 5 days a week for 40 minutes per session at moderate intensity; 2) reduce sitting time and increase non-exercise physical</td>
<td>Maintain usual lifestyle</td>
<td>12 weeks</td>
<td>81%</td>
<td>MET-hours, and changes in cardiorespiratory fitness by peak VO$_2$</td>
<td>activPAL inclinometer (MET/hour), Cardiopulmonary stress test and metabolic measurement system (VO$_2$ peak)</td>
</tr>
<tr>
<td>Study</td>
<td>Country</td>
<td>Participants</td>
<td>Design</td>
<td>Intervention</td>
<td>Outcome Measures</td>
<td></td>
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<tr>
<td>Levine (2007)</td>
<td>United States, men and women, sedentary, overweight/obese office workers, average age: 43</td>
<td>Crossover trial with five conditions, n=15</td>
<td>LIPA/ MVPA intervention</td>
<td>Office chair sitting and emulating normal office work</td>
<td>20 minutes, Not specified, Energy expenditure, High-precision indirect calorimeter (energy expenditure)</td>
<td></td>
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<tr>
<td>Lopez-Fontana (2014)</td>
<td>Spain, women, overweight obese, average age: 34</td>
<td>Randomized crossover trial with two conditions, n=40</td>
<td>LIPA/ MVPA (plus diet) intervention</td>
<td>No control group</td>
<td>10 weeks, 100%, Resting metabolic rate, energy expenditure and METs</td>
<td></td>
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</tr>
</tbody>
</table>
| Rose-Peddie (2013) | New Zealand, men and women, physically inactive in predominantly sedentary occupations, average age: 26 | Randomized crossover trial with three conditions, n=70                      | MVPA intervention             | Sitting continuously for 9 hours                                               | 9 hours, 93%, Mean oxygen consumption and carbon dioxide production at steady state, Metalyser II (oxyg
<table>
<thead>
<tr>
<th>Study</th>
<th>Location</th>
<th>Gender</th>
<th>Age Description</th>
<th>Study Design</th>
<th>Intervention</th>
<th>Details</th>
<th>Duration</th>
<th>Basal Metabolic Rate and METs</th>
<th>Energy Expenditure Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedersen (2013)</td>
<td>Australia, men and women, desk based office workers, average age: 42</td>
<td>Randomized controlled trial, n=32</td>
<td>LIPA/LIPA &amp; MVPA intervention</td>
<td>Able to access an e-health program on their desktop computer that enables them to break long periods of sitting with short periods of physical activity during work hours.</td>
<td>No access to program on their computer</td>
<td>13 weeks</td>
<td>100%</td>
<td>Compendium of Physical Activities (METs) and individual basal metabolic rate (energy expenditure)</td>
<td></td>
</tr>
<tr>
<td>Reiff (2012)</td>
<td>United States, men and women, average age: 23</td>
<td>Randomized controlled trial, n=20</td>
<td>LIPA intervention</td>
<td>Performing desk-based activities on a specially designed nontraditional standing desk</td>
<td>Sitting at a traditional classroom desk</td>
<td>45 minutes</td>
<td>100%</td>
<td>Ventilation, VO₂, VCO₂, respiratory exchange ratio, caloric expenditure</td>
<td>SenseWear armband accelerometer (METs and energy expenditure)</td>
</tr>
<tr>
<td>Speck (2011)</td>
<td>United States, men and women, average age: 45</td>
<td>Non-randomized crossover trial, 3 conditions, n=13</td>
<td>LIPA intervention</td>
<td>1) Sitting on an exercise ball; 2) standing while working at a computer</td>
<td>Sitting</td>
<td>7 minutes</td>
<td>Not specified</td>
<td>Energy expenditure, METs</td>
<td>Indirect calorimetry (energy expenditure) and calculated oxygen consumption (METs)</td>
</tr>
<tr>
<td>Steeves (2012)</td>
<td>United States, men and women, inactive, average age: 28</td>
<td>Crossover trial with four conditions, n=23</td>
<td>LIPA/ MVPA intervention</td>
<td>1) Standing, 2) stand and step in place for 5 min at a self-selected moderate pace, 3) treadmill</td>
<td>Sitting</td>
<td>1 week</td>
<td>100%</td>
<td>Energy expenditure</td>
<td>Metabolic measurement system (energy expenditure)</td>
</tr>
<tr>
<td>Swartz (2011)</td>
<td>United States, men and women, average age: 28</td>
<td>Randomized crossover trial with four conditions, n=20</td>
<td>MVPA intervention</td>
<td>Walking at 3 mph</td>
<td>30 minutes of continuous sitting</td>
<td>30 minutes</td>
<td>100%</td>
<td>Energy expenditure and oxygen consumption</td>
<td>Indirect calorimetry (energy expenditure and cardiopulmonary fitness) and flow-through hood technique (resting metabolic rate)</td>
</tr>
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<tr>
<td>LIPA, light-intensity physical activity; MVPA, moderate-to-vigorous-intensity physical activity; MET, metabolic equivalent units.</td>
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</tbody>
</table>
4.2.7 Figures

Figure 1
Summary of evidence search and selection

- 32,988 records identified through database searching
- 52 additional records identified through other sources

16,743 records after duplicates removed

331 records screened

16,412 records excluded

331 full-text articles assessed for eligibility

309 full-text articles excluded:
- Inappropriate operational definition of sedentary behavior
- No sedentary behavior as outcome
- No energy expenditure or metabolic health measure as outcome
- TV/screen time as sole measure of sedentary time
- Non-activity-based intervention to reduce sedentary time (excludes those with only motivational counselling, reinforcement etc.)

22 studies included in qualitative synthesis

20 studies included in quantitative synthesis (meta-analysis)
Figure 2

The energy expenditure directly associated with interventions where sedentary time was reallocated to physical activity.

<table>
<thead>
<tr>
<th>Study, Year (Reference)</th>
<th>SMD (95% CI)</th>
<th>Z Score</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barwais, 2015 (15)</td>
<td>1.650 (0.940-2.360)</td>
<td>4.556</td>
<td>0.000</td>
</tr>
<tr>
<td>Beers, 2008 (19)</td>
<td>4.100 (2.834-5.366)</td>
<td>6.348</td>
<td>0.000</td>
</tr>
<tr>
<td>Blankenship, 2014 (21)</td>
<td>0.795 (-0.055-1.644)</td>
<td>1.834</td>
<td>0.067</td>
</tr>
<tr>
<td>Buckley, 2014 (36)</td>
<td>1.105 (0.227-1.983)</td>
<td>2.467</td>
<td>0.014</td>
</tr>
<tr>
<td>Carr, 2014 (22)</td>
<td>3.490 (2.452-4.528)</td>
<td>6.592</td>
<td>0.000</td>
</tr>
<tr>
<td>Carter, 2015 (23)</td>
<td>2.720 (1.887-3.552)</td>
<td>6.403</td>
<td>0.000</td>
</tr>
<tr>
<td>Cox, 2011 (24)</td>
<td>1.400 (0.856-1.944)</td>
<td>5.041</td>
<td>0.000</td>
</tr>
<tr>
<td>Creasy, 2015 (20)</td>
<td>3.253 (2.292-4.213)</td>
<td>6.639</td>
<td>0.000</td>
</tr>
<tr>
<td>Dorvivier, 2013 (25)</td>
<td>5.218 (3.822-6.613)</td>
<td>7.328</td>
<td>0.000</td>
</tr>
<tr>
<td>Fountaine, 2016 (26)</td>
<td>0.370 (-0.264-1.005)</td>
<td>1.143</td>
<td>0.253</td>
</tr>
<tr>
<td>Koepp, 2013 (27)</td>
<td>2.646 (2.025-3.268)</td>
<td>8.342</td>
<td>0.000</td>
</tr>
<tr>
<td>Levine, 2007 (28)</td>
<td>0.905 (0.186-1.624)</td>
<td>2.468</td>
<td>0.014</td>
</tr>
<tr>
<td>Pedersen, 2013 (17)</td>
<td>0.582 (-0.104-1.268)</td>
<td>1.662</td>
<td>0.096</td>
</tr>
<tr>
<td>Reiff, 2012 (18)</td>
<td>1.617 (0.926-2.308)</td>
<td>4.586</td>
<td>0.000</td>
</tr>
<tr>
<td>Speck, 2011 (32)</td>
<td>1.118 (0.333-1.903)</td>
<td>2.790</td>
<td>0.005</td>
</tr>
<tr>
<td>Steeves, 2012 (33)</td>
<td>0.228 (-0.593-1.048)</td>
<td>0.544</td>
<td>0.587</td>
</tr>
<tr>
<td>Knapp - Hartung Estimator</td>
<td>1.888 (1.132-2.644)</td>
<td>5.322</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Heterogeneity ($I^2 = 91.62; P < 0.001; Q = 126.557$)

Reallocation to MVPA

<table>
<thead>
<tr>
<th>Study, Year (Reference)</th>
<th>SMD (95% CI)</th>
<th>Z Score</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blankenship, 2014 (21)</td>
<td>0.146 (-0.673-0.964)</td>
<td>0.348</td>
<td>0.728</td>
</tr>
<tr>
<td>Carter, 2015 (23)</td>
<td>3.219 (2.310-4.129)</td>
<td>6.940</td>
<td>0.000</td>
</tr>
<tr>
<td>Dorvivier, 2013 (25)</td>
<td>1.297 (0.565-2.028)</td>
<td>3.474</td>
<td>0.001</td>
</tr>
<tr>
<td>Dunn, 1999 (16)</td>
<td>0.479 (0.285-0.673)</td>
<td>4.843</td>
<td>0.000</td>
</tr>
<tr>
<td>Fountaine, 2016 (26)</td>
<td>1.585 (0.862-2.307)</td>
<td>4.300</td>
<td>0.000</td>
</tr>
<tr>
<td>Koepp, 2013 (27)</td>
<td>3.370 (2.663-4.077)</td>
<td>9.345</td>
<td>0.000</td>
</tr>
<tr>
<td>Levine, 2007 (28)</td>
<td>5.292 (3.839-6.745)</td>
<td>7.140</td>
<td>0.000</td>
</tr>
<tr>
<td>Steeves, 2012 (33)</td>
<td>4.123 (2.678-5.569)</td>
<td>5.591</td>
<td>0.000</td>
</tr>
<tr>
<td>Sissart, 2011 (34)</td>
<td>9.778 (7.618-11.937)</td>
<td>8.874</td>
<td>0.000</td>
</tr>
<tr>
<td>Knapp - Hartung Estimator</td>
<td>3.145 (0.909-5.381)</td>
<td>3.243</td>
<td>0.012</td>
</tr>
</tbody>
</table>

Heterogeneity ($I^2 = 98.37; P < 0.001; Q = 215.515$)

Reallocation to LIPA & MVPA

<table>
<thead>
<tr>
<th>Study, Year (Reference)</th>
<th>SMD (95% CI)</th>
<th>Z Score</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blankenship, 2014 (21)</td>
<td>0.146 (-0.673-0.964)</td>
<td>0.348</td>
<td>0.728</td>
</tr>
<tr>
<td>Dorvivier, 2013 (25)</td>
<td>1.297 (0.565-2.028)</td>
<td>3.474</td>
<td>0.001</td>
</tr>
<tr>
<td>Kozev Kadele, 2014 (31)</td>
<td>0.411 (-0.283-1.104)</td>
<td>1.161</td>
<td>0.246</td>
</tr>
<tr>
<td>Pedersen, 2013 (17)</td>
<td>2.006 (1.213-2.799)</td>
<td>4.957</td>
<td>0.000</td>
</tr>
<tr>
<td>Knapp - Hartung Estimator</td>
<td>0.963 (-0.381-2.307)</td>
<td>2.332</td>
<td>0.020</td>
</tr>
</tbody>
</table>

Heterogeneity ($I^2 = 78.81; P = 0.003; Q = 13.684$)

LIPA = light-intensity physical activity; MVPA = moderate-to-vigorous physical activity; SMD = standardized mean difference of direct energy expenditure. SMD > 1 suggests positive energy expenditure associated with reallocating sedentary time to physical activity.
4.3 **Part 3: Examining Which Individuals Can Derive The Most Clinical Benefit From A Sedentary Behaviour Intervention For CR Patients**

A modified version of this study has been published in the *Journal of Clinical Epidemiology*.


### 4.3.1 Abstract

Few studies have examined the correlates of real-world cardiac rehabilitation (CR) effectiveness. The objective of this study was to determine the relationship between baseline risk, behavioural attrition, and the number needed to treat (NNT) associated with CR. A retrospective study was conducted among 16,061 CR patients between 1995 and 2011 in Canada. Multiple logistic regression models were derived from patient characteristics and measured baseline risk (individual’s risk of death within 3 years) and behavioural attrition (individual’s risk of dropout). We examined the treatment efficacy of CR among non-dropouts using a 20% relative risk reduction. Further sensitivity analyses were performed to assess the robustness of our assumptions. We assumed no efficacy among dropouts. Both baseline risk and behavioural attrition were independently associated with NNT, though baseline risk had a stronger association with NNT than behavioural attrition. Increasing age, lower baseline fitness, history of diabetes, hypertension, and greater comorbidities were associated with lower NNT. Being female, living alone, living in the lowest neighbourhood income quintile, and greater adiposity
were associated with higher NNT. The clinical effectiveness of CR is largely driven by
the baseline risk rather than the behavioural attrition of the populations they serve. These
findings have implications for risk stratification among those with greatest survival yields
and programmatic needs.
4.3.2 Introduction

Cardiac rehabilitation (CR) programs have been shown to be highly efficacious in reducing the risk of mortality and re-hospitalization for patients who have had acute coronary syndromes or have undergone recent coronary revascularization procedures (Anderson, Oldridge et al. 2016). However, compared to the controlled conditions placed on determining efficacy, the clinical effectiveness of these programs in real-world settings is determined by the sample characteristics of the populations they serve. For example, studies suggest that the absolute risk reduction as a result of CR will be most pronounced among those at highest baseline risk (Alter, Manuel et al. 2004, Franklin, Lavie et al. 2013). Conversely, the associated survival yields are expected to be negligible among those who prematurely dropout of CR (Alter, Oh et al. 2009, Beauchamp, Worcester et al. 2012). To our knowledge, the inter-relationship between baseline risk, behavioural attrition (program attendance), and the number needed to treat (NNT) associated with CR is unknown. NNT is an important outcome as it provides an absolute measure of treatment effect by estimating the number of patients that need to be treated in order to have an impact on one person (Andrade 2015). This concept is clinically informative, as we know that not everyone is helped by an intervention – some benefit, some are harmed and some are unaffected.

The objective of this study was to examine how the baseline risk and behavioural attrition profiles of a population participating in CR correlate with the NNT associated with the program. A secondary objective was to determine which patient profiles (if any) correlated with more or less favorable NNT.
4.3.3 Methods

Context and Setting

This study was conducted at the Cardiac Prevention and Rehabilitation Program (Rumsey Centre) of the University Health Network-Toronto Rehabilitation Institute in Toronto, Ontario, Canada. Of approximately 220 CR programs in Canada, the Rumsey Centre is among the largest by patient volume, accommodating up to 1,800 patients a year and servicing a territory that encompasses 2.2 million mostly urban dwelling Ontarians. The Rumsey Centre is publicly funded with services provided free of charge, and a physician will refer a patient to the program a minimum of 4–8 weeks post-cardiovascular event or surgical intervention. Patients are expected to attend once a week for 6 months and participate in a standard CR protocol of individualized weekly exercise sessions, one-on-one counselling, education and peer-to-peer support (Hamm and Kavanagh 2000, Franklin, Whaley et al. 2013). Mortality reductions associated with the Rumsey Centre program have been described elsewhere as being consistent with meta-analyses of clinical trials (Alter, Oh et al. 2009).

Study Population and Data Collection

This study received Research Ethics Board approval from the University Health Network-Toronto Rehabilitation Institute (Toronto, Canada). We retrospectively obtained data from consecutive patient entries to the Rumsey Centre from 1995 to 2011. The inclusion criteria were CR patients with a record of at least one on-site appointment visit after their initial intake assessment. Baseline socio-demographic and clinical variables
were obtained by linking administrative and clinical registry data through the encrypted health card numbers of each patient. Anthropometric data was made available through on-site patient assessments and cardiorespiratory stress testing at baseline (intake), mid-program (3 months) and upon program completion (6 months). Prior cardiac hospitalizations were identified through hospital discharge abstracts obtained from the Canadian Institute of Health Information’s Discharge Abstract Database (DAD) using a retrospective period of five years. Information on cardiac and non-cardiac comorbidities was obtained from primary and secondary diagnostic fields for each corresponding hospital admission. Data on previous cardiovascular procedures including coronary angiography, percutaneous coronary intervention and bypass surgery were obtained through physicians’ claims (the Ontario Health Insurance Plan) and DAD databases for the five years prior to referral. The use of DAD and physicians' claims data to identify comorbid diseases and coronary procedures have been previously used and validated (Alter, Iron et al. 2004). Diabetes and hypertension history were identified using disease-specific validated algorithms from the Ontario Health Insurance Plan and DAD databases (Hux, Ivis et al. 2002). A proxy measure of socioeconomic status was determined by neighborhood income using 2001 Ontario neighborhood census data. Neighborhood income was categorized into quintiles, from lowest income (first quintile) to highest income (fifth quintile). Any deaths occurring within three years following a patient’s prescheduled completion of CR at the Rumsey Centre were determined using the Ontario Ministry of Health and Long-Term Care Registered Persons Database.
**Statistical Analysis**

Patient characteristics collected at baseline such as age, sex, socioeconomic status, clinical risk factors (referral diagnosis, smoker status, history of diabetes, hyperlipidemia, hypertension, number of comorbid conditions and previous hospitalizations) and anthropometric measurements (functional capacity, abdominal/hip girth and body mass index) were used to estimate risk-adjusted predictive models of baseline risk and behavioural attrition. Both regression models were generated using backwards regression techniques (comparing -2 Log Likelihood Ratios). The baseline risk model predicted the probability of death within three years from the date of entry into the CR program. The behavioural attrition model predicted the probability that a patient would dropout prematurely from their program. We verified behavioural attrition by estimating the absolute number of patients that would drop out of the program using risk profile-specific prevalence rates obtained from our real-world CR population. Dropouts were ascertained by the patients’ assigned rehabilitation supervisor using subjective criteria which included the following: (1) confirmation by a patient that he/she no longer wished to participate, or (2) three or more consecutively missed onsite visits and being unreachable by telephone on repeated (minimum of three) attempts over the ensuing two months, and (3) failing to attend at least 66% of prescheduled onsite classes and without a final exit cardiopulmonary fitness evaluation. The use of a 66% cut-off threshold for program dropout is consistent with the expectations of the Rumsey Centre program, and previous investigations have used similar criteria (Alter, Oh et al. 2009, Swardfager, Herrmann et al. 2011). The mean of the area under the receiver operating curve (c-statistic) was assessed to determine the ability of the regression models to discriminate outcomes.
(rather than by chance) (Pencina and D’Agostino 2015). Spearman’s correlation coefficient and weighted kappa statistics were used to determine the correlation and agreement between the regression models (Cohen 1968). The correlation and association between baseline risk and behavioural attrition were found to be weak ($r = 0.06$, weighted kappa $= 0.036 \ [95\% \ CI \ 0.026-0.046]$). The discriminative properties of the baseline risk and behavioural attrition models were good (c-statistic $= 0.81$) and moderate (c-statistic $= 0.65$), respectively, suggesting that both models had reasonable predictive accuracy.

We estimated the clinical effectiveness of CR by determining the NNT to prevent one death across increasing deciles of baseline risk and behavioural attrition (decile 1 as the lowest baseline risk and behavioural attrition, up to decile 10 of highest baseline risk and behavioural attrition). Although a recent meta-analysis has shown CR to have marginal non-significance on reducing all-cause mortality (Anderson and Taylor 2014), such reviews are difficult to interpret given the heterogeneity across studies, reduction in CR length over time, changes in delivery and management of care, and evaluation with intention to treat analyses rather than considering attrition rates (Lavie, Arena et al. 2016). Therefore, to calculate the NNT (1/absolute risk reduction), we assumed that CR patients incurred a 20% relative risk reduction for cardiovascular and all-cause mortality (regardless of their clinical risk). This is a conservative estimate based on methodologically rigorous observational studies of similar sized CR programs and modes of delivery (Suaya, Stason et al. 2009, Beauchamp, Worcester et al. 2012). Patients who dropped out prematurely were assumed to incur no efficacy from CR (i.e. relative risk reduction set to 0), a finding also supported by previous studies (Alter, Oh et al. 2009,
Martin, Hauer et al. 2012). The median NNT, prevalence, and patient profiles were reported for each decile of baseline risk and behavioural attrition. Baseline risk and behavioural attrition were also categorized into tertiles to examine how the NNT correlated with baseline risk-specific deciles of behavioural attrition and behavioural attrition-specific deciles of baseline risk. Several sensitivity analyses were undertaken. All tests were two-tailed with a P value < 0.05 considered to be statistically significant. All statistical analyses were performed using SAS software, version 9.3 (SAS Institute Inc., Cary, North Carolina, USA).

4.3.4 Results

The risk factor characteristics of the 16,061 patients who had undertaken a baseline intake examination at the Rumsey Centre program and were included in our study cohort are shown in Table 1. On average, patients were mostly between 50 to 79 years of age, male, married, living in the highest neighborhood income quintile, had a high body mass index, and attended the majority of CR classes.

The NNT associated with CR was found to inversely correlate with baseline risk regardless of behavioural attrition (Figure 1). The association between behavioural attrition and NNT was less pronounced and consistent than the association between baseline risk and NNT. While the NNT generally rose with increasing behavioural attrition, exceptions did occur, especially among patients with low baseline risk (Figure 2). Table 2 shows the association between predicted and observed 3-year mortality and dropout rates and deciles of NNT. The characteristics of all sampled patients and their
corresponding associations with NNT are presented in Table 3. Increasing age, presence and history of diabetes, hypertension, and increasing numbers of comorbidities were characteristics associated with lower NNT. Being female, living alone, living in the lowest neighbourhood income quintile, higher fitness (peak VO$_2$), and greater levels of adiposity (e.g. higher BMI, higher abdominal girth) were characteristics associated with higher NNT.

Several sensitivity analyses were undertaken to assess the robustness of our findings. First, to account for variation in findings of CR-associated all-cause mortality risk reduction, we estimated the NNT due to varying relative risk reduction for lowest and highest quartile categories of baseline risk and behavioural attrition (Supplementary Table 1). Second, all of our analyses were repeated among those who had attended at least one onsite visit, thereby allowing for an enhanced clinical dataset to be included in the statistical models of baseline risk and behavioural attrition. Third, we varied the definition used to categorize dropout (i.e. predicted dropout rates based on attendance rates of less than 33% vs. 33–66% vs. 67% and greater) as had been done in previous research (Alter, Oh et al. 2009, Alter, Zagorski et al. 2014). Fourth, all of our analyses were repeated to use non-parsimonious statistical models (i.e. all variables forced into the models) for the derivation of baseline risk and behavioural attrition risk in place of parsimonious stepwise regression techniques. Fifth, alterations were made to the cohort design in which a minimum 1-year hospital survival-free period was incorporated regardless of whether or not patients dropped out prematurely. In all sensitivity analyses, our results did not meaningfully change.
4.3.5 Discussion

Our study characterized the baseline risk and behavioural attrition profiles of a CR patient population. While variations in both baseline risk and behavioural attrition moderated NNT, we found that baseline risk exerted a greater influence on NNT than did variations in behavioural attrition.

If one assumes homogeneity in the efficacy of CR across patient subgroups, then the clinical effectiveness of such programs are driven by the baseline risk and behavioural attrition profiles of their patients (Martin, Hauer et al. 2012, Franklin, Lavie et al. 2013). Previous studies have emphasized the importance of baseline risk in the clinical effectiveness and cost effectiveness of CR but few have incorporated behavioural attrition into their estimations (Alter, Manuel et al. 2004, Leggett, Hauer et al. 2015).

Furthermore, the most recent Cochrane review had largely surveyed randomized controlled studies that were evaluated largely by intention to treat rather than factoring in on the differential attendance and adherence rates of typical CR patient populations (Lavie, Arena et al. 2016). To our knowledge, this study is the first to use both baseline risk and behavioural attrition to determine the NNT associated with CR in a real-world setting. We believe this approach to be a more realistic than clinical trials given that the latter are often based on highly selective, lower risk and more adherent participants (Anderson and Taylor 2014).
The baseline risks for the majority of our study participants were found to be unrelated to their behavioural attrition. The independent nature of these two measures underscores the need to incorporate both when predicting the effectiveness of CR in real-world settings (Martin, Hauer et al. 2012). However, certain patient subgroups were found to be exceptions. For example, higher risk patients, either because of their advanced age and/or lower cardiopulmonary fitness, tended to display better programmatic adherence to CR than their younger, more fit and lower risk counterparts. These differences may be explained by the greater time available among advanced age individuals as a consequence of being out of the workforce and the stronger perception of illness among higher risk individuals (Murray, Murphy et al. 2013). In contrast, those living in neighbourhoods with the lowest average income, those who lived-alone, females, and/or those with increased adiposity were associated with higher NNTs due to their increased behavioural attrition. This was the case despite these subgroups tending to be at higher baseline risk for cardiovascular and all-cause mortality (Aalto, Weinman et al. 2007, James, Wilkins et al. 2007, Holt-Lunstad, Smith et al. 2010). These variations in NNT suggest that some patient subgroups have more clinically effective baseline risk and behavioural attrition profiles than others.

Our findings have implications for future research, clinical practice and policy. Characterizing patient profiles according to projected estimates of baseline risk and behavioural attrition could help clinicians and policy makers optimize the real-world survival benefits associated with CR by prioritizing services to those expected to derive the greatest clinical yields. The use of risk-stratification techniques could also help to
inform future research that identifies “high-risk” population subgroups whose suboptimal behavioural attrition profiles undermine the clinical effectiveness of CR. We found patients who were most socioeconomically disadvantaged, females and/or those with increased adiposity to represent targets for behavioural co-interventions within CR programs where even marginal improvements in their programmatic adherence could yield important reductions in NNT. Alternatively, subgroups with high baseline risk and who already demonstrate good programmatic adherence such as advanced age and/or lower cardiopulmonary fitness individuals still stand to gain highly from CR and should remain as ideal candidates for such programs.

There are several limitations that merit discussion. First, we assumed that the relative risk reduction for mortality was the same for all participants. While randomized clinical trials support this assumption, it is possible that heterogeneity in CR efficacy does exist (Thompson and Clark 2009, Lawler, Filion et al. 2011). We accounted for this variation by examining the NNT associated with CR across a plausible relative risk reduction range in our sensitivity analysis, and found that our conclusions still held. Namely, that baseline risk exerted a greater influence on NNT than behavioural attrition. Second, the predictive risk models for baseline risk and behavioural attrition have not been validated. Moreover, the c-statistic for the behavioural attrition model was poorer than that for baseline risk, and the inclusion of more detailed clinical and/or behavioural factors may strengthen our results. Nonetheless, these findings should be considered as a conceptual illustration of how baseline risk and behavioural attrition profiles can determine a CR program’s projected NNT. Finally, our baseline risk and behavioural attrition data were derived
from a single center. While the center is one of the largest in North America, it is possible that baseline risk and behavioural attrition vary across CR programs.

In conclusion, our study demonstrated the extent to which the NNT associated with CR can vary according to baseline risk and behavioural attrition of patients. Furthermore, we found baseline risk to be a greater determinant of CR clinical effectiveness than behavioural attrition. These findings can inform CR risk stratification practices that identify patient profiles for which the expected survival yields and programmatic attentiveness needs are greatest.
### 4.3.6 Tables

#### Table 1

Baseline characteristics of cardiac rehabilitation participants \(N=16,061\)

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<tr>
<th>Sociodemographic factors</th>
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<td>Age category</td>
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<tr>
<td>20-49 years, n (%)</td>
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<td>50-64, n (%)</td>
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<td>65-79, n (%)</td>
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<td>≥80, n (%)</td>
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<td>Male, n (%)</td>
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<td>Married, n (%)</td>
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<td>5 (highest income)</td>
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<td>Chronic coronary artery disease, n (%)</td>
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<td>Other (%)</td>
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<td>Mean number of chronic conditions (SD)</td>
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<td>Hypertension, n (%)</td>
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<td>Diabetes, n (%)</td>
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<td>Smoker, n (%)</td>
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<td>Mean body mass index, kg/m(^2) (SD)</td>
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<td>Mean hip girth, cm (SD)</td>
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<td>Mean abdominal girth, cm (SD)</td>
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<td>Mean predicted 3 year mortality, (SD)</td>
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<td>Observed number of deaths within 3 years, n (%)</td>
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<tr>
<td>Mean predicted dropouts (SD)</td>
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<td>Observed dropouts, n (%)</td>
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<td>Onsite visit attendance</td>
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<td>0-33%, n (%)</td>
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<td>33.1%-67%, n (%)</td>
<td>5838 (36.3)</td>
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<tr>
<td>≥67.1%, n (%)</td>
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</tr>
<tr>
<td>Mean previous hospitalizations (SD)</td>
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Table 2
The association between predicted and observed mortality and dropout rates and deciles of number needed to treat*.

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<th>5</th>
<th>6</th>
<th>7</th>
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<th>9</th>
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<tr>
<td>Predicted 3 year mortality rate (i.e. baseline risk), (median)</td>
<td>7.7</td>
<td>4.5</td>
<td>3.2</td>
<td>2.5</td>
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<td>1.6</td>
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<td>0.7</td>
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<td>Predicted dropout rate (i.e. behavioural attrition), (median)</td>
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<td>24.3</td>
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<td>26.8</td>
<td>28.5</td>
<td>30.1</td>
<td>&lt;0.001</td>
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<tr>
<td><strong>Observed mortality and dropout</strong></td>
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<tr>
<td>Observed 3 year mortality, %</td>
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<td>0%-33%</td>
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<td>8.2</td>
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<td>11.5</td>
<td>12.1</td>
<td>13.4</td>
<td>&lt;0.001</td>
</tr>
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<td>19.3</td>
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<td>10.3</td>
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<tr>
<td>≥67.1%</td>
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<td>9.5</td>
<td>8.8</td>
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<td>11.1</td>
<td>11.3</td>
<td>12.4</td>
<td>&lt;0.001</td>
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</table>

*The number of patients needed to treat to prevent one additional death (NNT). Deciles are shown from 1 (lowest 10% NNT) to 10 (highest 10% NNT).*
| Table 3 |
The association between patient characteristics and deciles of number needed to treat*. |
<table>
<thead>
<tr>
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<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
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<tr>
<td>Age, years (median)</td>
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<td>75</td>
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<td>61</td>
<td>58</td>
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<td>51</td>
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<tr>
<td>Age within 20-49 years, %</td>
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<tr>
<td>Age within 65-79 years, %</td>
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<td>Age ≥80 years, %</td>
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<td>10.4</td>
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<td>13.6</td>
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<td>Neighbourhood income quintile, %</td>
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<td>Peak VO₂, ml/kg/m² (median)</td>
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<td>15.9</td>
<td>15.4</td>
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</tbody>
</table>

* The number of patients needed to treat to prevent one additional death (NNT). Deciles are shown from 1 (lowest 10% NNT) to 10 (highest 10% NNT).
Supplementary Table 1.

The number needed to treat according to varying relative risk reduction (RRR) of cardiac rehabilitation efficacy on all-cause mortality risk. The lowest quartile represents the lowest baseline risk and behavioural attrition categories; the highest quartile represents the highest baseline risk and behavioural attrition categories.

<table>
<thead>
<tr>
<th>Baseline Risk</th>
<th>Behavioural Attrition</th>
<th>Sample Size</th>
<th>Number Needed to Treat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1% RRR</td>
</tr>
<tr>
<td>Lowest Quartile</td>
<td>Lowest Quartile</td>
<td>1046</td>
<td>1052.63</td>
</tr>
<tr>
<td>Quintile</td>
<td>Highest Quartile</td>
<td>464</td>
<td>980.39</td>
</tr>
<tr>
<td>Highest Quartile</td>
<td>Lowest Quartile</td>
<td>466</td>
<td>336.70</td>
</tr>
<tr>
<td>Quartile</td>
<td>Highest Quartile</td>
<td>1030</td>
<td>306.75</td>
</tr>
</tbody>
</table>
4.3.7 Figures

Figure 1

The association between baseline risk† (deciles) and the relative increase in number needed to treat (NNT)* for tertiles of behavioural attrition‡. Decile 1 reflects the lowest baseline risk category; decile 10 reflects the highest baseline risk category. Actual NNT values are shown in brackets. P<0.05.

*The relative increase in the number needed to treat (NNT) is compared to a reference category with the lowest NNT (i.e. the lowest tertile of behavioural attrition and highest decile of baseline risk).

†Baseline risk, the predicted probability that a patient of a particular risk profile is likely to die within three years following a patient’s intake into cardiac rehabilitation.

‡Behavioural attrition, the predicted probability of premature program dropout from cardiac rehabilitation.
**Figure 2**

The association between behavioural attrition† (in increasing deciles of attrition) and the relative increase in number needed to treat (NNT)* for tertiles of baseline risk†. Decile 1 reflects the lowest behavioural attrition category; decile 10 reflects the highest behavioural attrition category. Actual NNT values are shown in brackets. *P<0.05.

*The relative increase in the number needed to treat (NNT) is compared to a reference category with the lowest NNT (i.e. the highest tertile of baseline risk and lowest decile of behavioural attrition).

†Behavioural attrition, the predicted probability of premature program dropout from cardiac rehabilitation.

‡Baseline risk, the predicted probability that a patient is likely to die within three years following a patient’s intake into cardiac rehabilitation.
Chapter 5

5 Discussion

This chapter summarizes and discusses the findings of the studies in this dissertation, examines their strengths and limitations, outlines suggestions for future research, and considers the clinical/public health implications and the knowledge translation plan of this dissertation.

5.1 Summary of the Studies

This body of research contributes to a better understanding of the relationship between exercise and sedentary behaviour among patients participating in an exercise-based CR program, and identifies factors that should be considered for future interventions targeted towards sedentary behaviour change in these individuals. The following is a summary of the key findings as they relate to the thesis objectives:

**Objective 1: To determine the health risks associated with prolonged sedentary time in adults independent of exercise participation, and whether high levels of exercise attenuate the health risks compared to low levels.**

After reviewing 41 studies that controlled for the effects of exercise, prolonged sedentary behaviour was found to be independently associated with a greater risk for all-cause mortality, cardiovascular incidence and mortality, cancer incidence (breast, colon, colorectal, endometrial, and epithelial ovarian) and mortality, and the incidence of type 2
diabetes. The greatest association was found for type 2 diabetes risk (pooled hazard ratio (HR), 1.91 [CI, 1.642 to 2.222]). Of the 10 studies that reported the effects of prolonged sedentary time at high and low levels of exercise participation on all-cause mortality, the hazards were 30% greater at lower levels of physical activity (pooled HR, 1.46 [CI, 1.22 to 1.75] than at higher levels (pooled HR, 1.16 [CI, 0.84 to 1.59]. This suggested that the risks for all-cause mortality were greatest among highly sedentary individuals who also engaged in low levels of exercise, and these risks become less pronounced as participation in exercise increased. This work provided an original contribution to the literature by focusing exclusively on studies that statistically adjusted for exercise (at least moderate intensity physical activity) when determining outcome associations. Furthermore, this work was the first to quantify the extent to which meeting physical activity recommendations modify the associations between sedentary time and health outcomes.

**Objective 2: Examine whether exercise participation in a CR program influences the sedentary behaviour of patients**

Two independent samples of patients participating in a CR program were examined to determine the extent that exercise participation in CR influences the sedentary behaviour and MVPA of patients. In Part 1, the change in sedentary behaviour and MVPA was examined among a representative sample of patients participating in a standard model of 6-month outpatient exercise-based CR. In Part 2, participants of a randomized controlled trial intended to reinforce exercise participation in CR, were examined to further ascertain the influence of exercise participation on sedentary behaviour.
Findings from Part 1 showed that patients were highly sedentary at the start of CR and this remained unchanged after 3 months of program participation irrespective of whether they met physical activity guidelines. Approximately 19% of patients at baseline were classified as being at high mortality risk as they did not meet physical activity recommendations and were highly sedentary. However, no characteristics distinguished these individuals from patients who met physical activity recommendations and/or had lower levels of sedentary behaviour. Thus there is a strong possibility that a substantial proportion of CR patients are already at greater mortality risk for prolonged sedentary behaviour particularly if they continue or revert to a physically inactive and sedentary lifestyle. These results suggest that the existing physical activity-focus of CR programs may be insufficient at reducing sedentary behaviours, and future studies are needed to examine the feasibility and clinical effectiveness of sedentary behaviour reduction strategies tailored towards CR patients. To the best of my knowledge, no previous study had examined the influence of CR participation on the sedentary behaviours of patients, with a focus on individuals who might be at highest mortality risk.

Part 2 examined whether an integrative intervention to enhance exercise participation (combining the listening of music playlist preferences with rhythmic auditory stimulation) was more efficacious at improving sedentary times than usual care among patients participating in CR. This study built on the findings of Part 1 that suggested that CR does not elicit a meaningful reduction in sedentary time. Findings showed that both accelerometer-derived ($r = -0.08, P=0.812$) and self-reported measurements ($r = -0.24$,
had a poor correlation between sedentary time and MVPA for the 31 study participants. This suggested that participation in exercise-based CR does not influence sedentary time. The majority of participants were also highly sedentary for 12 to 16 hours a day despite meeting recommendations of at least 150 minutes of MVPA per week. Thus the majority of participants in the integrative intervention were successful at meeting MVPA recommendations but otherwise were highly sedentary. Furthermore, the study found differences in self-reported and objective data where participants generally underestimated their sedentary time and overestimated their MVPA time, suggesting that these individuals might not be any better at perceiving their activity patterns than general populations.

**Objective 3:** Explore and identify factors that can inform future sedentary behaviour interventions for CR patients.

The aim of this objective was to inform implementable sedentary behaviour reduction strategies for CR patients and was examined in three parts. **Part 1** explored the awareness and understanding of sedentary behaviour, as well as the perceived facilitators and barriers to reducing sedentary behaviours from the perspectives of CR patients and staff involved in supporting their self-management. **Part 2** compared available intervention studies to examine the energy expenditure yields associated with reallocating sedentary time to varying intensities of physical activity (light-intensity physical activity (LIPA), moderate to vigorous-intensity physical activity (MVPA), or a combination of both). **Part 3** examined which profiles of CR patients (based on baseline risk and behavioural attrition attributes)
were associated with lower or greater clinical effectiveness, and accordingly, identify which individuals may benefit the most from a sedentary behaviour intervention.

Part 1 found that patients and staff did not give as much importance to reducing their sedentary behaviour as compared to improving their physical activity and other health behaviours. Intrapersonal factors and environmental factors (the information environment, social-cultural factors, the natural environment) within the behaviour setting contexts of leisure time, the home, and work were perceived as influencing the sedentary behaviours of patients. Physical and psychological health, social unacceptability, lack of information, and associating sedentary activities with enjoyment/relaxation were found to be important barriers to reducing sedentary behaviours. Getting healthier and being supported/motivated by their CR program were seen as important facilitators. Staff commonly identified patient health and more information as the most important factors. It was found that the present CR delivery model might not be effective in reducing sedentary behaviours unless additional efforts are made towards targeting sedentary behaviour reduction. Strategies informed by this study should consider increasing the awareness of individuals on the importance of increasing their daily movements to compliment a message of regular physical activity. Strategies to increase self-efficacy to interrupt extended bouts of sedentary behaviour needs development and testing. Furthermore, CR programs and other exercise- and lifestyle-based interventions should consider participatory approaches involving patients and staff to ensure that a sedentary behaviour reduction strategy is feasible at the individual-level and can be maintained for the long-term.
Part 2 hypothesized that LIPA-based interventions, by reallocating a greater daily duration of sedentary time, will result in greater daily cumulative energy expenditure than those interventions reallocating to MVPA alone. It was found that the daily cumulative energy expenditure associated with promoting MVPA alone (as is the focus of CR programs) is close to, albeit over a shorter time duration, the highest energy expenditure yields from co-interventions that promote both MVPA and LIPA (through light intensity daily movements). As such, while not the most optimal, the present exercise-based CR focus is expected to be a viable option for patients who are able to meet and maintain physical activity recommendations but are otherwise sedentary due to the greater effort and burden required to combine both spectrums of physical activity. The lowest energy expenditure increases were found for interventions that solely promoted the reallocation of sedentary time to LIPA. This suggests that a sedentary behaviour reduction strategy on its own will not yield sufficient health-promoting energy expenditure and metabolic benefits for CR patients unless combined with exercise promotion. However, given that CR programs persistently face exercise and program participation challenges due to numerous barriers (e.g. motivation, time, physical and psychological limitations) (Evenson and Fleury 2000, Daly, Sindone et al. 2002), promoting an increase in daily movements of light-intensity physical activity may be a suitable compromise and stands to at least confer some health benefits associated with reducing sedentary behaviour. This reaffirms the need for individualized interventions and provides reassurance that similar energy expenditures can be achieved through different intervention strategies. However, the messaging of ‘move more, sit less’ appears justified.
Part 3 examined who would derive the most benefit from cardiac rehabilitation intervention (who to focus on, rather than how to intervene). This was informed by considering how the clinical effectiveness of CR varied according to patient profiles of baseline risk and behavioural attrition. This study is unique as previously the clinical effectiveness of CR programs in real-world situations were unclear given that they were assessed by studies typically conducted in controlled conditions, on an intention-to-treat basis, or had assumed similar program efficacy across participants.

Although increasing baseline risk and decreasing behaviour attrition were associated with greater CR clinical effectiveness, baseline risk was found to exert a greater prevailing influence. Patients benefitting the most from CR (associated with the lowest NNT) were older individuals, had lower cardiopulmonary fitness, a history of diabetes, hypertensive, and had greater comorbidities at program intake. Females, those who lived alone, lived in the lowest neighbourhood income quintile, and had greater adiposity were found to receive less clinical benefit from CR. These findings suggest that CR programs benefit patients differently, and are likely to demonstrate the greatest gains in clinical effectiveness when resources are prioritized to those at highest baseline risk, or alternatively, towards strategies that improve program adherence to those at greatest risk of dropping out. While these findings are specific to CR as a programmatic intervention, one would logically surmise applicability to sedentary behavioural interventions as well given that these programs are feature multiple lifestyle interventions.
5.2 Synthesis of Findings

Prior to this dissertation, a growing body of evidence had suggested that prolonged sedentary time is associated with cardio-metabolic disorders and mortality (Katzmarzyk, Church et al. 2009, Healy, Matthews et al. 2011). To date, controlled trials in the sedentary behaviour research field had primarily focused on examining the effectiveness of interventions (Lee, Arthur et al. 2008, Dunstan, Kingwell et al. 2012, Barwais and Cuddihy 2014, Prince, Saunders et al. 2014). However, more compelling evidence is still needed to determine whether prolonged sedentary time is a causal modifiable risk factor for negative health outcomes as has been established with physical inactivity. As the Introduction (Section 1.1) and Conceptual Framework (Section 1.3) highlighted, establishing a distinct risk factor requires evidence from multiple sources in the absence of controlled clinical studies (Furberg, Hennekens et al. 1996). Accordingly, this thesis provided a partial contribution by finding that the associations between prolonged sedentary time and various negative health outcomes are indeed strong when the effects are disentangled from those of physical activity participation. While controlled trials were notably absent in the field, examining mainly longitudinal studies showed it is highly likely that prolonged sedentary time antedates disease onset. Yet, increasing physical activity levels were found to modify sedentary behaviour-related health outcomes, and a recent meta-analysis (published after the completion of the thesis studies) corroborates this by suggesting that physical activity reduces mortality risk and may also eliminate it completely through daily moderate-intensity physical activity of 60 to 75 minutes (Ekelund, Steene-Johannessen et al. 2016). As such, more work is needed to completely understand plausible biological mechanisms by which physical activity and sedentary behaviour interact and affect health in order to encourage the
future implementation of sedentary behaviour interventions and policy/public health initiatives.

The correlates of sedentary behaviour are context-specific (Owen, Leslie et al. 2000, Owen, Sugiyama et al. 2011) and this thesis was focused on informing the feasibility and components of future sedentary behaviour interventions specifically to a CR setting. The finding that the exercise promotion focus of CR programs is ineffective at reducing sedentary time is perhaps unsurprising given that two meta-analyses had shown physical activity-focused interventions have little effectiveness at reducing the sedentary time of adults (Prince, Saunders et al. 2014, Martin, Fitzsimons et al. 2015). The different behavioural processes influencing physical activity and sedentary behaviour likely explain this. Physical activity promotion has largely involved the targeting of controlled motivational processes such as intentions or self-efficacy, while engaging in sedentary behaviours are likely due to unconscious habits formed by environmental and behavioural cues (Maher and Conroy 2016). Accordingly, exercise promotion and sedentary behaviour reduction are not one in the same, and a specific focus by CR programs on changing sedentary behaviour is required. A prospective intervention must prioritize more sedentary behaviour-specific messaging, be mindful of the various intrapersonal and environmental factors that influence sedentary behaviours, and consider participatory approaches involving patients and staff to ensure that a sedentary behaviour reduction strategy is feasible at the individual-level and can be maintained for the long-term. More optimistically, existing resources offered by CR programs can be extended or modified to positively influence the daily sedentary behaviour of patients given that they already utilize similar approaches
towards addressing other lifestyle risk factors. As such, it is hoped that large improvements to patient health can be gained with comparatively small adjustments to existing CR service delivery protocols.

Convincing patients and staff to prioritise a low sedentary behaviour lifestyle is expected to be a challenge for a future intervention. The lower priority is likely because addressing other health behaviours often takes greater precedence among CR patients, while engaging in sedentary behaviours has a positive association with enjoyment, relaxation and relief from pain. Similar findings have been reported elsewhere (Gilson, Burton et al. 2011, Martínez-Ramos, Martín-Borràs et al. 2015) and may be a consequence of the perceived benefits of sedentary activities such as relaxation, relief from pain, increased social interaction and mental stimulation that are common among older and medically impaired populations. As had been described in the qualitative study of patient perspectives, these barriers to greater self-efficacy can be overcome by evaluating and stimulating a patient’s emotional and physical state, increasing their experience of success by setting achievable targets, providing constructive feedback, social and peer-support, and helping individuals vicariously observe others perform the same strategy (Strecher, DeVellis et al. 1986, Bandura 1991). The lower priority and motivation to reduce sedentary behaviour might also be due to a lower awareness of the perceived risks of prolonged sedentary time among both patients and practitioners. Accordingly, it is likely that providing more information and awareness should be a necessary foundation for any future intervention and public health strategy.
Lastly, understanding “who” (e.g. patient characteristics) may be more important than “how” (e.g. type, duration) when developing effective intervention strategies in the future.

Considering the significant time and resources required to develop individualized interventions for a broad spectrum of CR patients, a logical next step may be to examine the intermediate and long-term outcome changes for those patients expected to benefit the most from an intervention, namely those who are older, with lower cardiopulmonary fitness, have a history of diabetes, are hypertensive, and have greater comorbidities at program intake. Future studies expanding on this thesis should pilot sedentary behaviour interventions among these individuals, as they are more likely to show improvements in intermediate and long-term health outcomes. Subsequent positive or negative findings can then inform studies that are extended and scaled to the rest of the CR patient population.

As this body of research only touches on a few areas of importance within the sedentary behaviour research agenda, it is hoped that integrating these findings with others can help to expand the existing evidence and develop promising strategies to reduce sedentary time among CR patient populations, and eventually other populations as well.
5.3 Strengths

The strength of this thesis is its consolidation of numerous methodologies to develop compelling evidence on the risks of sedentary behaviour and strategies for sedentary behaviour reduction among CR patients. The use of the systematic review and meta-analysis methodology provided a systematic summary of individual studies of a large, often complex, and sometimes conflicting body of literature. The meta-analysis study design is also advantageous over traditional review methods in its ability to quantitatively inform the extent to which sedentary behaviour, and sedentary behaviour interventions are associated with health outcomes. Linking secondary data from administrative socio-demographic and health records for a large sample of CR patients provided a detailed and representative characterization of the baseline risk and behavioural attrition patterns of actual CR patients. The relationship between exercise and sedentary behaviour at a CR program were examined by prospective studies involving the collection of primary data among actual CR patients. This provided the opportunity to directly observe the sedentary behaviours and physical activity of patients, and utilized validated subjective and objective assessment methods. The use of a qualitative study design is particularly useful for the development of an intervention (Sandelowski 2004, Creswell 2012). Furthermore, the in-depth study of patient views and supplementation of the perspectives of staff can inform the development of a sedentary behaviour reduction strategy that is responsive to the needs of patients and is feasible for integration into practice.
5.4 Limitations

Specific limitations of the six studies included in this thesis were individually considered in the previous chapters. The following are general limitations regarding the collective works in the manuscript that should be considered in future work.

First, the evaluation of CR patients was limited to a single CR centre, although one of the largest and most recognized CR programs in North America. There is a strong possibility that these findings may not reflect patients from other CR programs with different delivery models or when individuals with dissimilar characteristics are served. Furthermore, while CR programs are ideal settings to examine the relationship between exercise and sedentary behaviour, surveyed patients were already at higher risk for morbidity and mortality than general populations and are also provided lifestyle and behavioural support by their CR program. As such, study effects might not be generalizable to other exercise-based programs, clinical populations, or general populations.

Second, the conclusions when examining which CR patients derived the greatest clinical benefit from a sedentary intervention strategy can only be inferred, as an association between baseline risk/behavioural attrition patient profiles and participation in exercise/sedentary behaviours are not known. As such, while sedentary behaviour interventions are likely to impact patients comparably to CR programs in general, it is unclear whether the highly sedentary patient who does not meet physical activity recommendations is also at high baseline risk at program initiation per se.
Third, the observational studies were heavily reliant on subjective measures of sedentary behaviour and physical activity. Accordingly, assessments may have been prone to self-report/testing bias and inaccurately reflect actual patterns of movement. While objective Actigraph GT3X+ accelerometers were used to verify self-reported measurements, the convergent validity between both measurement methods were found to be poor to moderate, though comparable in trends. As such, while the measurement methods used in this thesis show a consistent relationship between exercise and sedentary behaviour, the sedentary time of patient participants can only be considered an approximation.

Fourth, studies collecting sedentary time data were primarily focused on establishing associations with total sedentary time rather than breaks and periods in prolonged sedentary time. As such, nuances in outcome differences among individuals may not have been sufficiently detected given that interruptions in sedentary time have shown to be beneficially associated with various health risk variables (Healy, Dunstan et al. 2008, Healy, Matthews et al. 2011). This suggests that it is important to not only assess the amount of total sedentary time but also the manner in which it is accumulated.

Fifth, the understanding of sedentary behaviour, as well as the perceived facilitators and barriers to reducing sedentary behaviours were derived from a broad sample of CR patients. While Rhodes et al. have suggested numerous potential correlates to sedentary behaviour such as older age, being employed and gender (Rhodes, Mark et al. 2012), this thesis examined a general CR patient sample in order to be consistent with the thesis questions and earlier findings, as well as being limited by time and resource constraints. Future work is
needed to examine the perspectives of CR patients and other populations when stratified by correlates of physical activity and sedentary behaviour.

Lastly, it is possible that the sampled participants were more motivated to exercise, healthier and not reflective of the sedentary behaviour and physical activity behaviours of patients in general. Accordingly, these findings can serve as the foundation for more representative, larger sample-sized studies that are able to capture greater variations in sedentary behaviour and physical activity characteristics.
5.5 Suggestions for Future Research

The studies within this dissertation described many areas of future research; nonetheless, the following key areas are highlighted below:

1. There is a pressing need to develop better methods to assess sedentary behaviour in adults. Self-reported measures are wrought with inaccuracies related to social desirability and recall bias, while the commonly used Actigraph GT3X+ accelerometer device (used in this research) has been criticised for not being sufficiently reliable at discriminating between different sedentary states or periods of non-activity (Carr and Mahar 2011). At the time of this writing, the activPAL™ accelerometer has shown to be more accurate than the Actigraph GT3X+ in detecting sedentary behaviour (Godfrey, Culhane et al. 2007, Kim, Barry et al. 2015). More testing among larger sample-sized studies and varied populations is needed before this device can be relied upon in future studies. Furthermore, it was found that CR patient participants were hesitant to wear an accelerometer device on their waist for the full seven waking days of study measurement which suggests that potential strategies must ensure that objective activity monitoring devices have low participant burden in order to improve wear-time adherence.

2. Further studies are needed to clarify the association between breaks in sedentary time and sedentary bout length with health in adult populations. While this thesis found no significant change in sedentary breaks among patients during CR participation, other studies have detected differences in health outcomes when breaks and bout length were considered (Healy, Dunstan et al. 2008, Healy, Matthews et al. 2011). This suggests that patterns of
sedentary behaviour may be particularly important in adults and future studies should verify whether this is the case.

3. With larger sample sizes, future research should investigate specific risk profiles of CR patients (as well as in other populations) by various demographic, clinical, and socio-cultural variables, and accordingly, facilitate the further identification of individuals most likely to require a sedentary behaviour intervention and target them accordingly.

4. Informed by this work, future research should involve the actual development, pilot-testing, evaluation, and implementation of an intervention targeted towards reducing the sedentary behaviour of CR patients (in accordance with phases of the Medical Research Council framework for the design and evaluation of complex interventions to improve health (Craig, Dieppe et al. 2008)). For example, once such a program has been pilot-tested, subsequent research should involve a randomized controlled trial to test the proposed strategy’s effectiveness at reducing sedentary behaviour and improving health outcomes. As described in the earlier Synthesis of Findings (Section 5.2), the next logical step should be to determine whether a controlled trial study leads to improvements in intermediate and long-term outcomes (such as clinically meaningful changes in cardio-metabolic disease markers and disease incidence) among the CR patient profiles already identified in this thesis as likely to benefit. Subsequently, benefits to the rest of the patient population should be examined, and studies replicated at multiple CR sites in Canada and/or internationally.
5. This thesis work aimed to inform some of the criteria used to establish whether prolonged sedentary time can be considered a causal risk factor for various negative health outcomes (such as disentangling the strength of association from the effects of MVPA, determining whether sedentary time exposure antedates outcomes, and establishing specificity to a CR setting). Nonetheless, various other criteria highlighted by the Conceptual Framework (Section 1.3) remain unanswered. Accordingly, while beyond the scope of this work, more research is needed to determine whether there is a dose-response gradient between sedentary time and outcomes, establish the biologically plausible mechanism of action in humans, develop more experimental evidence (through controlled trial experiments for example), and to replicate/extend these findings to other populations and settings.

5.6 Knowledge Translation

Findings from this body of research can inform the development, pilot testing, evaluation, and implementation of a strategy to reduce sedentary behaviour among patients participating in an exercise-based CR program. At the time of thesis submission, the candidate had made many of the findings available to relevant end-users across various domains: through media sources (the first two studies received mention from national and international media), via peer-reviewed publications available to the research community and those involved in implementing practice, engaging stakeholders through presentations at CR programs and at national/international clinical and public health conferences, academic and non-academic presentations, and contributing to published educational materials distributed within the UHN-Toronto Rehabilitation Institute Cardiac Rehabilitation and Secondary Prevention
program itself (a contributed section on sedentary behaviour is available at
All published findings will continue to be disseminated to these channels as well as to
interested individuals (such as recruited study participants and program staff) through
newsletters and seminar presentations.

5.7 Clinical and Public Health Implications

This dissertation has important clinical and public health implications. Since 1952, the
cardiovascular death rate in Canada has declined by more than 75 per cent – and nearly 40
per cent in the last decade (Statistics Canada 2011). A major reason for this success has been
because of exercise promotion as a key component of CR practices (Lawler, Filion et al. 2011). With decades of recommended use and irrefutable evidence showing therapeutic
benefit there have been little emphasis on re-evaluating CR practices for improved patient
care and program effectiveness (Thompson and Lewin 2000, Lawler, Filion et al. 2011). The
emerging evidence that long periods of sedentary behaviour poses unique physiological and
cellular effects separate from those of exercise poses a challenge to present CR practice
paradigms (Hamilton, Hamilton et al. 2007). The few hours in a week that a patient spends
participating in a clinically supervised exercise-based CR program may not be enough to
outweigh the independent health hazards of sedentary behaviour if the patient does not
sufficiently meet physical activity recommendations. Findings informed by this dissertation
can lead to a more comprehensive 24-hour approach to optimising the rehabilitation
potential of cardiac patients at home and in-facility. Furthermore, CR patients serve to
highlight an exercise-engaged clinical population, albeit more vulnerable and at higher risk
for mortality than general populations and findings can inform sedentary behaviour reduction strategies for other clinical, non-clinical, and exercise-engaged populations. It is hoped that this work along with other studies in the field of sedentary behaviour/inactivity research will collectively advise public health recommendations and strategies that encourage Canadians to incorporate non-sedentary activities into their daily lives and ultimately prevent a significant proportion of hospitalizations and mortalities caused by modifiable risk factors.

5.8 Conclusion

This body of work contributes a better understanding of whether prolonged sedentary time is a causal modifiable risk factor for negative health outcomes, the risks and determinants of sedentary behaviour among CR patients, the facilitators and barriers of reducing sedentary behaviour in these individuals, and factors to consider when developing a future sedentary behaviour intervention. It was found that prolonged sedentary time is strongly associated with various cardio-metabolic disorders and mortality independent of physical activity, with greater mortality risks for those individuals who do not meet physical activity recommendations. When examining CR patients, it was found that participation in exercise alone had little influence on sedentary time, and in the absence of sedentary behaviour recommendations in CR guidelines, an additional strategy to reduce sedentary behaviour for patients is necessary. While aware of the risks of sedentary behaviour, patients and staff placed a lower priority in reducing their sedentary behaviour as compared to improving their physical activity and other health behaviours, and commonly identified various intrapersonal and environmental factors as facilitators and barriers to reducing sedentary behaviour. CR
programs and staff were also perceived to have a positive role in supporting patients in the self-management of their sedentary behaviour. These findings considered, the “who” may be more important than the “how” when targeting sedentary behaviour interventions as CR programs were found to not benefit all patients equally. Lastly, a strategy to reallocate sedentary time to physical activity (either LIPA, MVPA, or a combination of both) must be tailored to the individual, and consider their ability to implement and maintain a routine of exercise and/or daily movements. Collectively, these findings contribute towards a better understanding of whether prolonged sedentary time is a distinct, modifiable health risk factor and informs the development, pilot testing, and evaluation of a future sedentary behaviour intervention for CR patients.
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attendance and outcomes in coronary artery disease patients." Circulation: 111.066738.

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attendance and outcomes in coronary artery disease patients." *Circulation: CIRCULATIONAHA.* 111.066738.


Appendix

A. Thesis Publications

The following studies have been published or have been submitted for publication at the time of thesis submission. Some studies have been modified and/or formatted according to journal requirements.

Published:


Submitted or In-Review:


B. Search Strategies

Chapter 2.

Ovid MEDLINE [Searched August 2014]
<Advanced Search> [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (# of studies identified)
1  exercise.mp (226897)
2  physical activity.mp (53647)
3  habitual physical activity.mp (884)
4  sedentar*.mp (18113)
5  inactivity.mp (8720)
6  television.mp (16244)
7  sitting.mp (14147)
8  survival.mp (784956)
9  morbidity.mp (242449)
10  mortality.mp (479154)
11  disease.mp (2966535)
12  hospital*.mp (1069370)
13  utilization.mp (131293)
14  1 OR 2 OR 3 (256221)
15  4 OR 5 OR 6 OR 7 (54886)
16  8 OR 9 OR 10 OR 11 OR 12 OR 13 (4658603)
17  14 AND 15 AND 16 (4623)
18  Limit 17 to (English language and humans) (3854)

PubMed [Searched August 2014] (# of studies identified)
1  (exercise OR physical activity OR habitual physical activity) AND (sedentar* OR inactivity OR television OR sitting) AND (survival OR morbidity OR mortality OR disease OR hospital* OR utilization) (9371)
2  Filters activated: Full text, Humans, English (7354)

Ovid EMBASE [Searched April 2014]
<Advanced Search> [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (# of studies identified)
1  exercise.mp (348059)
2  physical activity.mp (112789)
3  habitual physical activity.mp (1152)
4  sedentar*.mp (25557)
5  inactivity.mp (13001)
6 television.mp (22220)
7 sitting.mp (28345)
8 survival.mp (1033309)
9 morbidity.mp (425127)
10 mortality.mp (942377)
11 disease.mp (6036977)
12 hospital*.mp (1663201)
13 utilization.mp (260238)
14 1 OR 2 OR 3 (423994)
15 4 OR 5 OR 6 OR 7 (82283)
16 8 OR 9 OR 10 OR 11 OR 12 OR 13 (3484232)
17 14 AND 15 AND 16 (3548)
18 Limit 17 to (English language and humans) (2751)

**EBSCO CINAHL** [Searched April 2014] (# of studies identified)
1. (exercise OR physical activity OR habitual physical activity) AND (sedentar* OR inactivity OR television OR sitting) AND (survival OR morbidity OR mortality OR disease OR hospital* OR utilization) (1191)

**Google Scholar** [Searched August 2014] (# of studies identified)
1. (exercise OR physical activity OR habitual physical activity) AND (sedentar* OR inactivity OR television OR sitting) AND (survival OR morbidity OR mortality OR disease OR hospital* OR utilization) (2,561)

**Web of Knowledge** [Searched April 2014] (# of studies identified)
Search by [Topic]
1. (exercise OR physical activity OR habitual physical activity) AND (sedentar* OR inactivity OR television OR sitting) AND (survival OR morbidity OR mortality OR disease OR hospital* OR utilization) (2929)
2. English language (2767)

**Cochrane Library** [Searched August 2014] (# of studies identified)
Search by [Title, Abstract, Keywords]
(exercise OR physical activity OR habitual physical activity) AND (sedentar* OR inactivity OR television OR sitting) AND (survival OR morbidity OR mortality OR disease OR hospital* OR utilization) (750)
Chapter 4. Part 2.

Medline (Ovid) is shown only. The electronic search was conducted on April 14, 2016. Equivalent searches were conducted in Pubmed, Embase, CINAHL, PsycInfo, the Cochrane Central Register of Controlled Clinical Trials and the Cochrane Database of Systematic Reviews.

1. [Do interventions that reduce sedentary adult behavior provide improved changes in energy expenditure?] (0)
2. [Population: Sedentary Adults] (0)
3. Sedentary Lifestyle/ (4370)
4. (sedentary or physical* inactive*).tw,kw. (26229)
5. (sitting adj2(prolonged or time or episode* or reduc* or increas*)).tw,kw. (1373)
6. or/3-5 (28418)
7. [Intervention: Physical Activity & Health Education] (0)
8. exp Exercise/ (137512)
9. exp Exercise Therapy/ (35605)
10. exp Sports/ (142969)
11. exp Exercise Movement Technique (6013)
12. Dancing/ (2116)
13. Health education/ (55145)
14. Patient education as topic/ (74504)
15. (physical* active* or exercis*).tw,kw. (282673)
16. (pedometer* or accelerometer* or step count* or “steps per day” or “steps/d”).tw (9439)
17. or/8-16 (535231)
18. [Outcomes: Energy Expenditure Measures] (0)
19. exp Oxygen Consumption/ [includes “metabolic equivalent” and anaerobic threshold”] (97326)
20. Physical Exertion/ (54012)
21. Physical Fitness/ (23534)
22. Calorimetry, Indirect/ (3294)
23. exp Energy Metabolism/ (316470)
24. exp Lipid Metabolism/ (67393)
25. (VO2* or oxygen consumption* or anaerobic threshold* or metabolic equivalent*).tw,kw. (50174)
26. ((activit* or exercise*) adj4 (bout* or intermitt* or continuous* or increas* or decreas* or higher or light* or moderate* or vigorous* or less* or more* or intens* or chang* or episode* or promot*)).tw. (529254)
27. (metabol* or cardiometabol*).tw,kw. (948034)
28. cardiopulmonary fitness.tw,kw.
29. (energy adj2 expenditure*).tw,kw. (19678)
30. (energy adj2 expenditure*).tw,kw. (19678)
31. 6 and 17 and 30 (14152)
32. (animals not (humans and animals)).sh (4191698)
33. 31 not 32
34. [Removal of minor publication types] (0)
35. editorial.pt. (398865)
36. letter.pt (910429)
37. comment.pt (658664)
38. news.pt (175624)
39. patient education handout.pt (4407)
40. or/35-39 (1636898)
33 not 40 (11613)
C. Research Ethics Approval

Chapter 3, Part 1 (University Health Network)

Notification of REB Initial Approval

Date: August 31st, 2015
To: Dr. David Alter
Toronto Rehabilitation Institute
550 University Avenue, Room 102
Toronto, Ontario, Canada
M5G 2A2

Re: 15-9247-DE
Determining the Prevalence of Sedentary Behaviour Among Cardiac Rehabilitation Patients

REB Review Type: Expedited
REB Initial Approval Date: August 31st, 2015
REB Expiry Date: August 31st, 2016

Documents Approved:
- Protocol
  Version date: July 21st, 2015
- Consent Form
  Version date: July 21st, 2015
- Medical Health Questionnaire
  Version date: July 21st, 2015
- Letter of Appreciation
  Version date: July 21st, 2015
- Sedentary Behaviour Questionnaire
  Version date: July 21st, 2015

The UHN Research Ethics Board operates in compliance with the Tri-Council Policy Statement; ICH Guideline for Good Clinical Practice E6(R1); Ontario Personal Health Information Protection Act (2004); Part C Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations and the Medical Devices Regulations of Health Canada. The approval and the views of the REB have been documented in writing. The REB has reviewed and approved the clinical trial protocol and informed consent form for the trial which is to be conducted by the qualified investigator named in the letter.

Furthermore, members of the Research Ethics Board who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

Best wishes on the successful completion of your project.

Sincerely,

Ann Haesters, BA MA BEd PhD (ABD)
Co-Chair, University Health Network Research Ethics Board
June 9, 2015

Dr. David Alter 
DEPT OF MEDICINE
FACULTY OF MEDICINE

Mr. Aviroop Biswas 
DEPT OF MEDICINE
FACULTY OF MEDICINE

Dear Dr. Alter and Mr. Aviroop Biswas,

Re: Your research protocol entitled, “Determining the prevalence of sedentary behaviour among cardiac rehabilitation patients”

ETHICS APPROVAL

Original Approval Date: June 9, 2015
Expiry Date: June 8, 2016
Continuing Review Level: 1

We are writing to advise you that the Health Sciences Research Ethics Board (REB) has granted approval to the above-named research protocol under the REB’s delegated review process. Your protocol has been approved for a period of one year and ongoing research under this protocol must be renewed prior to the expiry date.

Any changes to the approved protocol or consent materials must be reviewed and approved through the amendment process prior to its implementation. Any adverse or unanticipated events in the research should be reported to the Office of Research Ethics as soon as possible.

Please ensure that you submit an Annual Renewal Form or a Study Completion Report 15 to 30 days prior to the expiry date of your current ethics approval. Note that annual renewals for studies cannot be accepted more than 30 days prior to the date of expiry.

If your research is funded by a third party, please contact the assigned Research Funding Officer in Research Services to ensure that your funds are released.

Best wishes for the successful completion of your research.

Yours sincerely,

[Signature]

OFFICE OF RESEARCH ETHICS
Mehari Building, 12 Queen's Park Crescent West, 2nd Floor, Toronto, ON M5S 3B8 Canada
Tel. +1 416 946-3273 Fax. +1 416 946-5703 ethics.review@utoronto.ca http://www.research.utoronto.ca/for-researchers/administrators/ethics/
February 2, 2016

Dr. David Alter
DEPT OF MEDICINE
FACULTY OF MEDICINE

Mr Aviroop Biswas
DEPT OF MEDICINE
FACULTY OF MEDICINE

Dear Dr. Alter and Mr Aviroop Biswas,

Re: Your research protocol entitled, "Perceptions associated with the engagement in sedentary behaviour among cardiac rehabilitation patients"

<table>
<thead>
<tr>
<th>ETHICS APPROVAL</th>
<th>Original Approval Date: February 2, 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Expiry Date: February 1, 2017</td>
</tr>
<tr>
<td></td>
<td>Continuing Review Level: 1</td>
</tr>
</tbody>
</table>

We are writing to advise you that the Health Sciences Research Ethics Board (REB) has granted approval to the above-named research protocol under the REB’s delegated review process. Your protocol has been approved for a period of one year and ongoing research under this protocol must be renewed prior to the expiry date.

Any changes to the approved protocol or consent materials must be reviewed and approved through the amendment process prior to its implementation. Any adverse or unanticipated events in the research should be reported to the Office of Research Ethics as soon as possible.

Please ensure that you submit an Annual Renewal Form or a Study Completion Report 15 to 30 days prior to the expiry date of your current ethics approval. Note that annual renewals for studies cannot be accepted more than 30 days prior to the date of expiry.

If your research is funded by a third party, please contact the assigned Research Funding Officer in Research Services to ensure that your funds are released.

Best wishes for the successful completion of your research.

Yours sincerely,

[Signature]
Chapter 4, Part 1 (University Health Network)

University Health Network
Research Ethics Board
10th Floor, Room 1056
700 University Ave
Toronto, Ontario, M5G 1Z5
Phone: (416) 581-7849

Notification of REB Initial Approval

Date: January 8th, 2016
To: Dr. David Alter
Sunnybrook Health Sciences Centre, 2075 Bayview Avenue
Toronto, Ontario, Canada M4N 3M5

Re: 15-9899-DE
Perceptions Associated with the Engagement in Sedentary Behaviour Among Cardiac Rehabilitation Patients

REB Review Type: Expedited
REB Initial Approval Date: January 8th, 2016
REB Expiry Date: January 8th, 2017

Documents Approved:
- Protocol
- Consent Form - Staff
- Consent Form - Patients
- Letter of Appreciation
- Interview Guide - Staff
- Interview Guide - Patients

Version date: December 21st, 2015
Version date: January 8th, 2016
Version date: January 9th, 2016
Version date: December 21st, 2015
Version date: November 6th, 2015
Version date: November 6th, 2015

The UHN Research Ethics Board operates in compliance with the Tri-Council Policy Statement; ICH Guideline for Good Clinical Practice E6(R1); Ontario Personal Health Information Protection Act (2004); Part C Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations and the Medical Devices Regulations of Health Canada. The approval and the views of the REB have been documented in writing. The REB has reviewed and approved the clinical trial protocol and informed consent form for the trial which is to be conducted by the qualified investigator named in the letter.

Furthermore, members of the Research Ethics Board who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

Best wishes on the successful completion of your project.

Sincerely,

Ann Heesters, BA MA BED PhD (ABD)
Co-Chair, University Health Network Research Ethics Board
D. Consent Forms

Chapter 3, Part 1

CONSENT FORM TO PARTICIPATE IN A RESEARCH STUDY

Study Title: Determining the prevalence of sedentary behaviour among cardiac rehabilitation patients

Investigator/Study Doctor: Dr. David Alter

Contact Information: 416-597-3422 ext. 5267; david.alter@ices.ca

Please note that the security of e-mail messages is not guaranteed. Messages may be forged, forwarded, kept indefinitely, or seen by others using the internet. Do not use e-mail to discuss information you think is sensitive. Do not use e-mail in an emergency since e-mail may be delayed.

Co-Investigators: Dr. Paul Oh, Dr. Guy Faulkner, Mr. Aviroop Biswas

Introduction:

You are being asked to take part in a research study. Please read the information about the study presented in this form. The form includes details on study’s risks and benefits that you should know before you decide if you would like to take part. You should take as much time as you need to make your decision. You should ask the study doctor or study staff to explain anything that you do not understand and make sure that all of your questions have been answered before signing this consent form. Before you make your decision, feel free to talk about this study with anyone you wish including your friends, family, and family doctor. Participation in this study is voluntary.

Background/Purpose:

Sedentary behaviours involve low levels of energy expenditure associated with sitting that you do in the hours that you are awake i.e. lying down, television watching and using the computer. There is evidence to suggest that spending too much time in sedentary behaviours is bad for your health regardless of whether you are regularly physically active. These risks are associated with developing disease and conditions that may affect your overall health and lifestyle.

Our study aims to understand the prevalence of sedentary behaviours among cardiac rehabilitation programs. This study also aims to examine how sedentary behaviours change over time as you participate in your cardiac rehabilitation program. Information from this study will be used to better understand who are most sedentary and ways to target sedentary behaviour interventions at a cardiac rehabilitation program. You are being asked to participate in this study because you have been referred by a physician to attend a cardiac rehabilitation program.

Study Design:

This study will collect information on the daily and weekly time you spend sedentary and being physically active. We will gather this information this by asking you to complete two questionnaires at your cardiac rehabilitation intake assessment appointment (baseline) and at an appointment 3 months later (follow up). The
first questionnaire will ask you to record your sedentary times over a week, and the second is from the information you provided through the Medical Health Questionnaire when you entered the program.

You may also be selected to additionally wear a small activity tracking device on your hip for each day of a week. This device will accurately measure sedentary and physical activity time and help us verify the information you provided us through the questionnaires.

**Study Visits and Procedures:**

The study team will ask you questions about your sedentary behaviours before you began cardiac rehabilitation. This is called the baseline visit. The results of the tests/questions at the baseline visit will also help the study team to decide whether you can continue in this study.

Boxes marked with an X show what will happen at each visit.

<table>
<thead>
<tr>
<th>Visit</th>
<th>Visit 1 (Month 1)</th>
<th>Visit 2 (Month 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of time needed</td>
<td>1 hour</td>
<td>1 hour</td>
</tr>
<tr>
<td>Provide Medical History</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Complete Questionnaires</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Activity monitor provided (to certain participants)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Activity Monitor Tracking Form (to certain participants)</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

You will be asked to complete two questionnaires (a sedentary behaviour questionnaire and a medical health questionnaire) at two points in time, at the start of your cardiac rehabilitation program (intake assessment) and at the 3rd month stage of your program. Those of you have received an activity tracking monitor will also be asked to complete a tracking form, which you will complete whenever you remove the device (e.g. before taking a shower, going for a swim) or before you go to sleep.

The questionnaires are to assess your daily/weekly sedentary time, your exercise time and your current state of health and presence of any risk factors. Your current mental health will also be assessed by questions from the CES-D Scale of the medical health questionnaire. The questionnaires will take approximately 5 to 10 minutes to complete. You may skip any questions that make you uncomfortable or that you do not wish to answer.

This study will enroll approximately 130 participants from UHN-Toronto Rehabilitation Institute, of whom half will also receive an activity tracking device. If you are chosen to also wear an activity tracking device, you will be asked to wear the device on your hip for a week at your intake assessment appointment and at an appointment at the 3rd month stage of your program.

Participation in this study will not alter the standard of care you receive at your cardiac rehabilitation program, of health assessments, exercise (aerobic and resistance training), education and counselling.

**Risks:**

There are no additional risks associated with this study apart from those already associated with your regular participation in cardiac rehabilitation (you can learn of these risks by asking the clinical staff at the cardiac rehabilitation program). There is also a possibility of risks that we do not know about and have not been seen in individuals to date. Please call the study doctor or a clinical staff member if you have any side effects even if you do not think it has anything to do with this study.

**Benefits:**
While we do not expect you to receive any benefits from this study, there is a possibility that you may change your sedentary behaviour patterns as you continue to participate in the cardiac rehabilitation program. Information learned from this study may help us develop ways to reduce sedentary behaviours among future cardiac rehabilitation patients.

**Reminders and Responsibilities:**
If you are chosen to wear an activity tracking device, we would like you to wear the device on the same position your hip throughout each day, for a week. Please remove the device when you bathe/shower as it is not waterproof. We will show you how to wear this device.

**Alternatives to Being in the Study:**
You can always choose not to participate in this study. If you choose not to participate, you are still expected to attend your scheduled cardiac rehabilitation classes.

**Confidentiality:**

**Personal Health Information**
If you agree to join this study, the study doctor and his study team will look at your personal health information and collect only the information they need for the study. Personal health information is any information that could identify you and includes your:
- name,
- address,
- full date of birth,
- prior and existing medical conditions
- medical tests or procedures.

Your participation in this study will also be recorded in your medical record at this hospital. This is for clinical safety purposes.

**Research Information in Shared Clinical Records**
If you participate in this study, information about you from this research project may be stored in your hospital file and in the UHN computer system. The UHN shares the patient information stored on its computers with other hospitals and health care providers in Ontario so they can access the information if it is needed for your clinical care. The study team can tell you what information about you will be stored electronically and may be shared outside of the UHN. If you have any concerns about this, or have any questions, please contact the UHN Privacy Office at 416-340-4800, x6937 (or by email at privacy@uhn.ca).

Representatives of the University Health Network (UHN) including the UHN Research Ethics Board may come to the hospital to look at the study records and at your personal health information to check that the information collected for the study is correct and to make sure the study is following proper laws and guidelines.

The study doctor will keep any personal health information about you in a secure and confidential location for 10 years. A list linking your study number with your name will be kept by the study doctor in a secure place, separate from your study file.

All information collected during this study, including your personal health information, will be kept confidential and will not be shared with anyone outside the study unless required by law. You will not be named in any reports, publications, or presentations that may come from this study.

**Voluntary Participation:**
Your participation in this study is voluntary. You may decide not to be in this study, or to be in the study now and then change your mind later. You may leave the study at any time.

We will give you new information that is learned during the study that might affect your decision to stay in the study.

**Withdrawal from the Study:**
You may withdraw from the study at any time without any impact on your current or future care at this institution. If you withdraw your consent, the study team will no longer collect your personal health information for research purposes, unless it is needed for review of safety. In the event that you withdraw from the study prematurely after providing consent, we may use data collected from you for our analysis.

**Costs and Reimbursement:**
The questionnaires/activity tracking devices will be provided to you free of charge as long as you are participating in the study. You will not be reimbursed for participating in this study.

**Rights as a Participant:**
If you are harmed as a direct result of taking part in this study, all necessary medical treatment will be made available to you at no cost by the cardiac rehabilitation program.

By signing this form you do not give up any of your legal rights against the investigators, or the Toronto Rehabilitation Institute for compensation, nor does this form relieve the investigators institutions of their legal and professional responsibilities.

**Conflict of Interest:** The study researchers have an interest in completing this study. Their interests should not influence your decision to participate in this study.

**Commercialization:** Your personal information and findings from this study will not be commercialized.

**Publication of results:** We may publish our findings or make public presentations based on the data collected. We will make sure that your personal information cannot be identified. You are always welcome to contact a member of the study team for a summary of the research results.

**Questions about the Study:**
If you have any questions, concerns or would like to speak to the researchers for any reason, please call Dr. David Alter at 416-597-3422 ext. 5267

If you have any questions about your rights as a research participant or have concerns about this study, you can contact the following:

- The Chair of the University Health Network Research Ethics Board (UHN REB) or the Research Ethics office number at 416-581-7849. The REB is a group of people who oversee the ethical conduct of research studies. The UHN REB is not part of the study team. Everything that you discuss will be kept confidential. You will be given a signed copy of this consent form and you may keep a copy of the information letter for your own reference.

Consent:

This study has been explained to me and any questions I had have been answered.
I know that I may leave the study at any time. I agree to the use of my information as described in this form. I agree to take part in this study.

________________________________________  ___________________________  ____________
Print Study Participant’s Name                Signature                        Date

My signature means that I have explained the study to the participant named above. I have answered all questions.

________________________________________  ___________________________  ____________
Print Name of Person Obtaining Consent        Signature                        Date

Was the participant assisted during the consent process? □ YES □ NO
If YES, please check the relevant box and complete the signature space below:

□ The person signing below acted as an interpreter for the participant during the consent process and attests that the study as set out in this form was accurately interpreted has had any questions answered.

________________________________________  ___________________________  ____________
Print Name of Interpreter                      Signature                        Date

________________________________________  ___________________________
Relationship to Participant                  Language
Chapter 4, Part 1 (Staff consent)

CONSENT FORM TO PARTICIPATE IN A RESEARCH STUDY

Study Title:
Perceptions Associated with the Engagement in Sedentary Behaviour Among Cardiac Rehabilitation Patients

Investigator/Study Doctor: Dr. David Alter

Contact Information: 416-597-3422 ext. 5267; david.alter@uhn.ca

Please note that the security of e-mail messages is not guaranteed. Messages may be forged, forwarded, kept indefinitely, or seen by others using the Internet. Do not use e-mail to discuss information you think is sensitive. Do not use e-mail in an emergency since e-mail may be delayed.

Co-Investigators: Dr. Paul Oh, Dr. Guy Faulkner, Mr. Avi Biswas

Introduction:
You are being asked to take part in a research study. Please read the information about the study presented in this form. The form includes details on study’s risks and benefits that you should know before you decide if you would like to take part. You should take as much time as you need to make your decision. You should ask the study doctor or study staff to explain anything that you do not understand and make sure that all of your questions have been answered before signing this consent form. Before you make your decision, feel free to talk about this study with anyone you wish including your friends, family, and family doctor. Participation in this study is voluntary.

Background/Purpose:
In today’s society, actions that cause us to sit down (also called, being ‘sedentary’) for long periods of time have become the norm. The sedentary behaviours that we take part in our daily routine usually include: watching television, using the computer, driving a car, and working at a desk. Previous research studies show that spending long periods of time in these sedentary behaviours can be bad for your health, and these risks can still remain even if we exercise regularly.

The purpose of this study is to gather the opinions of staff members involved in cardiac rehabilitation care on their knowledge of sedentary behaviours, why they think cardiac rehabilitation patients may engage in sedentary behaviours, and their thoughts on strategies by which cardiac rehabilitation programs can reduce the sedentary behaviours of patients.

You are being asked to participate in this study because you are involved in the circle of care of a patient attending Toronto Rehabilitation Institute’s Cardiac Rehabilitation program. Up to 10 people will participate in this study at UHN.

Study Visits and Procedures:
You will be asked to take part in a one-time, 30 minute focus group interview with a member of our study team. 9 other staff members will all be interviewed as part of your focus group, which will be held at a private meeting room on the premises of the Toronto Rehab Cardiac Rehab program at a prescheduled time that is most convenient for all participants. After this interview, you will have completed your participation in this study.

The audio responses from your interview will be recorded to ensure that your responses are collected and analyzed accurately. You may skip any questions that make you uncomfortable or that you do not wish to answer.

**Risks:**

There are no risks to your health if you participate in this study. There is a possibility that you may feel discomfort during the course of the interview, in which case you can choose to not answer any question or withdraw from the study. Your responses will be kept anonymous beyond the members of the study team.

**Benefits:**

You may not receive direct benefit from being in this study. Information learned from this study may help the development of strategies to reduce the sedentary behaviours of cardiac rehabilitation patients.

**Confidentiality:**

If you agree to join this study, the study doctor and his study team will collect certain personal information that is needed for this study. Personal information is any information that could identify you and includes your:

- name,
- year of birth,
- current role/employed position in the cardiac rehabilitation program
- number of years of experience in current role

This information will be used to identify possible relationships between your role in patients’ circle of cardiac rehabilitation care and the responses you provide in your focus group interview.

Your interview responses will be audiotaped. To ensure that your responses remain confidential the audio file will be stored in a secure file server on UHN computer network. Only the study team will have access to your recorded audio responses, and these files will be erased and deleted after we have analyzed the data.

All information collected during this study will be kept confidential and will not be shared with anyone outside the study unless required by law. You will not be named in any reports, publications, or presentations that may come from this study.

**Voluntary Participation:**

Your participation in this study is voluntary. You may decide not to be in this study, or to be in the study now and then change your mind later. You may leave the study at any time without affecting your employment status.

**Withdrawal from the Study:**

You may withdraw from the study at any time without any impact on your employment at this institution. If you withdraw your consent, the study team will no longer collect your personal information for research purposes. In the event that you withdraw from the study prematurely after providing consent, we will no longer store or use any of your information.

**Costs and Reimbursement:**
You will not be reimbursed for participating in this study.

**Rights as a Participant:**

By signing this form you do not give up any of your legal rights against the investigators, sponsor or involved institutions for compensation, nor does this form relieve the investigators institutions of their legal and professional responsibilities.

**Conflict of Interest:** The study researchers have an interest in completing this study. Their interests should not influence your decision to participate in this study.

**Publication of results:** We may publish our findings or make public presentations based on the data collected. We will make sure that your personal information cannot be identified. You are always welcome to contact a member of the study team for a summary of the research results.

**Questions about the Study:**

If you have any questions, concerns or would like to speak to the study team for any reason, please call Dr. David Alter at 416-597-3422 ext. 5267

If you have any questions about your rights as a research participant or have concerns about this study, you can contact the following:

- The Chair of the University Health Network Research Ethics Board (UHN REB) or the Research Ethics office number at 416-581-7849. The REB is a group of people who oversee the ethical conduct of research studies. The UHN REB is not part of the study team. Everything that you discuss will be kept confidential.

You will be given a signed copy of this consent form.

**Consent:**

This study has been explained to me and any questions I had have been answered.

I know that I may leave the study at any time. I agree to the use of my information as described in this form. I agree to take part in this study.

_____________________________  ______________________  ______________

Print Study Participant’s Name   Signature   Date

My signature means that I have explained the study to the participant named above. I have answered all questions.
Chapter 4, Part 1 (Patient Consent)

CONSENT FORM TO PARTICIPATE IN A RESEARCH STUDY

Study Title: Perceptions Associated with the Engagement in Sedentary Behaviour Among Cardiac Rehabilitation Patients

Investigator/Study Doctor: Dr. David Alter

Contact Information: 416-597-3422 ext. 5267; david.alter@uhn.ca

Please note that the security of e-mail messages is not guaranteed. Messages may be forged, forwarded, kept indefinitely, or seen by others using the Internet. Do not use e-mail to discuss information you think is sensitive. Do not use e-mail in an emergency since e-mail may be delayed.

Co-Investigators: Dr. Paul Oh, Dr. Guy Faulkner, Mr. Avi Biswas

Introduction:

You are being asked to take part in a research study. Please read the information about the study presented in this form. The form includes details on study’s risks and benefits that you should know before you decide if you would like to take part. You should take as much time as you need to make your decision. You should ask the study doctor or study staff to explain anything that you do not understand and make sure that all of your questions have been answered before signing this consent form. Before you make your decision, feel free to talk about this study with anyone you wish including your friends, family, and family doctor. Participation in this study is voluntary.

Background/Purpose:

In today’s society, actions that cause us to sit down (also called, being ‘sedentary’) for long periods of time have become the norm. The sedentary behaviours that we take part in our daily routine usually include: watching television, using the computer, driving a car, and working at a desk. Previous research studies show that spending long periods of time in these sedentary behaviours can be bad for your health, and these risks can still remain even if we exercise regularly.

The purpose of this study is to gather the opinions of current cardiac rehabilitation patients on their knowledge of sedentary behaviours, why they may take part in sedentary behaviours, and their thoughts on strategies to help them to be less sedentary in their daily lives. You are being asked to participate in this study because you have attended a cardiac rehabilitation program for at least a month. Up to 20 people will participate in this study at UHN.

Study Visits and Procedures:

You will be asked to take part in a one-time, 30 minute interview with a member of our study team. This interview will be held at a private meeting room on the premises of the Toronto Rehab Cardiac Rehab program after your scheduled cardiac rehabilitation class. After this interview, you will have completed your participation in this study. The audio responses from your interview will be recorded to ensure that your
responses are collected and analyzed accurately. You may skip any questions that make you uncomfortable or that you do not wish to answer. Participation in this study will not alter the standard of care you receive at your cardiac rehabilitation program, of health assessments, exercise (aerobic and resistance training), education and counselling.

**Risks:**

There are no risks to your health if you participate in this study. There is a possibility that you may feel discomfort during the course of the interview, in which case you can choose to not answer any question or withdraw from the study. Your responses will be kept anonymous beyond the members of the study team.

**Benefits:**

You may not receive direct benefit from being in this study. Information learned from this study may help the development of strategies to reduce the sedentary behaviours of future cardiac rehabilitation patients.

**Alternatives to Being in the Study:**

You can always choose not to participate in this study. If you choose not to participate, you are still expected to attend your scheduled cardiac rehabilitation classes.

**Confidentiality:**

**Personal Health Information**

If you agree to join this study, the study doctor and his study team will look at your personal health information and collect only the information they need for the study. Personal health information is any information that could identify you and includes your:

- name,
- year of birth,
- prior and existing medical conditions
- medical tests or procedures.

This information will be used to identify possible relationships between your background/health characteristics and the responses you provide in your interview.

Your interview responses will be audiotaped. To ensure that your responses remain confidential, your unique participation identification number will be used to identify your responses, and the audio file will be stored in a secure file server on the UHN computer network. Only the study team will have access to your recorded audio responses and these files will be erased after we have analyzed the data.

All information collected during this study, including your personal health information, will be kept confidential and will not be shared with anyone outside the study unless required by law. You will not be named in any reports, publications, or presentations that may come from this study.

**Voluntary Participation:**

Your participation in this study is voluntary. You may decide not to be in this study, or to be in the study now and then change your mind later. You may leave the study at any time without affecting your care/employment status/academic standing.

**Withdrawal from the Study:**

You may withdraw from the study at any time without any impact on your current or future care at this institution. If you withdraw your consent, the study team will no longer collect your personal health information for research purposes. In the event that you withdraw from the study prematurely after providing consent, we will no longer store or use any of your information.
**Costs and Reimbursement:**

You will not be reimbursed for participating in this study. Your study visit will occur after your participation in one of your scheduled cardiac rehabilitation program visits.

**Rights as a Participant:**

By signing this form you do not give up any of your legal rights against the investigators, sponsor or involved institutions for compensation, nor does this form relieve the investigators institutions of their legal and professional responsibilities.

**Conflict of Interest:** The study researchers have an interest in completing this study. Their interests should not influence your decision to participate in this study.

**Publication of results:** We may publish our findings or make public presentations based on the data collected. We will make sure that your personal information cannot be identified. You are always welcome to contact a member of the study team for a summary of the research results.

**Questions about the Study:**

If you have any questions, concerns or would like to speak to the study team for any reason, please call Dr. David Alter at 416-597-3422 ext. 5267

If you have any questions about your rights as a research participant or have concerns about this study, you can contact the following:

- The Chair of the University Health Network Research Ethics Board (UHN REB) or the Research Ethics office number at 416-581-7849. The REB is a group of people who oversee the ethical conduct of research studies. The UHN REB is not part of the study team. Everything that you discuss will be kept confidential.

You will be given a signed copy of this consent form.

**Consent:**

This study has been explained to me and any questions I had have been answered.

I know that I may leave the study at any time. I agree to the use of my information as described in this form. I agree to take part in this study.

---------------------------------------  ---------------------------------------  ---------------------------------------
Print Study Participant’s Name            Signature                          Date

My signature means that I have explained the study to the participant named above. I have answered all questions.
E. Assessment Tools
Chapter 3, Part 1 (Sedentary Behaviour Questionnaire)

Participant ID: ____________

*Sedentary Behaviour Questionnaire – Complete once for weekday and once for weekend*

<table>
<thead>
<tr>
<th>Activity</th>
<th>None</th>
<th>≤15 min</th>
<th>30 min</th>
<th>1 hour</th>
<th>2 hours</th>
<th>3 hours</th>
<th>4 hours</th>
<th>5 hours</th>
<th>6 hours</th>
<th>If &gt;6 hours, how many?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Watching television (including videos on VCR/DVD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Playing computer or video games</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>3. Sitting listening to music on the radio, tapes, or CDs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Sitting and talking on the phone</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Doing paperwork or computer work (office work, emails, paying bills, etc.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Sitting reading a book or magazine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Playing a musical instrument</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>8. Sitting and driving in a car, bus, or train</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Please complete the following questionnaire and bring it to your scheduled assessment.

1- SYMPTOMS

a) Do you currently get chest pain/ tightness/ pressure/ burning, shortness of breath or dizziness?

   NO _____ (If NO – proceed to question #2)  

   YES _____ (If YES - please describe the symptoms

------------------------------------------------------------------------------------------------------------------------

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have you had these symptoms in the past?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are the symptoms similar to your previous event?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have you been prescribed nitroglycerine?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you use nitroglycerine to relieve your symptoms?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How long do your symptoms last?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are your doctors aware of these current symptoms?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I get these symptoms:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>At rest (day or night)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climbing stairs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After eating a large meal</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
When I am under stress or upset
With ordinary day to day activities
When I really overdo it

If your symptoms are relieved by rest, how long does it take?
□ less than 5 minutes □ 5-10 minutes □ > 10 min

If you have taken nitroglycerine, how long does it take to relieve the symptoms?
□ less than 5 minutes □ 5-10 minutes □ > 10 min

Please mark an X on the location that you get your chest pain/discomfort?

Front  Back

b) Are you aware of any irregularity in your heart beat? (palpitations, extra beats, skips)

NO _____ YES _____ (If YES, please describe ______________________________________)

2- MEDICAL CONDITIONS

At any time have you been told that you may have any of the following?

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Blood Pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroke/ TIA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asthma/ Emphysema/ Bronchitis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fibromyalgia/ Chronic fatigue</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epilepsy/ Seizures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>Answer Options</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------------</td>
<td>----------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thyroid problems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depression/ Anxiety</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Hernia                                            | Type of Hernia _______  
If yes, was it repaired? ☐ YES ☐ NO |
| Eye Condition                                     | Type of Condition _______  
If yes, are you being treated? ☐ YES ☐ NO |
| High cholesterol                                  |                      |
| Any other serious illness/disease (i.e. Cancer, kidney, liver, infectious) |                      |

**DIABETES**

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you have Diabetes</td>
<td>YES NO (If NO proceed to question #3)</td>
</tr>
<tr>
<td>Do you get low blood sugar levels?</td>
<td></td>
</tr>
<tr>
<td>Do you inject insulin?</td>
<td></td>
</tr>
<tr>
<td>Do you have an Endocrinologist?</td>
<td></td>
</tr>
</tbody>
</table>

If you have diabetes, do you have any of the following complications related to your diabetes?

<table>
<thead>
<tr>
<th>Complication</th>
<th>Answer Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eyes (retinopathy, glaucoma)</td>
<td>YES NO Comments</td>
</tr>
<tr>
<td>Kidney problems</td>
<td></td>
</tr>
<tr>
<td>Feet (ulcers)</td>
<td></td>
</tr>
<tr>
<td>Neuropathy (numbness or tingling in hands/feet)</td>
<td></td>
</tr>
</tbody>
</table>
3- PHYSICAL ACTIVITY

Please indicate if you have previously participated in any of the following activities:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time (minutes)</th>
<th>Times per week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking or Jogging (Distance)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistance training (Weight training)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please indicate if you are currently participating in any of the following activities:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time (minutes)</th>
<th>Times per week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking or Jogging (Distance)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistance training (Weight training)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Do you have any muscle, bone or joint problems which may affect your participation in an exercise program? □ YES □ NO

If YES, please describe: ______________________________________________________

4- RISK FACTORS

A) Sleep Apnea

<table>
<thead>
<tr>
<th>Question</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have you had a sleep study?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have you been told you have sleep apnea?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you currently use a CPAP/APAP machine when you sleep?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B) Smoking

<table>
<thead>
<tr>
<th>Question</th>
<th>YES</th>
<th>NO</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have you ever smoked cigarettes, cigars, pipe or</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
marijuana with tobacco?  

Do you smoke now?  
If NO, when did you quit?  

If YES, how many per day?  
If YES, how many years did you smoke?  

C) Alcohol  

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Do you drink alcohol? (liquor, beer, wine)  
If YES, how many drinks per week?  

D) Family History  

Has anyone in your family (mother, father, sister, brother) ever been diagnosed with:  

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
<th>Family Member #1</th>
<th>Age at onset</th>
<th>Family member #2</th>
<th>Age at onset</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Heart disease (e.g. angina, heart attack, heart failure, cardiomyopathy, valves)  
High blood pressure  
Stroke  
Diabetes  

E) Emotional Well Being  

Do you consider any of the following a concern for you?  

<table>
<thead>
<tr>
<th>NO</th>
<th>Rarely</th>
<th>Occasionally</th>
<th>Frequently</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Housing  
Financial  
Work  
Stress
Anger
Sadness
Family
Smoking
Other lifestyle issues

F) Nutrition

<table>
<thead>
<tr>
<th>Question</th>
<th>YES</th>
<th>NO</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are you satisfied with your eating habits?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you have a history of dieting?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you struggle with managing your blood sugar levels?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you struggle with managing your cholesterol?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What gets in the way of you changing your eating habits?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How many fruit and/or vegetable servings do you eat each day not including fruit juice?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Employment

A) Please check the one box below that best describes your current employment status. (If more than one box applies to you, check the box that appears earlier / higher in the list):

- Work full-time, that is 35 or more hours per week
- Work part-time, that is, less than 35 hours per week
- Work for myself (Self-employed)
- Not working, but looking for work
- Student
- Retired
- Not in the paid workforce (homemaker, not looking for work)
- On disability
- Other – please explain: ____________________________________________

B) Does your employment status (from above) match your desired status? (for example, you are currently working full-time and you want to be working full-time, then you would check the ‘yes’ box)
C) If you returned to work since starting Cardiac Rehab, what was the date? ___________
   (dd/mm/yyyy)

D) Please check the box that describes the level of exertion at your work:
   □ Sedentary
   □ Light work
   □ Medium work
   □ Heavy work
   □ Very heavy work
   □ Not applicable – I do not work, and am not going back to work

2. Transportation
   How long did it take you to get to our facility today? _______________ (minutes one way)

3. Ethnicity/ Cultural Background:
   Which option best represents your background (please check one box):
   □ Aboriginal (includes Inuit, Métis peoples of Canada, First Nations – North American Indian)*
   □ Arab (includes Egyptian, Kuwaiti, Libyan)
   □ West Asian (includes Armenian, Egyptian, Iranian, Lebanese, Moroccan, Afghanistan, Assyrian and Iranian)
   □ Black (includes African, Nigerian, Somali) Chinese
   □ Filipino
   □ Japanese
   □ Korean
   □ Latin American (includes Chilean, Costa Rican, Mexican)
   □ South Asian (includes Bangladeshi, Punjabi, Sri Lankan Bangladeshi, Sri Lankan)
   □ South East Asian (i.e. Cambodian, Laotian, Vietnamese, Malaysian)
   □ White/Caucasian
   □ Other ____________________________
### Chapter 4, Part 1 (Staff Semi-Structured Interview Guide)

<table>
<thead>
<tr>
<th><strong>Perceptions</strong></th>
<th>What comes to your mind when you think of sedentary behaviour? [Clarify as “long periods of sitting” if needed]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intervention</strong></td>
<td>What factors do you think influence whether cardiac rehabilitation patients sit/are sedentary during their day? [Prompt: these could be, work, friends/family, environment, home life, health etc.]</td>
</tr>
<tr>
<td></td>
<td>Which of these factors do you think have the greatest influence on patient sedentary behaviour?</td>
</tr>
<tr>
<td></td>
<td>Can you suggest ways in which you can help patients to be less sedentary during their daily routine?</td>
</tr>
<tr>
<td></td>
<td>We are hoping to one day create a program that helps cardiac rehabilitation patients sit less alongside its focus on getting them to be more active. Do you think there is a place for a program like this within cardiac rehabilitation?</td>
</tr>
<tr>
<td></td>
<td>What might help patients maintain this daily routine when they are less sedentary/sit less?</td>
</tr>
<tr>
<td></td>
<td>Can you suggest factors that might make an intervention like this successful, or hinder it?</td>
</tr>
<tr>
<td><strong>End</strong></td>
<td>Thank you for your time. Would you like to add or suggest anything else?</td>
</tr>
</tbody>
</table>
### Chapter 4, Part 1 (Patient Semi-Structured Interview Guide)

<table>
<thead>
<tr>
<th>Section</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preliminary 1</td>
<td>Can you describe an active person? How would you compare yourself to this person?</td>
</tr>
<tr>
<td>Perceptions 2</td>
<td><strong>Have you heard about “sedentary behaviour”?</strong> [Alternative prompt: “sitting” instead of sedentary behaviour]. What have you heard about it?</td>
</tr>
<tr>
<td>Factors &amp; Determinants 3</td>
<td><strong>How important is being sedentary/sitting in context of other health behaviours you are engaged in?</strong> [Prompt: As compared to exercising, eating a healthy diet etc.]</td>
</tr>
<tr>
<td>Factors &amp; Determinants 4</td>
<td>As fully as you can, describe your typical weekday and weekend routine, particularly those moments when you are active and are sedentary/sitting?</td>
</tr>
<tr>
<td>Factors &amp; Determinants 5</td>
<td>Can you think of why you might be sedentary/sitting in your daily routine? [Prompt: these could be: work, while with your friends/family, environment, home life, health etc.]</td>
</tr>
<tr>
<td>Intervention Feasibility 6</td>
<td>We are looking to develop an intervention to help cardiac rehabilitation patients be less sedentary/sit less in their daily lives. What are your thoughts on an intervention aimed to help you to be less sedentary/sit less? What would incentivize you to participate and engage in this intervention?</td>
</tr>
<tr>
<td>End</td>
<td>Thank you for your time.</td>
</tr>
</tbody>
</table>