Cross-Associations between Physical Activity and Sedentary Time on Metabolic Health: A Comparative Assessment Using Self-Reported and Objectively Measured Activity

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ABSTRACT

Physical activity and sedentary time have distinct physiologic and metabolic effects, but little is known about their joint associations. Data from the Canadian Health Measures Survey (n=5950) was used to i) examine the independent and joint associations of physical activity and sedentary time on obesity and metabolic health, and ii) compare these relationships when using subjective or objective measures. Meeting or not meeting physical activity guidelines was cross-classified with being sedentary or non-sedentary, creating four groups. Analogous self-reported physical activity/sedentary time groups were made. Logistic regression analyses revealed although self-reported groups appeared to display a varied relationship with the outcomes analysed relative to objectively measured groups, the odds of several metabolic risk factors were higher in those who were inactive *and* sedentary compared to those who were active *and* non-sedentary. Results also revealed that being active while otherwise sedentary *or* non-sedentary while otherwise inactive were similarly protective.

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Abbreviations

1+ condition	One or more of stroke, myocardial infarction, diabetes or cardiovascular disease
AEE	Activity Energy Expenditure
BMI	Body Mass Index
CCHS	Canadian Community Health Survey
CI	Confidence Interval
CHMS	Canadian Health Measures Survey
CPM	Counts Per Minute
CVD	Cardiovascular Disease
DBP	Diastolic Blood Pressure
Hba1c	Glycated Hemoglobin
HDL	High Density Lipoprotein
IPAQ	International Physical Activity Questionnaire
LIA	Light Intensity Activity
LTPA	Leisure-time Physical Activity
MEC	Mobile Examination Centre
MET	Metabolic Equivalent
MetS	Metabolic Syndrome
MVPA	Moderate-to-Vigorous Physical Activity
NEAT	Non-Exercise Activity Thermogenesis
NPHS	National Population Health Survey
OMPAG	Objectively Measured Physical Activity Group
OR	Odds Ratio
PA	Physical Activity
PAM	Physical Activity Monitor
SBP	Systolic Blood Pressure
ST	Sedentary Time
SRPAG	Self-Reported Physical Activity Group
T2D	Type 2 Diabetes
TG	Triglycerides
WC	Waist Circumference

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INTRODUCTION

The health benefits of physical activity (PA) are well documented. Regular PA is inversely related to numerous cardiovascular and metabolic risk factors, including overweight and obesity; waist circumference (WC) and weight gain; and is associated with a reduced risk of cardiovascular disease (CVD), hypertension and type 2 diabetes (T2D) (Gilmour, 2007; Wagner et al., 2001; Warburton et al., 2010). In Canada, using self-reported PA data, national surveillance has been important in detecting these associations while monitoring PA patterns. However, between 1988 and 2000, an era in which the prevalence of active Canadians grew by more than 50% (Craig et al., 2004), obesity levels nearly doubled in a similar time frame (Shields et al., 2011). Currently, we are seeing a drastic increase in the prevalence of T2D (Lipscombe & Hux, 2007), a likely manifestation of the rise in obesity. The paradox between increasing obesity levels in the face of increased PA may partially be explained by increasing levels of sedentary time (ST). Contrary to PA, ST is positively related to obesity, (Levine et al., 2005), and has been documented to be associated with insulin resistance, T2D and dyslipidemia, *independent* of time spent in PA (Dunstan et al., 2005).

Although PA surveillance has been effective in Canada, the need for objectively measured PA has been proposed due to various limitations of self-reported PA data (Tremblay, 2004). Highlighting the differences between subjective and objectively measured PA, Bryan & Katzmarzyk (2009) found 65% of Canadians were meeting PA guidelines in 2007 by self-report, while Colley et al. (2011) noted only 15% were active when measured using accelerometers. Given the independent effects of PA and ST on obesity and metabolic health and the differences in self-reported and objectively measured PA, it is important to understand the inter-relationship between PA, ST and metabolic risk and compare them under both measurement conditions.

REVIEW OF THE LITERATURE

Body Mass Index

Health Canada and the World Health Organization define overweight as a body mass index (BMI) greater than or equal to 25 kg/m^2 and obesity as a BMI of 30 kg/m^2 or more (Health Canada, 2003; World Health Organization, 2014). Obesity is further classified into 3 classes: Class I (BMI = 30.0 kg/m^2 – 34.9 kg/m^2); Class II (BMI = 35.0 kg/m^2 - 39.9 kg/m^2), and; Class III (BMI $\geq$ 40.0 kg/m^2). Using these definitions, the prevalence of obesity in Canada has risen substantially in recent decades, increasing approximately ten percentage points, to 24% of the population since the late 1980s (Shields et al., 2011). Of the 24% of obese Canadians, 15.1% are class I, 5.8% class II and 3.1% class III (Shields et al., 2011). Data from the 2009-2011 Canadian Health Measures Survey estimates that an additional 40% percent of Canadian males and 29% of Canadian females are overweight (Statistics Canada, 2012).

Abdominal Obesity

Similar to BMI, the prevalence of abdominal obesity has increased in Canadian adults during the same time period. Defined by an elevated WC (≥102 cm for men and ≥88 cm for women) (Health Canada, 2003), the prevalence of abdominal obesity has approximately tripled in Canada between 1981 (M: 10.1%; F: 12.8%) (Janssen et al., 2010) and 2009/2011 (M: 29%; F: 41%) (Statistics Canada, 2012).

Factors that contribute to the development of overweight, obesity, and abdominal obesity are multifactorial and can vary significantly from person to person. Biological, environmental, behavioural and genetic factors all appear to influence the propensity to accumulate fat (Stunkard, 1988); however, at the most fundamental level increasing body mass is attributed to a net positive energy balance which occurs when energy intake exceeds energy expenditure. When sustained for a prolonged period of time, the net result is weight gain.

The high prevalence of both obesity and abdominal obesity pose significant health risks to the Canadian population, as elevated BMI and WC are associated with increased morbidity and mortality (Huxley et al., 2010). A 26 year follow-up of the Framingham Heart study revealed that obesity was associated with CVD, the leading cause of death worldwide (World Health Organization, 2011), independent of age, smoking, cholesterol and blood pressure (Hubert et al., 1983). Both measures of obesity are also highly predictive of other cardiometabolic diseases, including diabetes, hypertension and dyslipidemia (National Institute of Health, 1998).). In addition to being risk factors for various chronic diseases, both obesity and abdominal obesity are associated with all-cause and cause-specific mortality (Staiano et al., 2012). Particularly concerning is the association between obesity and metabolic health, as obesity is the single best predictor of T2D (Daousi et al., 2006).

Metabolic Health

Concurrent to the recent rise in obesity in Canada, there was a predictable increase in the prevalence of T2D. Between 1995 and 2005 the prevalence of T2D has increased by 69% (Lipscombe & Hux, 2007). Characterized by chronic hyperglycemia due to insulin resistance, T2D can lead to various long-term metabolic, micro- and macro- vascular complications, and is a major risk factor for CVD (Grundy, 2012). Currently, approximately 2.4 million Canadians are diabetic (Public Health Agency of Canada, 2011). More disconcerting, however, is the number of people with diabetes is expected to continue to rise, reaching 3.7 million Canadians by 2018/2019 (Public Health Agency of Canada, 2011). Furthermore, projections from the World

Health Organization predict that the number of people with diabetes worldwide will more than double between 2000 to 2030 (Wild et al., 2004), the majority of which are T2D.

One of the early warning signs of the impending increase in T2D stems from population-level surveillance of the metabolic syndrome (MetS). According to the harmonized definition (Alberti et al., 2009), MetS occurs when an individual has a cluster of cardiometabolic risk factors, operationalized as a combination of 3 or more of: abdominal obesity, elevated blood pressure, elevated triglycerides, low high-density lipoprotein (HDL), and elevated blood glucose. The prevalence of MetS in Canada is approximately 22% of adults, while 39% had two or more components and 64% had at least one (Statistics Canada, 2012). Although each individual component is an independent major risk factor for CVD (Kahn et al., 2005), the underlying mechanism behind MetS is not fully understood (Ma & Zhu, 2013). Even though all components are weighted equally in the classification of MetS, insulin resistance is believed to be the principal risk factor behind the cardiometabolic clustering (Reaven, 2006). MetS is associated with approximately a 5-fold increase in developing T2D and a 2-fold increase in developing CVD compared to those without the syndrome (Lorenzo et al., 2007), after adjusting for age, sex, ethnic origin and family history of diabetes.

Physical Activity

Total energy expenditure is the umbrella term accounting for all forms of human energy output. It can be further sub-divided into the resting metabolic rate, the thermic effect of feeding and [physical] activity energy expenditure. These account for ~ 65%, ~10% ~25% of total energy expenditure, respectively (Ravussin et al., 1986). Resting metabolic rate and the thermic effect of feeding are processes of metabolism whose regulation, in the short term, are largely nonmodifiable. Activity energy expenditure, however, comprising a significant portion of total energy expenditure (~25%), is directly modifiable and thus a natural avenue for lifestyle and behaviour modification for energy expenditure.

The relationship between PA and metabolic health has been well documented. Self-reported data from the Canadian Community Health Survey revealed that adults who had sufficient leisure-time physical activity (LTPA) levels were less likely to be overweight or obese compared to those who are physically inactive (Gilmour, 2007). Other research has reported similar results, where regular moderate and high intensity PA was inversely associated with BMI, WC and weight gain over 5 years (Wagner et al., 2001). The association between PA and metabolic health is equally as strong, as regular PA is inversely associated in a dose-response manner with the risk of CVD, hypertension and T2D (Warburton et al., 2010).

Despite the dramatic rise in obesity and T2D, the temporal trends of PA have not paralleled that of weight gain. In fact, self-reported PA data suggests that LTPA levels have *increased* in the past 30 years in Canada (Bruce & Katzmarzyk, 2002) and the United States (Steffen et al., 2006). Canadian data revealed that LTPA levels increased significantly from 1994 to 2005, whereas the prevalence of leisure-time *inactivity* (i.e. not meeting PA guidelines) amongst men and women dropped by 10% and 13% respectively (Juneau & Potvin, 2010). A separate study by Craig et al. (2004) found that compared to 1981, Canadians were 1.6 times as likely to be active during leisure time in 1988. LTPA levels increased further into the next decade, in which adults were 1.2 times as likely to be sufficiently active during LTPA in 2000 as they were in 1995 (Craig et al., 2004). When taken together, these results highlight a growing disconnect between PA patterns and obesity rates over time.

The research examining the temporal trends of caloric intake is inconsistent and it appears to be only modestly related to the rise in obesity (Nielsen et al., 2002). Nationally representative data from the 2004 Canadian Community Health Survey found that the caloric intake for all ages and genders has remained stable or decreased relative to 1972 (Garriguet, 2007). Although the limitations of self-reported data are well known and likely to result in an over-estimation of total PA (Klesges et al., 1990) and the ability to accurately estimate population level dietary trends is limited (Archer et al., 2013), when taken together, the available data suggest that explanations beyond simple changes in LTPA and caloric intake must be considered to adequately understand the causes of the current obesity epidemic.

Sedentary Time

Recently, a new paradigm in the field of PA has emerged as a possible reason for this disconnect: sedentary physiology. Levine et al. (2006), Hamilton et al. (2007) and Tremblay et al. (2010) contend that ST is distinct from physical inactivity and may evoke a unique physiological response. Under this premise, PA is defined as any activity at or above 3 metabolic equivalents (METS), thereby being at least moderate intensity. Light intensity activity (LIA) refers to any time spent walking leisurely (less than 3.0 mph), and includes most activities of daily living, and ranges from 2 to less than 3 METS (Colley et al., 2011), while ST is described as “prolonged sitting time and absence of whole body movement” (Healy et al., 2008), and ranges from 1 to less than 2 METS (Colley et al., 2011). Therefore, one can be both *sedentary* and physically active (e.g. someone who exercises at a moderate intensity for 30 minutes a day but sits for prolonged periods of time throughout the day).

In most epidemiological studies, LTPA is conventionally used to estimate total activity energy expenditure (AEE), as LIA is difficult to measure due to its sporadic and intermittent nature. However, failing to consider LIA when calculating AEE is misleading, as LIA is neither moderately nor vigorously intense, and represents a significant portion of PA energy expenditure. Indeed, in obese and sedentary individuals, it can represent up to 90% of calories burned in AEE, as these individuals are less likely to engage in LTPA (Levine et al., 2008). Even amongst those who meet the minimum “PA Guidelines”, the majority only spend 2-4% of their waking hours in moderate-vigorous physical activity (MVPA) (Craft et al., 2012; Healy et al., 2007). Therefore, Healy et al. (2007) assert that “most physical activity during waking hours can be categorized broadly into two distinct modes: light-intensity physical activity and sedentary time”. Thus, those who spend more time in LIA must spend less time in ST, and vice versa. Even if time spent in LTPA has increased in the past few decades, if LIA levels have decreased and in turn increased ST to a great enough magnitude, this could shift the energy balance (Levine et al., 2006). This may contribute in part to the increasing rates of obesity and the associated complications in the face of increased self-reported LTPA.

Impact of Sedentary Time

Engaging in excessive ST has become commonplace. Work, school, transportation and leisure time today have been subverted by technological advancement and shifted from primarily active endeavours to primarily sedentary. Accelerometer data shows that the average Australian adult today sits for 8.4 hrs/day (Healy et al., 2007) while the average Canadian adult sits for 9.5 hrs/day (Colley et al., 2011). The domain in which the shift towards sedentariness has been most pervasive is the workplace. Since 1960, the average occupational MET level has decreased by almost 10%, while the prevalence of moderate intensity jobs has decreased from 48% to 20% in the U.S (Church et al., 2011). Not only are jobs exceedingly promoting sitting, but employees are spending more time at their sedentary workplace. Canadians today spend an extra 30 minutes/day at work than in 1986 (Turcotte, 2005). Over a 260 day work year, this can add up to three extra 40-hour work weeks per year. Further, Canadians spend an additional 25.4 minutes travelling to work (one-way), of which ~80% use a private vehicle (Statistics Canada, 2011). Taken together, less active jobs, longer work hours and increased commuting can lead to a significant reduction in energy expenditure.

When comparing ST during work hours and leisure time, the effect of the workplace environment is considerable. For example, McCrady and Levine (2009) examined differences in sitting time between work days and weekends in people with sedentary jobs and found that participants sat for an average of 597 minutes/day (~ 10 hr) on work days compared to 484 minutes/day (~8 hr) on weekends. Another study showed "white collar" employees spend just over 4 hours of their time at work sitting, approximately half of a typical work day (Mumerry et al., 2005). People with obesity are a particularly high-risk group for engaging in ST, and have been shown to sit for 2 hours a day *more* than non-obese persons, corresponding to a 352 kcal difference (Levine et al., 2005). Conversely, lean persons tend to spend more time in LIA, walking for up to 3.5 miles/day more than people with obesity (Levine et al., 2008).

Beyond weight gain, engaging in excessive ST appears to be a risk factor for various metabolic abnormalities, independent of MVPA (Healy et al., 2008). Analysis from the Australian Diabetes Obesity and Lifestyle Study show that self-reported television viewing time, a proxy measure for ST, is associated with insulin resistance, diabetes, and dyslipidemia, even in physically active adults (Dunstan et al., 2005). Other studies have demonstrated a dose-response relationship exists between ST and glucose tolerance wherein those in the highest quartile of ST are more likely to have impaired glucose tolerance, elevated blood lipids and a large WC, all of which are risk factors for T2D and MetS (Healy et al., 2007). More recently, Mabry et al. (2012) and Chu and Moy (2013) found that participants who sat the most were 1.48 and 2.8 times more likely to have MetS, respectively, compared to those who sat the least. Furthermore, the association between MetS and ST has also been found using objective accelerometer data (Healy et al., 2008). Elevated WC, triglycerides and clustered metabolic risk score are all positively correlated with time spent in ST in adults over 20, independent of MVPA (Healy et al., 2008).

Physical Activity and Sedentary Time

PA and ST are both independently related to obesity and metabolic risk (Healy et al., 2008; Celis-Morales et al., 2012; Chomistek et al., 2013; Sisson et al., 2009; Maher et al., 2013). However, much of the research surrounding ST has examined the relationship with obesity and metabolic health independent of MVPA, while PA research has historically overlooked the significant impact of ST. In order to understand the influence of both PA and ST on health risk, capturing all aspects of daily activity is critical.

Several studies to date have examined the joint associations of ST and PA by cross classifying the two. Using the Women`s Health Initiative, Chomistek et al. (2013) noted strong associations between PA, sitting time and heart disease in middle-to older aged women. After cross-classifying by self-reported PA and sitting time, women who were physically inactive (≤1.7 MET-h/wk) and spent ≥10 hr/day sitting, reported significantly increased risk of CVD, stroke, and coronary heart disease. They also noted the effect of prolonged sitting was attenuated by being *highly* active (>20 MET-h/wk), however; active women who merely met the lower threshold of the PA guidelines (8.4-20 MET-h/wk) were still at an increased risk of CVD. This is similar to the results of Sisson et al. (2009) wherein the odds of MetS were significantly greater for U.S. women who spent ≥3 hr/day in leisure-time ST, a measure of self-reported overall screen time (non-work related TV and computer). Like Chomistek et al. (2013), the protective effect of MVPA was highlighted, as the risk of MetS was significantly reduced for those met minimum PA guidelines. Conversely, men who spent ≥3 hr/day in leisure-time ST were at an increased risk of MetS independent of PA guidelines (Sisson et al., 2009). Interestingly, there appears to be a stronger relationship with leisure-time ST, or TV/screen time, than with total ST (which includes reading, eating, etc.). In a similar vein as Sisson et al. (2009), Maher et al. (2013) noted strong associations between obesity, objectively measured MVPA, and self-reported TV time. In their analysis of the 2003-2006 NHANES survey, MVPA was consistently the most strongly related measure to obesity. On the other hand, high levels of MVPA appeared to undermine any effects of total ST on obesity, while self-reported TV time (≥3 hr/day) was associated with higher odds of obesity for men in the lowest tertile of activity, and women in the lowest and middle tertiles. Total ST alone was not significantly related to obesity status (Maher et al., 2013).

Another way researchers compensate for the shortcomings of quantifying MVPA and/or ST is to measure steps/day. While pedometers cannot distinguish between PA and ST, intensity, frequency or duration, they do provide a robust objective measure of total daily activity. In addition, having a high daily step count is positively associated with spending time in MVPA. A 2003 study noted that of people who took ≥10 000 steps/day, 51% of them reached 30 minutes of MVPA in bouts ≥10 minutes compared to only 17% of those who didn't reach the step target (Le Masurier et al., 2003). When bouts of ≥5 minutes were counted towards meeting the guidelines,77% of the ≥10 000 step group reached 30 minutes of MVPA/day versus only 29% of the <10 000 group. Furthermore, a review by Tudor-Locke et al. (2011) suggested that 10 000 steps/day is a reasonable target to be categorized as “active”. Moreover, steps/day can be useful for categorizing people into PA groups, as steps/day strongly predicted BMI across PA/sedentary groups (Tudor-Locke et al., 2008). Collectively, these studies point to the utility of measuring steps/day as a supplementary way to quantify total PA.

Physical Activity Surveillance (Objective vs. Subjective)

PA surveillance in Canada has been taking place since the 1970s and is a key aspect of monitoring the health of the Canadian public and informing policy. The major recurring surveys monitoring PA levels in Canada, the Physical Activity Monitor (PAM) series and the Canadian Community Health Survey (CCHS) – formerly the National population Health Survey (NPHS) – rely on self-reported PA data, obtained from a questionnaire based on the Minnesota Leisure Time Physical Activity Questionnaire (Katzmarzyk & Tremblay, 2007). The surveys collect information on the types of activities performed, and the frequency and duration of each activity over a given time period (e.g. in past 12 months). A corresponding MET level is assigned to each activity, and average daily leisure-time activity energy expenditure is calculated in kcal/kg/day. Conventionally, the cut-point of ≥ 3kcal/kg/day has been used as the target for being “active”, and is roughly equivalent to walking at least 1 hour each day. Self-reported ST is collected by proxy measures, estimating time spent in leisure-time screen-based activities (Katzmarzyk & Tremblay, 2007). This method of surveillance is cost-effective and has provided public health officials with broad population-level assessments of patterns of PA over several decades. Not surprisingly, monitoring PA and ST by way of self-report has a number of limitations related to reliability, validity and recall biases (Tremblay, 2004). The use of self-reported data has been subject to such scrutiny, as these studies are used for evidence-based decision making, including the formation of the PA guidelines. Recently, however, accelerometer technology has contributed to the transformation of PA surveillance in Canada.

In 2009, the inaugural Canadian Health Measures Survey (CHMS) introduced the use of accelerometers, making it the first nationally representative survey to objectively measure PA. For 7 days, the PA levels of participants were monitored and broken down into minutes/day spent in sedentary, light, and moderate-vigorous intensity activities. Although accelerometers are subject to their own biases (i.e. non-response and healthy responder bias) (Colley et al., 2011), prevalence estimates based on objective measures now point to a much greater problem of inactivity than was initially suspected. In 2007, an estimated 65% of Canadian adults met PA guidelines (30-60 min of MVPA 4days/wk) by self-report in the CCHS (Bryan & Katzmarzyk, 2009), whereas the 2009 CHMS revealed that only 15% of Canadians were sufficiently active (Colley et al., 2011). To examine the impact the inconsistencies between subjective and objectively measured PA have on the relationship between PA and metabolic health, Celis-Morales et al. (2012) compared the relationship between International Physical Activity Questionnaire (IPAQ) measured PA/ST and metabolic health versus accelerometer measured PA/ST and metabolic health. As expected, they found IPAQ measured PA was over-reported vs. accelerometer derived PA, and IPAQ measured ST was under-reported vs. accelerometers. Notably, however, they found that IPAQ-reported sitting time and accelerometer derived ST were both associated with all measured metabolic outcomes, although the relationship was weaker for some self-reported variables (Celis-Morales et al., 2012). A second study that compared objective and subjective PA with metabolic health noted a similar relationship, observing that accelerometer-derived MVPA was more strongly associated with anthropometric and physiological biomarkers; however, self-report still captured the associations (Atenzia et al., 2011).

Accordingly, direct observation is necessary to expand our understanding of the relationships between ST, PA and metabolic health (Tremblay, 2004). However, despite its limitations, self-reported data still has strong and independent associations with metabolic health relative to objectively measured PA (Celis-Morales et al., 2012; Atienza et al., 2011). Although further research is necessary to discern the mechanisms behind the differences between objectively measured PA and self-reported PA, both measurement methods are proven to be informative vehicles for PA surveillance.

RATIONALE

Universal PA guidelines, adopted in Canada as *The Canadian Physical Activity Guidelines*, were released as a framework to promote PA, encouraging a healthy lifestyle and espousing the cardiovascular health benefits of regular PA. The guidelines recommend a minimum of 150 minutes of moderate-to-vigorous-intensity aerobic exercise a week in bouts of ten minutes or more (World Health Organization, 2010). A systematic review by Warburton, D. et al. (2010) provides strong evidence of the effectiveness of the guidelines for reaping health benefits - reducing the risk of various chronic diseases and premature mortality in adults. However, these recommendations are designed for LTPA and do not include any framework for how much time should be spent engaging in sedentary behaviors. Duvivier et al. (2013) recently observed that the acute effect of 13 hours of sitting activity on insulin and other metabolic markers was not offset by 1 hour of vigorous exercise, highlighting the need for a more thorough exploration of the inter-relationship between PA and ST.

Numerous studies have noted the independent effects of PA and ST on various aspects of health (Healy et al., 2008; Celis-Morales et al., 2012; Chomistek et al., 2013; Sisson et al., 2009; Maher et al., 2013) and several have examined the differences in objectively measured and self-reported PA (Atenzia et al., 2011; Celis-Morales et al., 2012); however, no studies have looked at the joint associations of PA and ST and compared the relationships between objective and subjective measures.

OBJECTIVES

1) To examine the independent and joint association between PA and ST (active/sedentary, active/non-sedentary, inactive/sedentary, and inactive/non-sedentary) phenotypes on obesity and metabolic health.

2) To compare the relationship between PA and ST and health risk when using subjective or objective measures.

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ABSTRACT

***Background*:** Physical activity and sedentary time have distinct physiologic and metabolic effects, but little is known about their joint associations.

***Methods*:** Data from 2 cycles (2007-2009; 2009-2011) of the Canadian Health Measures Survey (n=5950) was used to i) examine the joint association between the active/non-sedentary (referent group), active/sedentary, inactive/non-sedentary, and inactive/ sedentary phenotypes on obesity and metabolic health, and ii) compare these relationships when using subjective or objective measures. The "active" cut-point for the objectively measured physical activity groups (OMPAG) was ≥150 min/wk MVPA in bouts of 10 minutes or more and ≥480 min/day of sedentary time for "sedentary". Analogous self-reported physical activity groups (SRPAG) were made. Weighted associations between groups and metabolic syndrome (MetS), individual MetS components, 1+ condition (1 or more of diabetes, myocardial infarction, stroke, cardiovascular disease) and obesity (BMI≥30kg/m^2) were estimated by logistic regression.

***Results*:** Overall, the prevalence of MetS and 1+condition were systematically higher across SRPAG vs OMPAG. After adjustments for age, sex, ethnicity, income, education, accelerometer wear time and BMI, the odds (OR , 95% CI) of 1+ condition (OR=3.05, 1.47-6.34) and abdominal obesity (OR=2.75, 1.16-6.55) were higher in the inactive/sedentary group vs the referent group (OR=1.00) within OMPAG. Within SRPAG, higher odds were observed for the inactive/sedentary group for MetS, obesity, abdominal obesity and elevated triglycerides relative to the referent group. Although inactive/sedentary groups had the highest odds of 1+ condition, MetS, obesity, elevated triglycerides and abdominal obesity by either OMPAG or SRPAG, the finding of similar protective effects of active/sedentary and inactive/non-sedentary is novel.

***Conclusion*:** Meeting physical activity guidelines and <480 min/day of sedentary time appear to

be protective against obesity and metabolic risk. Given that SRPAG appears to provide a stronger association with metabolic health, the value of complementary objective and subjective assessment of physical activity and sedentary time warrants further scrutiny.

Key words: *exercise physiology, public health, surveillance, self-report, measurement*

INTRODUCTION

Self-reported Canadian physical activity (PA) surveillance data suggests that levels of moderate-to-vigorous physical activity (MVPA) have increased since the 1980s (Bruce & Katzmarzyk, 2002; Craig et al., 2004; Juneau & Potvin, 2010), while caloric intake has remained relatively stable (Garriguet, 2007). Paradoxically, the prevalence of obesity and type 2 diabetes has greatly increased during the same time frame (Lipscombe & Hux, 2007; Shields, M. et al. 2011). One contributor to this disconnect may be changes in sedentary time (ST). Although there is no systematic surveillance data on temporal changes in ST among Canadians, evidence suggests that occupational sitting time (Juneau & Potvin, 2010) and overall screen time have increased in recent decades (Shields & Tremblay, 2008).

Although physical *in*activity and ST are associated with adverse effects on similar metabolic risk factors (Dunstan et al., 2005; Healy et al., 2008), the mechanisms of action may not be the same (Hamilton, 2007). Current universally adopted PA Guidelines recommend ≥150 minutes/wk of MVPA in bouts of 10 minutes or more (World Health Organization, 2010) in order to reduce risk of premature mortality and various chronic diseases (Warburton, 2010). However, even amongst those who meet these recommendations, the majority of people spend only 2-4% of their waking hours in MVPA (Craft et al., 2012; Healy et al., 2007). Because current guidelines offer no framework for the other ~96% of time, conventional PA surveillance has primarily focused on MVPA and leisure-time physical activity (LTPA) and largely overlooked a significant portion of daily activity energy expenditure. Duvivier et al. (2013) recently observed that the acute effect of 13 hours of sitting activity on insulin and other metabolic markers was not offset by 1 hour of vigorous exercise, highlighting the need for a more thorough exploration of the inter-relationship between ST and MVPA.

Complicating the relationships between ST, PA and metabolic health is the use of subjective data. In 2007, an estimated 65% of Canadian adults met the PA guidelines (30-60 min of MVPA 4days/wk) by self-report (Bryan & Katzmarzyk, 2009). In 2009, the inaugural Canadian Health Measures Survey (CHMS) – the first nationally representative study to use accelerometers – revealed that only 15% of Canadians were sufficiently active. Given that self-reported information is subject to both healthy responder and recall bias (Tremblay, 2004), direct observation is vital to improve our understanding of the relationships between ST, PA and metabolic health (Tremblay, 2004). Nevertheless, the overwhelming evidence of an epidemiological association between PA and health is based on self-report, and likely to persist in national surveillance due to its relative ease of collection and cost-effectiveness (Katzmarzyk & Tremblay, 2007).

The objective of this study was to therefore quantify the inter-relationships between PA and ST on obesity and metabolic health, and to compare these relationships when using self-report or objective measures.

METHODS

Participants

Initiated in 2007, the CHMS is a cross-sectional study conducted biannually, designed to collect key surveillance information concerning the health of Canadians (Tremblay et al., 2007). The survey collects information through household interviews, direct physical measures, PA monitors, blood and urine samples, and environmental measures. Approximately 96% of Canadians are represented. Individuals were selected using an advanced sampling strategy in order to produce a nationally representative sample (**Appendix A**). Excluded are full-time members of the Canadian Forces; residents of aboriginal settlements or reserves; select remote regions, and; institutionalized residents (Statistics Canada, 2010a).

Two cycles of the CHMS were used in the present study; Cycle 1 (2007-2009) and Cycle 2 (2009-2011) were combined with an initial sample size of n=11 387. After exclusions were made for age (≥18 y, n=3 788) and accelerometer wear time (≥4 valid days, n=1 649) the final analytic sample remaining was n=5 950.

Objectively Measured PA/ST

Data from Actical accelerometers were used to objectively assess PA and ST. Minimum adherence for inclusion in the study was 4 valid days of wear time, wherein 10 hours of wear time was required for a valid day (Colley et al., 2011). Wear time was calculated by subtracting non-wear time from 24 hours. Non-wear time was characterized as at least 60 consecutive minutes of zero accelerometer counts with allowance for up to 2 consecutive minutes of counts between 0 and 100 (Colley et al., 2011).

In order to capture the PA intensity, Actical monitors measure acceleration in all directions in 1 minute epochs by summing total counts per minute (CPM). Each intensity level corresponds to a CPM cut-point (**Appendix B**), and the time spent in each intensity was summed and converted into total minutes per day (Colley et al., 2011). PA guideline adherence was defined as accumulating 150 minutes or more of MVPA in bouts of 10 minutes or more in 7 days (World Health Organization, 2010), and denoted as “active”. Not meeting PA guidelines was denoted as “inactive” (**Table 1**). An allowance of 2 minutes of not meeting the cut-point throughout the10 consecutive minutes of MVPA was permitted (Colley et al., 2011). For participants with only 4-6 valid days of accelerometer wear, their average daily time in MVPA was calculated and multiplied by 7. ST was dichotomized into ≥480min/day (“sedentary”) and

<480min/day (“non-sedentary”) (**Table 1**). Objectively measured PA groups (OMPAG) were created by cross classifying PA and ST. The four groups were subsequently denoted 1) active/non-sedentary; 2) active/sedentary; 3) inactive/non-sedentary, and; 4) inactive/sedentary, with the active/non-sedentary group serving as the referent group.

Self-reported PA/ST

Self-reported LTPA and ST data were collected during the household interview. Daily energy expenditure was calculated using the frequency, intensity and duration of leisure-time physical activities engaged in over the past 12 months and their corresponding intensities expressed as MET (metabolic equivalent) values (Statistics Canada, 2010a; Statistics Canada, 2012a)(**Appendix C**). Daily energy expenditures for all activities where then summed for a total (leisure-time) daily energy expenditure expressed in kcal/kg/day. Self-reported LTPA was dichotomized into “active” (≥3kcal/kg/day) and “inactive” (<3kcal/kg/day) groups (**Table 1**). Self-reported leisure-time ST was calculated by summing time spent (hours) in a typical week in the past 3 months engaged in: computer, computer games and internet, video games, television or videos, and reading (Statistics Canada, 2010b; Statistics Canada, 2012b). ST was subsequently dichotomized as “sedentary” (≥20hrs/wk) or “non-sedentary” (<20hrs/wk) (**Table 1**). Analogous to OMPAG, four self-reported LTPA groups (SRPAG) were created: 1) active/non-sedentary; 2) active/sedentary; 3) inactive/non-sedentary, and; 4) inactive/sedentary, with the active/non-sedentary group serving as the referent group.

Outcome Variables

Participants were classified as having diabetes if they self-reported a diagnosis of diabetes or had elevated blood glucose (≥7.1 mmol/L) or HbA1c levels (≥ 6.5%) (Stamatakis et al., 2012). Cardiovascular disease (CVD), heart attack, and stroke were self-reported. In order to have sufficient power for PA-by-ST comparisons, diabetes, CVD, heart attack and stroke were collapsed into a single variable ("1+ condition"). Obesity was defined by measured height and weight as a body mass index (BMI) ≥30kg/m².

Metabolic Syndrome (MetS) was classified according to the harmonized definition (Alberti et al., 2009) as having three or more of: elevated blood pressure (≥130/85 mmHg) or hypertensive medication use; abdominal obesity (waist circumference (WC) ≥ 102cm (men) or 88 cm (women)); elevated triglycerides (TG) (≥1.69mmol/L); low HDL (<1.04 mmol/L (men) or 1.29 mmol/L (women)) or cholesterol medication, or; elevated blood glucose (5.6 mmol/L) or diabetes medications.

Covariates

Age, sex, ethnicity, education, income adequacy (total household income divided by number of residents), accelerometer wear time, and BMI were all included as covariates in the final model. Aerobic fitness was determined using the Modified Canadian Aerobic Fitness Test (Weller et al., 1993) step test, an indirect submaximal fitness test used to determine aerobic capacity (Statistics Canada, 2010b; Statistics Canada, 2012b). A composite musculoskeletal fitness score was derived from tests of grip strength, sit and reach, and partial curl ups (Statistics Canada, 2010b; Statistics Canada, 2012b). Both aerobic fitness and musculoskeletal fitness were scored on a 5 point scale (needs improvement--excellent) and were dichotomized as "high" (good, very good, excellent) and "low" (needs improvement, fair).

Statistical Analysis

Baseline characteristics of the sample were calculated using x^2 and analysis of variance across OMPAG. Logistic regression was then used to estimate the odds ratios (OR, 95% confidence interval (CI)) of chronic disease and MetS across SRPAG and OMPAG. Models were adjusted for age, sex, ethnicity, income adequacy, wear time and BMI. Smoking status and alcohol consumption were initially included in the model but were not statistically significant and subsequently removed. All analyses were weighted to be representative of the Canadian population using survey procedures in SAS Version 9.3 and 9.4 (SAS Institute Inc., Cary, NC., USA). The bootstrap technique (Statistics Canada, 2013) was used to calculate 95% CIs and standard errors. Analyses with cell counts under 10 were supressed and statistical significance was set at $\alpha < 0.05$ for all analyses.

RESULTS

Characteristics of the sample are described in **Table 2**. Comparing across OMPAG, the active/non-sedentary group was the youngest (40.3 y) and primarily male (59.6%) while the inactive/sedentary group was the oldest (46.5 y) and primarily female (54.4%). The mean WC and BMI were lower in the active groups (non-sedentary, WC: 86.1 cm; BMI: 25.4 kg/m^2|| sedentary, WC: 86.3 cm; BMI: 25.5 kg/m^2) compared to the inactive groups (non-sedentary, WC: 91.8 cm; BMI: 27.4 kg/m^2 || sedentary, WC: 91.6 cm; BMI: 27.2 kg/m^2). There were significant and diverse differences for income, SBP, DBP, Glucose, HDL, TG and Hba1c across all groups.

The mean time spent in MVPA (**Table 3**) decreased systematically across OMPAG. Active groups accumulated 77.0 min/day (non-sedentary) and 53.2 min/day (sedentary) while inactive groups accumulated 26.3 min/day (non-sedentary) and 16.4 min/day (sedentary). Across SRPA, MVPA ranged from 18.3 min/day to 33.0 min/day. Daily ST ranged from 425.2 min/day to 601.9 min/day across OMPAG and from 570.2 min/day to 591.7 min/day across SRPA.

Prevalence of chronic disease and MetS components are shown in **Figure 1**. Chronic diseases differed significantly within OMPAG and SRPAG, with the inactive/sedentary groups having the greatest prevalence of 1+ condition (OMPAG: 13.4%; SRPAG: 15.8%), MetS (OMPAG: 17.8%; SRPAG: 22.1%) and obesity (OMPAG: 26.7%; SRPAG: 30.7%). Within OMPAG, abdominal obesity, elevated blood glucose, TG and HDL were significantly different across all groups ($p<0.05$). When compared to the referent group , the prevalence of abdominal obesity was significantly greater in the inactive/sedentary group (36.6% vs 15.2%) while the prevalence of elevated blood pressure was significantly greater in both sedentary groups (active:23.1% vs 14.6%; inactive: 27.8% vs 14.6%). Within SRPAG, all components of MetS varied across groups, and both sedentary groups had a significantly higher prevalence of abdominal obesity (active: 30.0% vs 20.6%; inactive: 43.2% vs 20.6%) and elevated blood pressure (active: 28.4% vs 16.9%; inactive: 32.5% vs 16.9%).

Aerobic fitness levels (**Figure 2**) were similar between OMPAG and SRPAG. Within OMPAG, 75.4% of the referent group had a high aerobic fitness while 70.2% of the referent group within SRPAG did. The prevalence of high aerobic fitness was lowest in the inactive/sedentary groups within OMPAG (53.0%) and SRPAG (42.7%). High aerobic fitness levels were similar across active/sedentary and inactive/non-sedentary groups within OMPAG and SRPAG (**Figure 2**.) No significant differences were seen in the prevalence of high musculoskeletal fitness across OMPAG. Conversely, the prevalence of high musculoskeletal fitness within SRPAG was significantly lower in the inactive/sedentary group (51.2%) relative to the referent group (70.8%).

The age and sex adjusted odds ratio (95% CI) for chronic disease and MetS revealed various significant relationships within OMPAG and SRPAG. Upon including ethnicity, education, income, accelerometer wear time and BMI into the models, however, only two relationships retained significance within OMPAG (**Table 4.**). The odds of 1+ condition and abdominal obesity held at 3.05 (CI: 1.47-6.34) and 2.75 (CI: 1.16-6.55) for the inactive/non-sedentary groups, respectively, relative to the referent group. Within SRPAG, significance remained for the inactive/sedentary group for MetS, obesity, abdominal obesity and elevated TG's compared to the referent group. The odds of MetS held for the inactive/non-sedentary group at 2.20 (CI: 1.13-4.29) and the odds of abdominal obesity held at 1.59 (CI: 1.09-2.31) for the active/sedentary group.

DISCUSSION

The results of the present study demonstrate that, when measured objectively, not meeting PA guidelines in combination with being sedentary (≥480min/day) is associated with a significantly increased risk of being abdominally obese (OR=2.75, CI: 1.16, 6.55) and having 1+condition (OR=3.05, CI: 1.47, 6.34). However, when PA and ST were measured using self-report, the groups displayed more robust and varied associations with metabolic health compared to OMPAG.

Objectively Measured Physical/Sedentary Activity and Metabolic Health

Numerous studies have noted the independent effects of ST and MVPA on metabolic health and CVD (Healy et al., 2008; Celis-Morales et al., 2012; Chomistek et al., 2013; Sisson et al., 2009; Maher et al., 2013). Similar to our study, Healy et al. (2008) noted strong associations between time spent in sedentary activities and MVPA with abdominal obesity, while Chomistek et al. (2013) noted the joint effect of low PA with prolonged sitting increased the risk of CVD relative to highly active and non-sedentary women.

Comparable to a previous self-report study examining steps/day and BMI by cross classifying sufficient/insufficiently active and low/high occupational sitting time into 4 groups (Tudor-Locke et al., 2009) , the active/sedentary and inactive/non-sedentary phenotypes displayed similar BMIs and steps/day. Likewise, in the present study the active/sedentary and inactive/non-sedentary groups displayed similar metabolic risk profiles and neither group had significantly greater odds of any of the observed outcomes relative to the referent group. The finding that the effect of prolonged sitting (≥ 480 min/day) on metabolic risk is attenuated by meeting the PA guidelines is consistent with previous research (Sisson et al., 2009; Maher et al., 2013); however, the finding that the excess risk incurred by being inactive is *offset* by low sedentary time for all outcomes is, to the authors' knowledge, novel.

Although only 2 groups (active/non-sedentary; active/sedentary) in our study actually achieved the recommended level of PA, it is notable that 3 groups (active/non-sedentary; active/sedentary; and inactive/non-sedentary) all averaged ≥10 000 steps/day. The PA Guidelines make no recommendation for steps/day, however, 10 000 steps/day has been proposed as a reasonable target to be categorized as active (Tudor-Locke et al., 2011). In line with this, the inactive/sedentary group in our study had a significantly lower prevalence of "high" aerobic fitness, while the active/sedentary group and the inactive/non-sedentary groups did not differ significantly from the referent group. A four week intervention study found that women who reached 10 000 steps/day were more likely to spend more time in MVPA and meet PA guidelines (Le Masurier et al., 2003). Consistent with these findings, the inactive/non-sedentary group, although insufficiently active, spent more time in MVPA than the inactive/sedentary group.

Self-Reported vs Objective PA

Objectively measured PA and ST was associated with abdominal obesity and 1+ condition, with only the inactive/sedentary group demonstrating elevated risk. However, associations were observed for several distinct outcomes in addition to abdominal obesity, namely MetS, obesity, and elevated TG, when measured by self-report. Similar to OMPAG, SRPAG yielded higher odds of obesity and metabolic risk predominantly in the inactive/sedentary group. In addition, MetS and abdominal obesity displayed elevated odds in the active/sedentary (abdominal obesity) or inactive/non-sedentary (MetS) groups within SRPAG. These findings are in contrast to two previous studies which found stronger associations between objectively assessed PA and metabolic health as compared to self-report (Celis-Morales et al., 2012; Atienza et al., 2011). The extent to which differences in study questionnaires and demographics could have contributed to this divergent finding is unclear. However, similar to our study, Sisson et al. (2009) noted that men and women who spent ≥3hr/day in self-reported leisure-time ST and were physically inactive were more likely to have MetS and, in women, meeting PA guidelines attenuated the relationship. Active men, however, were at similar risk to inactive men when spending ≥3hr/day in ST.

Atienza et al. (2011) proposed that muscular strength could account for the differences in metabolic risk between objective and self-reported PA due to its inverse association with metabolic risk (Jurca et al., 2005). This may partially explain the differences in our sample as musculoskeletal fitness varied across SRPAG, but not OMPAG. Here, the inactive/sedentary group had a significantly lower prevalence of “high” musculoskeletal fitness relative to the referent group. A further explanation is that because the sedentary cut-point of 100 CPM does not distinguish between different sedentary activities such as standing and sitting, important differences in total energy expenditure and blood glucose levels could be masked within our objectively measured sedentary groups (Buckley et al., 2013).

Limitations

There are several limitations that warrant discussion. First, because the study is cross-sectional, causality cannot be inferred. Second, we cannot exclude the possibility of a healthy responder effect in both the self-reported PA and those participants completing the accelerometer portion of the survey. Although a missing sample analysis revealed minimal differences between the full sample and those with valid accerlerometry (**Appendix D**), accelerometers cannot capture activities in water, non-step based activities, or upper body activities. Self-reported PA is also subject to recall bias and influence from social desirability (Tremblay, 2004), potentially biasing towards the null. Furthermore, self-reported ST encompassed leisure-time ST only and did not include occupational ST. Lastly, dietary intake was not accounted for, and may differ between PA-sedentary groups.

Implications

The main findings of this study were that inactive/sedentary groups had a significantly greater risk of several metabolic outcomes; however, these associations varied according to whether PA and ST was measured objectively or subjectively. Given that self-reported activity appears to provide a stronger association with metabolic health, the value of complementary objective and subjective assessment of PA and ST warrants consideration, and have been shown to identify unique aspects of health (Atienza et al. 2011). Additionally, similar protective effects of active/sedentary and inactive/non-sedentary were seen regardless of measurement method. Indeed, achieving 10 000 steps/day is inversely associated with metabolic risk and positively associated with aerobic fitness, and can be accrued without meeting MVPA guidelines. This finding suggests that for those who don’t meet the PA guidelines, decreasing ST and replacing it with light intensity PA could be an effective intervention target, in agreement with past accelerometer based research (Healy et al., 2008)

FIGURE LEGEND

Figure 1. Prevalence of chronic disease and metabolic syndrome components by objectively measured physical activity groups (OMPAG) and self-reported physical activity groups (SRPAG)

Figure 2A. Prevalence of "high" aerobic fitness by objectively measured physical activity group (OMPAG) and self-reported physical activity group (SRPAG)

Figure 2b. Prevalence of "high" musculoskeletal fitness by objectively measured physical activity group (OMPAG) and self-reported physical activity group (SRPAG)

Table 1. Active/Inactive and Sedentary/Non-sedentary cut-points for objectively measured PA and self-reported PA

	Objectively Measured PA	Self-Reported PA
Active	≥150mins/wk of MVPA in bouts of 10mins or more	≥3kcal/kg/day in leisure-time PA
Inactive	<150mins/wk of MVPA in bouts of 10mins or more	<3kcal/kg/day in leisure-time PA
Non-Sedentary	<480mins/day ST	<20hrs/wk in leisure-time ST
Sedentary	≥480mins/day ST	≥20hrs/wk in leisure-time ST

≥150mins/wk of MVPA in bouts of 10mins or more is the universally adopted physical activity guideline for adults ||
≥3kcal/kg/day in leisure-time physical activity is the "active" self-reported physical activity cut-point from the CHMS

Table 2. Weighted characteristics by objectively measured physical activity groups (OMPAG)

	Active		Inactive		
	Non-Sedentary	**Sedentary**	**Non-Sedentary**	**Sedentary**	**p-value**
Age (yrs)	N=102 40.3 (33.7-47.1)	N=623 43.0 (40.9-45.0)	N=450 43.4 (40.8-46.0)	N=4775 46.5 (45.9-47.0)	<0.0001
Sex	N=102	N=623	N=450	N=4775	<0.05
Male	59.6% (37.7-81.6)	51.4% (46.6-56.2)	58.5% (50.3-66.7)	45.6% (44.1-47.2)	
Female	40.4% (18.4-62.3)	48.6% (43.8-53.4)	41.5% (33.3-49.7)	54.3% (52.8-55.9)	
Ethnicity	N=102	N=618	N=449	N=4693	NS
White	82.0% (65.7-98.3)	81.6% (74.7-88.4)	85.7% (79.4-91.9)	86.0% (80.4-91.6)	
Other	18.0% (1.7-34.3)	18.4% (11.6-25.3)	14.3% (8.1-20.6)	14.0% (8.5-19.6)	
Education	N=102	N=623	N=450	N=4733	NS
<HS	13.8% (5.9-25.5)	9.1% (5.8-12.3)	12.5% (9.0-16.0)	11.8% (10.0-13.6)	
HS grad	36.9% (14.9-59.0)	27.4% (20.8-34.0)	32.4% (24.9-39.9)	24.9% (21.9-27.8)	
Uni. grad	49.2% (27.0-71.5)	63.6% (55.7-71.4)	55.2% (45.7-64.6)	63.3% (59.2-67.4)	
Income	N=97	N=606	N=437	N=4648	<0.05
Low	23.7% (8.8-38.7)	18.0% (13.8-22.1)	18.9% (12.9-24.9)	18.1% (15.5-21.0)	
Middle	49.9% (37.4-62.5)	26.0% (20.5-31.4)	31.6% (24.5-38.6)	30.5% (27.4-33.6)	
High	26.3% (12.0-40.7)	56.0% (49.4-62.8)	49.5% (40.5-58.5)	51.4% (47.6-55.2)	
Smoking	N=102	N=621	N=450	N=4775	NS
Yes	21.2% (1.9-40.4)	13.6% (8.5-18.7)	26.0% (18.4-33.7)	18.1 % (16.1-20.2)	
Former	22.1% (5.9-38.3)	29.1% (24.0-34.3)	32.6% (22.2-42.9)	30.4 % (27.4-33.3)	
Never	56.7% (30.9-82.5)	57.3% (50.5-64.1)	41.4% (33.6-49.2)	51.5% (48.3-54.7)	
Alcohol	N=84	N=542	N=379	N=4020	NS
<1/wk	64.8% (45.0-84.6)	58.9% (53.4-64.3)	49.9% (41.7-58.1)	57.4% (54.2-61.0)	
>1/wk	35.2% (15.4-55.0)	41.1% (35.7-46.6)	50.1% (41.9-58.3)	42.4% (39.0-45.8)	
WC* (cm)	N=102 86.1(82.9-89.3)	N=621 86.3(84.5-88.2)	N=447 91.8(90.0-93.6)	N=4711 91.6(90.3-92.9)	<0.0001
BMI* (kg/m^2)	N=102 25.4(24.1-26.6)	N=621 25.5(25.0-26.1)	N=446 27.4(26.7-28.2)	N=4731 27.2(26.8-27.7)	<0.0001
SBP (mmHg)	N=102 112.4(109.7-115.1)	N=623 111.0(108.8-113.3)	N=450 113.7(112.0-115.3)	N=4773 112.8(111.6-114.0)	<0.05
DBP (mmHg)	N=102 72.5(70.8-74.1)	N=623 70.7(69.2-72.3)	N=450 73.8(72.4-75.2)	N=4773 71.8(71.0-72.5)	<0.0001
Glucose (mM)	N=100 4.9(4.7-5.1)	N=619 4.9(4.9-5.0)	N=443 4.9(4.8-5.1)	N=4728 5.1(5.0-5.1)	<0.05
HDL (mM)	N=98 1.4(1.2-1.5)	N=613 1.4(1.4-1.5)	N=439 1.4(1.3-1.4)	N=4715 1.4(1.4-1.4)	<0.05
TG (mM)	N=53 1.1(0.9-1.2)	N=326 1.1(1.0-1.2)	N=216 1.2(1.1-1.4)	N=2315 1.3(1.3-1.4)	<0.0001

Hba1c (%)	N=97 5.6(5.4-5.7)	N=604 5.6(5.5-5.7)	N=431 5.6(5.5-5.7)	N=4655 5.7(5.6-5.8)	<0.0001

Mean or Prevalence (%) and 95% confidence interval || *pregnant women excluded || HS – High school || Uni. Grad – university graduate || NS – Not Significant

Table 3. Accelerometer measured PA by objectively measured physical activity groups (OMPAG) and self-reported physical activity groups (SRPAG)

				Intensity			
	Objective	**N**	**Valid days**	**Sedentary (min/day)**	**Light (min/day)**	**MVPA (min/day)**	**Step Count**
Active	Non-Sedentary	102	5.6 (5.2-6.0)	432.0(411.6-452.5)	307.4(275.9-339.0)	77.0(61.9-91.9)	16370 (14496-18242)
	Sedentary	623	6.3 (6.2-6.4)	589.2(579.1-599.2)	204.0(193.1-214.9)	53.2(50.4-56.0)	11327 (10997-11675)
Inactive	Non-Sedentary	450	5.8(5.5-6.0)	425.2 (418.1-432.2)	346.3(332.4-360.3)	26.3 (23.9-28.7)	12194(11623-12764)
	Sedentary	4775	6.2(6.2-6.3)	601.9(597.5-606.3)	223.5(216.7-230.3)	16.4(15.0-17.3)	7642(7415-7870)
	Self-Report						
Active	Non-Sedentary	562	6.2(6.0-6.3)	570.2(557.3-583.2)	245.5(229.7-261.3)	33.0(29.6-36.4)	10410 (9852-10967)
	Sedentary	737	6.3(6.2-6.4)	585.8(578.0-593.6)	217.8(206.4-299.1)	30.8(26.1-35.5)	9192(8711-9673)
Inactive	Non-Sedentary	1907	6.3(6.2-6.3)	575.3(568.1-582.6)	255.0(245.5-264.4)	21.0(19.6-22.5)	8881(8528-9234)
	Sedentary	2744	6.1(6.0-6.2)	591.7(585.7-597.8)	217.4(211.1-223.6)	18.3(16.5-20.1)	7740(7472-8007)

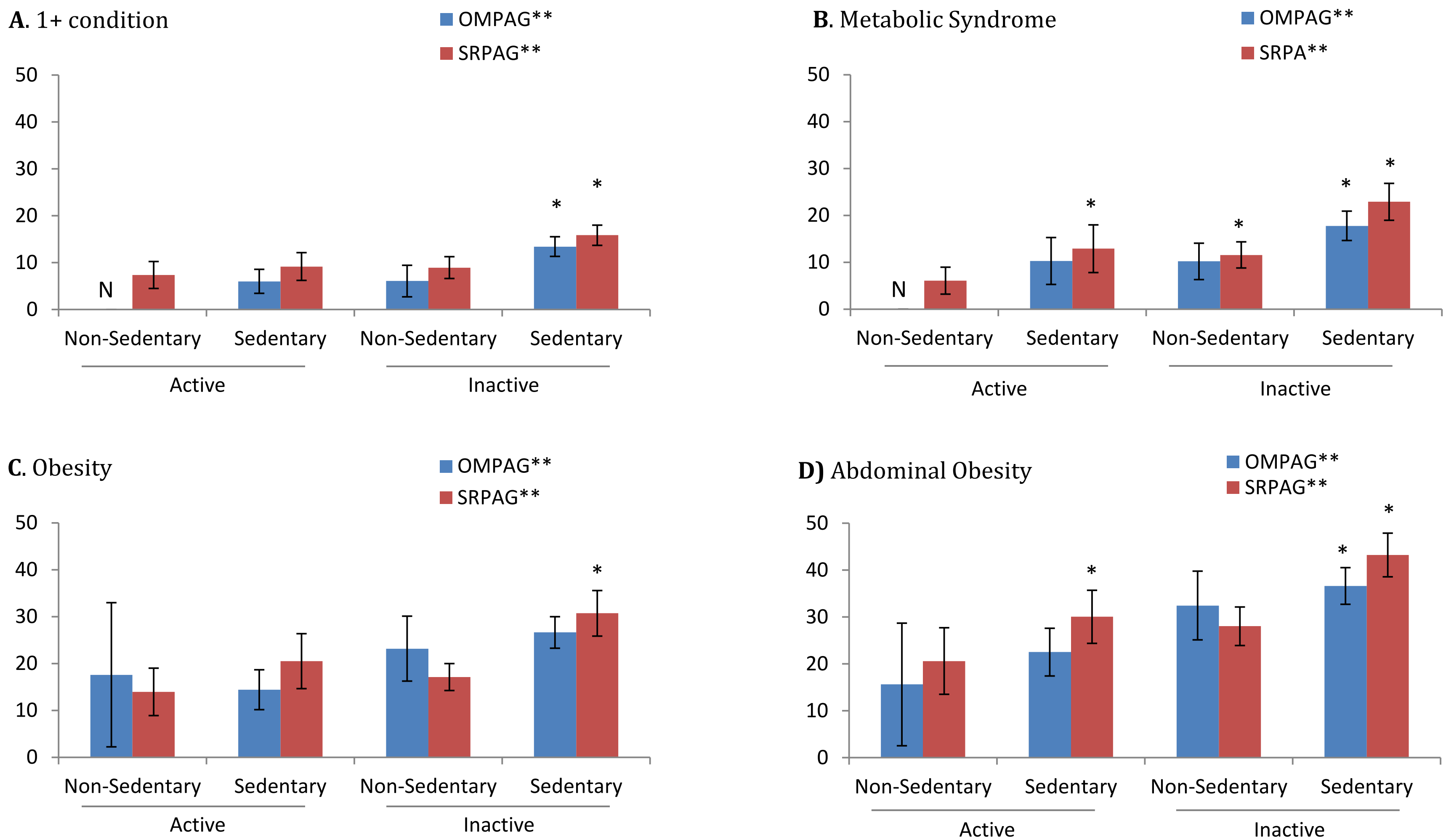
Mean and 95% confidence interval

Table 4. Multivariate adjusted odds ratios of chronic disease and individual metabolic syndrome components by objectively measured physical activity groups (OMPAG) and self-reported physical activity groups (SRPAG)

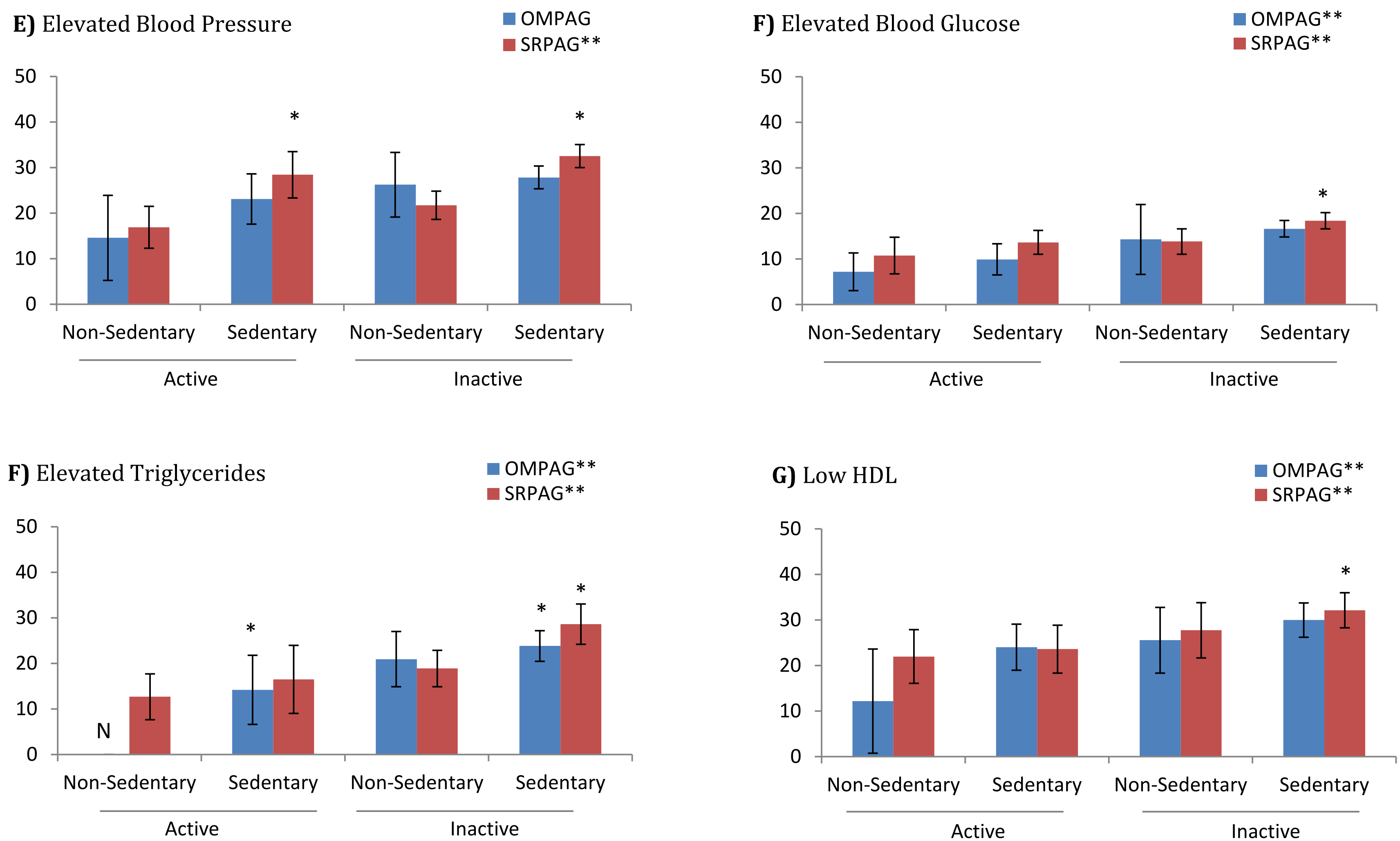
	Active				Inactive			
	Non-Sedentary		Sedentary		Non-Sedentary		Sedentary	
Chronic Disease	**OMPAG**	**SRPAG**	**OMPAG**	**SRPAG**	**OMPAG**	**SRPAG**	**OMPAG**	**SRPAG**
1+ condition	1.00	1.00	1.57(0.71, 3.48)	0.72(0.42, 1.23)	1.37(0.64, 2.95)	1.08(0.64, 1.82)	**3.05(1.47, 6.34)**	1.26(0.79, 2.01)
Obesity*$	1.00	1.00	0.79 (0.20, 3.15)	1.52 (0.86, 2.67)	1.25(0.32, 4.86)	1.40 (0.87, 2.24)	1.53 (0.38, 6.08)	**2.77(1.63, 4.70)**
MetS*	1.00	1.00	1.65 (0.36, 7.47)	1.77 (0.88, 3.55)	1.19(0.29, 4.88)	**2.20(1.13, 4.29)**	1.94 (0.52, 7.29)	**2.87(1.39, 5.94)**
MetS Components								
Abd. Obesity*$	1.00	1.00	1.62 (0.69, 3.81)	**1.59(1.09, 2.31)**	2.38(0.91, 6.23)	1.55 (0.92, 2.60)	**2.75(1.16, 6.55)**	**2.88(1.86, 4.46)**
Blood pressure	1.00	1.00	1.38 (0.73, 2.62)	1.28 (0.79, 2.08)	1.65(0.68, 4.04)	1.41 (0.87, 2.29)	1.36 (0.71, 2.61)	1.52 (0.99, 2.35)
Glucose	1.00	1.00	1.10 (0.52, 2.34)	0.92 (0.57, 1.48)	1.58(0.55, 4.57)	1.28 (0.79, 2.06)	1.70 (0.82, 3.55)	1.13 (0.69, 1.85)
TG	1.00	1.00	1.65 (0.28, 9.73)	0.93 (0.44, 1.93)	2.03(0.35, 11.78)	1.40 (0.76, 2.57)	2.44 (0.43, 13.95)	**2.09(1.25, 3.50)**
HDL	1.00	1.00	2.44 (0.67, 8.88)	1.08 (0.76, 1.53)	2.08(0.59-7.32)	1.23 (0.80, 1.91)	2.90 (0.85, 9.91)	1.32 (0.94, 1.85)

Odds ratios and 95% confidence intervals || Adjusted for age, sex, ethnicity, education, income, wear time, and BMI || Chronic Disease – 1+ condition: 1or more of diabetes, myocardial infarction, stroke, or cardiovascular disease; Obesity: BMI ≥ 30kg/m²; MetS: ≥3 components || MetS Components – Abdominal obesity: ≥102 cm (men) and ≥ 88 cm (women); Blood pressure: ≥130mmHg (systolic) or ≥85mmHg (diastolic); Glucose: ≥5.6mM; Triglycerides: ≥1.69mM; HDL <1.04 (men) and <1.29 (women) || OMPAG – Objectively measured physical activity group || SRPAG – Self-reported physical activity group || TG – Triglycerides || Abd. Obesity – abdominal obesity || *pregnant women excluded || $not adjusted for BMI

Figure 1.



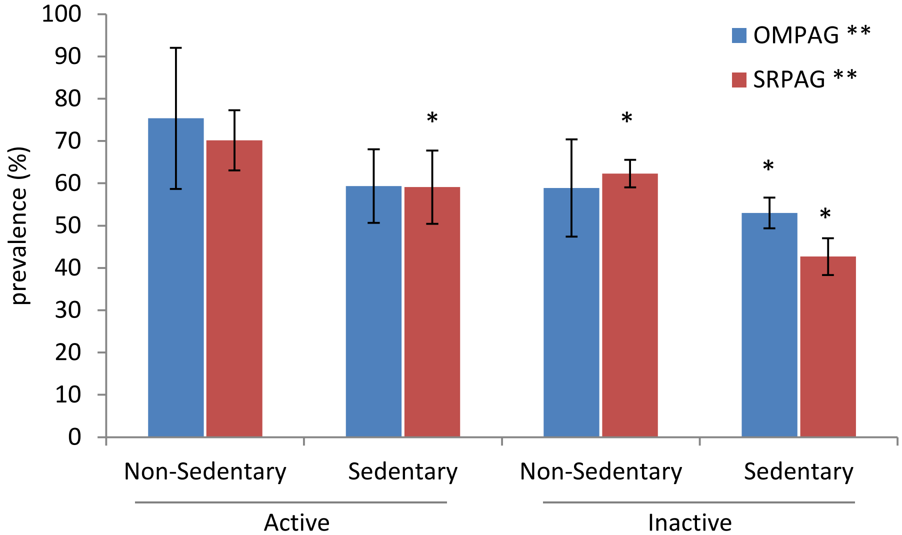
Prevalence (%) and 95% confidence intervals ||N-Estimate suppressed || ** significant for overall x^2 || * significantly different from refferent group (Active/Non-Sedentary)



Prevalence (%) and 95% confidence intervals || N-Estimate suppressed || ** significant for overall x^2 || * significantly different from refferent group (Active/Non-Sedentary

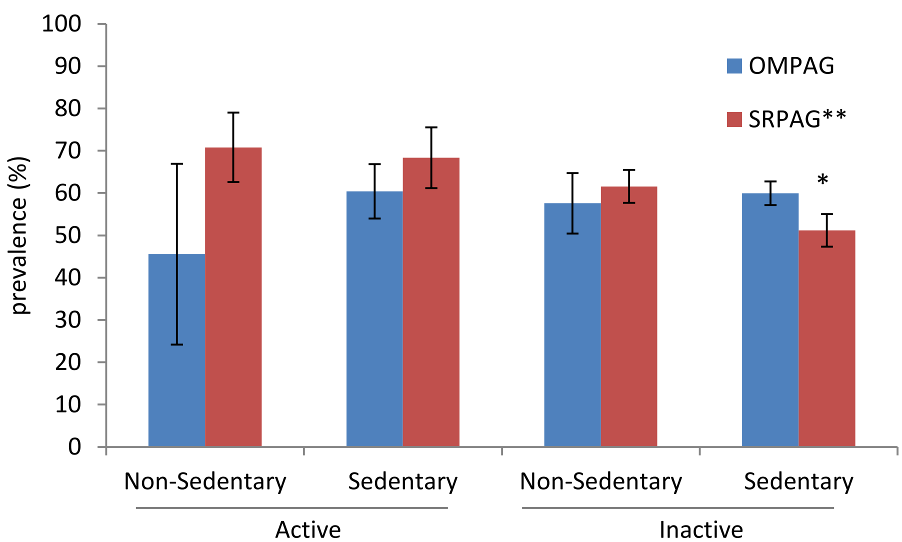
Figure 2.

A. High Aerobic Fitness



Prevalence (%) and 95% confidence interval || High aerobic fitness – mCAFT step test "good" rating or higher || ** significant for overall x^2 || * significantly different from refferent group (Active/Non-Sedentary)

B. High Musculoskeletal fitness



Prevalence (%) and 95% confidence interval || High musculo-skeletal fitness – "good" rating or higher || ** significant for overall x^2 || * significantly different from refferent group (Active/Non-Sedentary)

EXTENDED DISCUSSION

Sample Size and Response Bias

PA surveillance in Canada has traditionally relied upon self-reported questionnaires which were primarily modeled after the Minnesota Leisure Time Physical Activity Questionnaire (Katzmarzyk & Tremblay, 2007). Evidence-based decision making surrounding PA and *The Canadian Physical Activity Guidelines* are based on data gathered using this method and depend on the validity and reliability of such questionnaires to make safe and effective decisions. With the advent of accelerometer technology, an objective way to measure PA intensity, the further use of self-reported data has been brought under question. Use of accelerometers is also not without its challenges, and participation in the CHMS is voluntary. To note, there are multiple phases of the survey and thus several critical stages where considerable amounts of participants withdraw (although they are able to withdraw at any point). This may yield a response bias. In the first CHMS cycle (2007-2009), the household response rate was 69.6%, meaning of the 8 772 dwellings selected to participate, 6 106 provided the sex and date of birth of all members of the household. From these households, 7 483 participants were selected to complete the survey, of which 5 604 attended the mobile examination centre (MEC) (84.9%). In total, cycle 1 has a combined weighted response rate of 51.7%. Additionally, inclusion in this study demanded adherence to minimum accelerometer wear time requirements of 10 hr/day for 4 days. Although this cut-point is not arbitrary, it was chosen for economical rather than physiological reasons. Using a subsample from the first four collection sites, Colley et al. (2010) examined previously adopted and possible new wear time cut-points. In the first cycle, the trade-off for raising the cut-point to 12 hr/day would be an increase in experimental validity; however, a subsequent loss of 13% of individuals meeting the criteria compared to the 10 hour cut-point would considerably reduce the sample size. Sacrificing validity (8 hr/day cut-point) for increasing inclusion would only increase the sample by 4%. Analogous reasoning was used to select the 4 day cut-point (Colley et al., 2010). Nevertheless, the final response rate of those with 4 valid days of accelerometer wear still resulted in a drop in participation rates to 41.8%. Cycle 2 (2009-2011) had a 55.4% initial response rate, 81.9% MEC attendance, and 77.7% of participants recorded at least 4 valid days of accelerometer wear. In absolute terms, the initial combined sample size in the present study was n=11 387, which shrunk to n=7 599 after deletions for age (≥18 y) and finally to n=5950 after deletions for valid accelerometry. Each phase of the survey and analysis (i.e. household response, individual participation, mobile examination centre completion, and valid accelerometer data) is subject to response bias, particularly a healthy responder effect. This occurs when the participants of a study are healthier than non-participants (Delgado-Rodriguez and Llorca, 2004). In this case, participants may have less metabolic risk factors and be more active than non-participants. However, when comparing the ≥18 y sample before and after deletions were made for accelerometer wear, only minor differences were noted (**Appendix C**). Nonetheless, the initial response rates were 69.6% and 55.4% for cycle 1 and 2 respectively, meaning at least 30% of the household's contacted declined participation. There is no information on the characteristics of these individuals; however, the non-participant sample is large enough to effect the results of the present study had they been included.

Discrepancies in Objective PA vs Subjective PA

Although self-report and accelerometers yielded similar associations with obesity and metabolic health, the two measurement methods capture different aspects of PA and ST. Both methods have distinct limitations, and thus have the potential to erroneously classify individuals into inappropriate PA/ST groups. These misclassifications may account for the differences seen between self-reported and objectively measured activity, as evidenced by the differences in group sizes (**Appendix E**).

A second bias to which the accelerometers are prone is the Hawthorne effect ("reactivity"). Described as change in behaviour in participants who are aware of being observed (Delgado-Rodriguez and Llorca, 2004), accelerometer data is inherently disposed to this effect. Little data exist on the reactivity of healthy adults to accelerometer wear, although it has been noted in children. During unscripted free-play, children knowingly wearing an accelerometer displayed increased levels of PA compared to children unknowingly wearing one (Foley et al., 2011). If reactivity to accelerometer wear was systemic and equally affected all participants, group membership may have been corrupted, as they were based on absolute (i.e. 150 min/wk of MVPA, ≥ 480 min/day ST), not relative (i.e. quantiles, etc.,) cut-points. Likewise, disproportionate reactivity (e.g. inactive individuals may be more likely to react to wearing an accelerometer than active individuals) in the sample could affect group membership, and outcomes such as steps/day may be inflated.

Because accelerometers are still a relatively novel approach to quantifying PA there is currently no consensus on intensity cut-points. The CHMS dataset set the intensity cut-points at 100 CPM, 100- 534, and ≥1535 for ST, LIA and MVPA, respectively. These cut-points are based on two studies aimed at developing cut-points specific to the Actical monitor (Colley & Tremblay, 2011; Wong et al., 2011). However, previous studies have used cut-points of >1200 CPM and 1969 CPM for MVPA (Heil, 2006; Welk et al., 2004) when using the same monitors. Therefore, it is possible the cut-points used in for the CHMS do not capture all moderate or light intensity minutes correctly and may misclassify certain physical activities.

Compared to misclassifying light and moderate intensity PA, it appears the misclassification of sedentary activities may be more problematic. Although many studies have used the 100 CPM threshold (Colley et al., 2011; Healy et al., 2008), the CHMS validated the measure using step counts. More specifically, sedentary minutes were defined as the absence of steps (Wong et al., 2011), meaning that sitting and standing were not differentiated. However, failing to discriminate between sitting and standing can be problematic as the two sedentary activities can yield significantly different energy expenditures. For example, Buckley et al. (2013) found that compared to sitting, occupational standing alone increased energy expenditure by almost a calorie a minute (0.83 kcal/min). Although this may seem insignificant, a typical 8 hour work shift would expend 398 kcals more if it was spent standing rather than sitting. In addition to expending more energy, standing appears to be positively associated with blood glucose. They noted that post-prandial blood glucose levels were reduced by 43% when participants were standing compared to sitting. Together, these unaccounted differences in sitting versus standing using the 100 CPM cut-point, in conjunction with possible over-reporting of LTPA and under-reporting of ST by self-report (Celis-Morales et al., 2012), could account for discrepancies in the self-reported PA/ST groups compared to objectively measured PA/ST groups.

In addition to a cut-point with slight ambiguity, another area in which accelerometers and self-reported ST differ is distinguishing between different types of sitting. While accelerometers account for each minute spent wearing it, without an accompanying PA log, the activity engaged in is unknown. In the present study, objectively measured ST was determined by summing every minute spent with a CPM of under 100 (i.e. when no steps were taken). This includes time spent at home, at work, and in transit. On the other hand, self-reported ST accounted only for leisure-time ST. Specifically, hours in a typical week in the past 3 months engaged in computer use, computer games and internet, video games, television or videos, and reading (Statistics Canada. 2010b; Statistics Canada. 2012b). Previous research has demonstrated, however, that differences may exist between types of sitting. When looking at the relationship between MetS and ST, Bertrais et al. (2005) found that while overall screen time was significantly associated with MetS, reading was not. Falciglia and Gussow (1980) have suggested that watching television may trigger eating, and Gore et al. (2003) noted that snacking in front of a TV was associated with elevated fat and total caloric intake. Although we combined TV, computer, and reading for self-reported ST in the present study, it did not account for any time at work or in transit.

Confounding the relationship further is the finding that breaks in ST are associated with a host of metabolic risk markers (Healy et al., 2008). Defined as any rise in count above the 100 CPM threshold, Healy et al. (2008) found that those in the highest quartile of breaks had significantly lower WC and 2-hr plasma glucose than those in the lowest quartile, independent of PA and ST. In the present study, objectively measured PA was summed on a per day basis, with no temporal information on how the ST was accrued, while self-reported PA was collected by a 3 month recall. In short, it is clear that not all sedentary activities are created equally. As such, we cannot exclude the possibility that these differences may have affected the relationships between self-reported PA/ST and objectively measured PA/ST with obesity and metabolic health.

Public Health Implications

Numerous studies have found that ST and MVPA independently effect obesity, metabolic health and CVD (Healy et al., 2008; Celis-Morales et al., 2012; Chomistek et al., 2013; Sisson et al., 2009, Maher et al., 2013). It was therefore expected that the combination of inactive/sedentary in the present study would have the highest odds of 1+ condition, obesity, MetS, and individual components of MetS. This proved more accurate for the self-reported PA groups, who displayed more robust associations with obesity and metabolic health than when objective measures of PA and inactivity were used. Moreover, as with previous studies, these analyses suggest that meeting PA guidelines attenuates the increased risk associated with being sedentary (Sisson et al., 2009; Maher et al., 2013).

The novel finding of this study, that when measured objectively, the effect not meeting PA guidelines on obesity and metabolic health is attenuated by sitting for <480 mins/day (or < 8 hours/day), indeed may have implications for public health. As being non-sedentary yielded a similar protective effect as being physically active, the results of our study suggest a more pragmatic approach to the primary prevention of disease. For the general population, engaging in 150 min/wk of MVPA in bouts of 10 minutes or more appears unrealistic, as only 12% (CI: 10.0-14.1) of Canadians currently meet them (**Appendix E**). Although only 9.8% (CI: 8.0-11.4) of Canadians were under the 480 min/day threshold of ST, it may be easier to encourage individuals to *replace* ST with LIA, as opposed to replacing ST or LIA with MVPA. Comparing the activity of the active/sedentary and the inactive/non-sedentary groups (**Table 3**), it is noteworthy that the inactive/non-sedentary group spent the most time in LIA relative to any other group and had a higher daily step count than the active/sedentary group. In line with this, Tremblay et al. (2007) and Levine. et al. (2006) have both suggested that increasing NEAT (non-exercise activity thermogenesis) could be an effective way of reducing the obesity burden. In a 2009 review, Rhodes et al. (2009) found that frequency, intensity, duration, total energy expenditure and volume of PA had little to no effect on PA guideline adherence, and suggested that environmental, social, cognitive and behavioural determinants may play a more substantive role.

Using the transtheoretical model, Garber et al. (2008) examined the correlates of stages of change for PA. The transtheoretical model posits that behaviour change occurs in 5 stages, *precontemplation, contemplation, preparation, action,* and *maintenance* (Proschaska & DiClemete, 1983). They found that older age, having health limitations, not feeling healthy, and being obese, were predictors of being in the *precontemplation* and *contemplation* stages. In our sample, the inactive/sedentary group had a similar profile, being older and having a higher prevalence of MetS, 1+ condition and abdominal obesity. Accordingly, some individuals in the inactive/sedentary group may be in the *precontemplation/contemplation* phase, suggesting barriers to PA are preventing them from reaching the *preparation/action/maintenance* stages. As such, an additional PA guideline or public message to increase LIA or reduce ST may have fewer barriers. Consistent with our findings and those of Tudor-Locke et al. (2011), 10 000 steps/day may be a more feasible target.

Collectively, the results of this study support the accumulation of 150 min/wk of MVPA in bouts 10 minutes or more for maintaining cardiometabolic health. However, because of the noted barriers to reaching this goal, further work needs to investigate the population-level trade-off between potential uptake of PA and the associated health benefits of more modest step counts or lighter intensity activity amongst subgroups of the population with pre-existing health limitations or barriers to more extreme behaviour change.

CONCLUSION

The introduction of the CHMS has greatly expanded the depth of PA surveillance in Canada. Using objectively measured PA to monitor temporal trends, adherence to guidelines and associations with hypokinetic diseases allows for increased validity and reliability, and a new lens on PA surveillance. However, accelerometers have unique biases and limitations which must be considered and further examined. Compared to self-reported PA, accelerometers are more susceptible to a healthy responder effect and uniquely prone to the Hawthorne effect. Intensity cut-points are another facet of accelerometry that requires further scrutiny; many different cut-points for light, moderate and vigorous intensity continue to be used. Measuring ST objectively is associated with even more uncertainties related to differences in sitting, standing, TV viewing, and breaks in sedentary time, and thus subject to misclassifying individuals. Comparably, self-reported PA is prone to over-reporting and recall bias. Together, self-reported PA/ST and accelerometers capture and group individuals differently, likely accounting for the discrepancies in the associations between measurement method and obesity and metabolic health. The above limitations notwithstanding, self-report and accelerometers capture unique aspects of PA and reveal distinct relationships with obesity and metabolic health.

Moving forward, these analyses support the collection of both self-report PA data and objectively measured PA, for economical and scientific reasons. Moreover, theses analyses suggest that meeting PA guidelines while otherwise being sedentary *and* decreasing sedentary time to <8 hr/day, in the face of being inactive, are similarly protective against obesity and metabolic risk. Future research should further explore ST with an aim to establish sedentary guidelines, examine adherence to increased LIA, and investigate ways of promoting intermittent unstructured PA.

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APPENDIX A

Sampling Strategy

The Canadian Health Measures Survey (CHMS) is a biannual cross-sectional survey that was launched in 2007. The survey collects information relating to physical activity, environmental markers, physical health, nutrition, and lifestyle. Modeled after the National Health and Nutrition Survey (NHANES) in the U.S, the CHMS collects health related information from a nationally representative sample of ~5000 Canadians.

In order to produce accurate national estimates, the CHMS samples across 11 age/gender groups, selecting 500-600 participants per group. The first cycle targeted Canadians between 6 and 79 years old. The second cycle expanded the target population to 3 to 79 years old. Participants were selected from 5 regions: British Columbia, the Prairies (Alberta, Saskatchewan, Manitoba, and Yellowknife, Northwest Territories), Ontario, Quebec and the Atlantic provinces (New Brunswick, Prince Edward Island, Nova Scotia and Newfoundland and Labrador). Within the 5 regions, the mobile examination centre (MEC), traveled to 15 collection sites in Cycle 1 and 18 sites in Cycle 2. Data was collected over two years for each survey.

Within each collection site dwellings were stratified into age groups, in which the household had at least one person in the specified age group, using the 2006 census and supplementary housing data to account for newly constructed dwellings. A random sample of dwellings was then selected from each stratum, in a manner in which the sample size would be consistent across age groups. Each selected dwelling was then contacted, and survey respondents were selected from these dwellings. Selection probabilities (weights) were assigned to respondents based on age in order to ensure nationally representative sampling. Unlike other subsamples, activity monitoring was not selected randomly and all participants who attended the MEC were given accelerometers.

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2. Statistics Canada. 2012. Canadian Health Measures Survey (CHMS) Data User Guide: Cycle 2. Ottawa, Ont., Canada.

APPENDIX B

Objectively measured PA/ST intensity cut-points

Intensity	Mets (metabolic equivalents)	CPM (counts per minute)
Sedentary	1 – 1.9	< 100
Light	2 – 2.9	100-1534
Moderate	3 – 5.9	1535-3961
Vigorous	≥ 6	≥ 3962

References:

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APPENDIX C

Self-report PA

Self-reported physical activity was collected during the Household Questionnaire. Information was collected on the type of activity, duration, and frequency. Pre-determined (average) MET levels were assigned to each activity, expressed in kcal/kg/hour. Energy expenditure (EE) was converted from yearly EE to daily EE and all activities were summed, producing daily leisure-time energy expenditure (DEE) in kcal/kg/day. The threshold for "active" was ≥ 3kcal/kg/day.

Activity EE:

$$EE_{\mathrm{a}} = \frac{(n\ x\ 4\ x\ d\ x\ MET\ value)}{365}$$

n= frequency of activity in last 3 months
x 4= convert from 3 month to yearly frequency
d= average duration of activity (in hours)
MET value = energy cost of activity (kcal/kg/hour)
/365= converting to daily EE

Daily EE:

$$DEE = EE_{\mathrm{a}} + EE_b + \ldots + EE_w + EE_x$$

Duration cut-points and averages

Cut-points	Average duration in minutes	Average duration in decimal hours
<15 minutes	13 minutes	.2167
16 – 30 minutes	23 minutes	.3833
31 – 60 minutes	45 minutes	0.75
>60 minutes	60 minutes	1

Activity Type and MET value (kcal/kg/hour)

Activity	MET value	Notation
Walking for exercise	3	*a*
Gardening or yard work	3	*b*
Swimming	3	*c*
Bicycling	4	*d*
Popular or social dance	3	*e*
Home exercises	3	*f*
Ice hockey	6	*g*
Ice skating	4	*h*
In-line skating or rollerblading	5	*i*
Jogging or running	9.5	*j*
Golfing	4	*k*

Exercise class or aerobics	4	*l*
Downhill skiing or snowboarding	4	*m*
Bowling	2	*n*
Baseball or softball	3	*o*
Tennis	4	*p*
Weight training	3	*q*
Fishing	3	*r*
Volleyball	5	*s*
Basketball	6	*t*
Soccer	5	*u*
Other 1	4	*v*
Other 2	4	*w*
Other 3	4	*x*

Sample Calculation for jogging or running:

(Q) In the past 3 months, how many times did you jogging or running?
About how much time did you spend on each occasion?

(A) 3 times/week (i.e. 36 times in last 3 months) for 30 minutes

Calculation:

$$1.4366\, kcal/kg/day = \frac{(36\ x\ 4\ x\ .3833\ x\ 9.5)}{365}$$

References:

1. Statistics Canada. 2010. Canadian Health Measures Survey (CHMS) Derived Variables (DV) Specifications. Ottawa, Ont., Canada.

APPENDIX D

Missing sample analysis

Full sample includes all participants ≥18 y old
Final sample includes all participants ≥18 y old with valid accelerometry

	Full sample (7599)	Final sample (5950)
Age (yrs)	N=7599	N=5950
	46.51 ± 16.80	47.24 ± 16.11
Sex	N=7599	N=5950
Male	46.49%	45.97%
Female	53.51%	54.03%
Race	N=7452	N=5862
White	87.21%	87.58%
Other	12.79%	12.42%
Education	N=7533	N=5901
<HS	14.31%	12.81%
HS grad	25.77%	24.59%
Uni. grad	59.92%	62.20%
Income	N=7375	N=5788
Low	6.39%	5.17%
Low upper	16.05%	14.51%
High upper	32.20%	32.98%
High	45.36%	47.34%
Smoker	N=7580	N=5938
Yes	20.24%	17.67%
Former	30.18%	31.41%
Never	49.58%	50.93%
Alcohol	N=6354	N=5025
<1/wk	58.81%	57.35%
>1/wk	41.19%	42.65%
WC* (cm)	N=7495	N=5881
	91.98 ± 15.79	91.52 ± 15.20
BMI *(kg/m^2)	N=7523	N=5900
	27.39 ± 5.74	27.17 ± 5.43
SBP (mmHg)	N=7593	N=5948
	112.86 ± 16.10	113.05 ± 15.95
DBP (mmHg)	N=7593	N=5948
	71.21 ± 9.54	71.46 ± 9.38
Glucose (mM)	N=7500	N=5890
	5.13 ± 1.41	5.08 ± 1.24

HDL (mM)	N=7464 1.37 ± 0.39	N=5865 1.39 ± 0.39
TG (mM)	N=3732 1.37 ± 0.86	N=2910 1.35 ± 0.39
Hba1c (%)	N=7357 0.0572 ± 0.00755	N=5787 0.0568 ± 0.00705

Mean or Prevalence (%) and Standard Deviation || *pregnant women excluded || HS – High school || Uni. Grad – university graduate

Appendix E

PA Guideline Adherence

Prevalence of meeting objectively measured PA guidelines and sedentariness by gender

	≥150mins/wk of MVPA in bouts of 10mins or more (N=725)	<150mins/wk of MVPA in bouts of 10mins or more (N=5225)	<480mins/day ST (N=552)	≥480mins/day ST (N=5298)
Men	13.4% (10.9-15.9)	86.6% (84.1-89.1)	12.1% (9.3-14.8)	87.9% (85.2-90.7)
Women	10.8% (8.7-13.0)	89.2% (87.0-91.3)	7.7% (6.1-9.2)	92.3% (90.8-93.9)
Total	12.0% (10.0-14.1)	88.0% (85.9-89.9)	9.8% (8.1-11.4)	90.3% (88.6-92.0)

(% & CL) – prevalence and 95% confidence intervals

Prevalence of meeting self-reported PA guidelines and sedentariness by gender

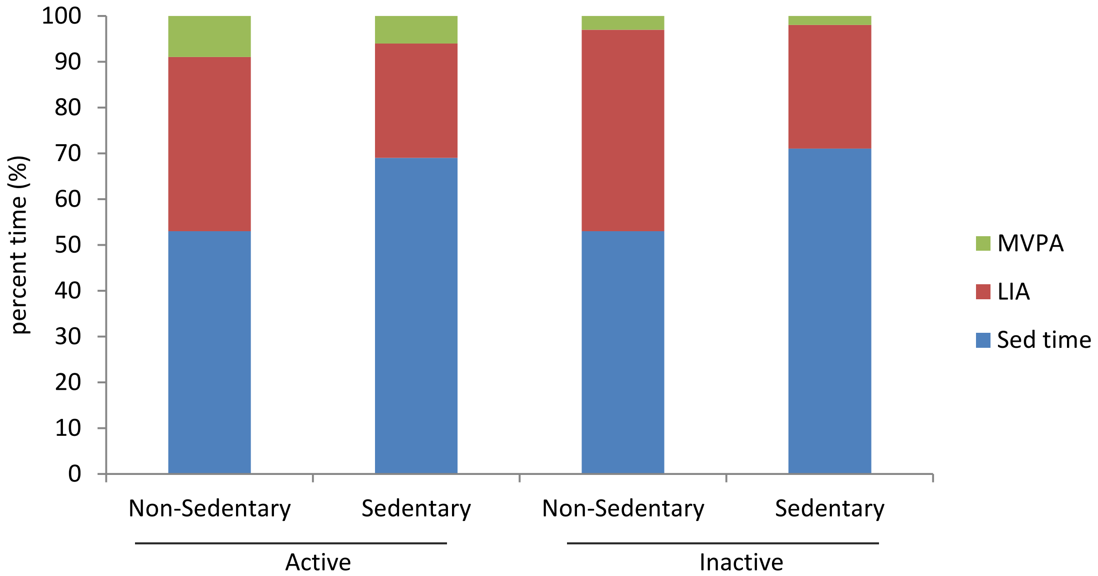
	≥3kcal/kg/day in leisure-time PA (N=1299)	<3kcal/kg/day in leisure-time PA (N=4651)	<20hrs/wk in leisure-time ST (N=2469)	≥20hrs/wk in leisure-time ST (N=3481)
Men	23.7% (20.4-26.9	76.3% (73.1-79.6)	40.1% (37.2-42.9)	59.9% (57.1-62.8)
Women	18.6% (16.2-20.9)	81.4% (79.1-83.8)	45.4% (42.3-48.5)	54.6% (51.5-57.7)
Total	21.0% (18.5-23.5)	79.0% (76.6-81.5)	42.9% (40.4-45.3)	57.1% (54.7-59.6)

(% & CL) – prevalence and 95% confidence intervals

Appendix F

Percent time (daily) spent in different intensities

A) OMPAG



B) SRPAG