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

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

Methods The Canadian Health Measures Survey (n = 5950) was used to (i) examine the joint relationship between 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 objective (accelerometer) total activity or subjective (self-report) leisure-time measures. Weighted associations for the metabolic syndrome (MetS), individual MetS components, 1+ disease (1 or more of diabetes, myocardial infarction, stroke, cardiovascular disease) and obesity were estimated using logistic regression.

Results After adjustments, the odds (OR, 95% CI) of 1+ disease (OR = 3.05, 1.47 - 6.34) and abdominal obesity (OR = 2.75, 1.16 - 6.55) were higher in the inactive/sedentary group versus the referent group (OR = 1.00) when measured objectively. Within self-report leisure-time groups, elevated odds were observed for the inactive/sedentary group for MetS, obesity, abdominal obesity and elevated triglycerides. Inactive/non-sedentary and active/sedentary groups were similarly protective when measured by accelerometer.

Conclusion Using accelerometer data, the inactive/sedentary group was at higher risk for 1+ disease and abdominal obesity only, whereas the active/sedentary and inactive/non-sedentary groups were not at higher risk for any health outcome.

Keywords epidemiology, measurement, physical activity, sedentary time

Introduction

Self-reported Canadian physical activity surveillance data suggests that levels of moderate-to-vigorous physical activity (MVPA) have increased since the 1980s,1-3 while evidence regarding temporal changes in the diets of Canadians is inconclusive.4,5 Paradoxically, the prevalence of obesity and type 2 diabetes has greatly increased during the same time frame.6-7 Two contributing factors to this disconnect may be: (i) changes in sedentary time and (ii) physical activity measurement. There is no long-term systematic surveillance data on temporal changes in sedentary time among Canadians; however, evidence suggests that occupational sitting time3 and overall screen time have increased in recent decades,8 while self-reported physical activity data is subject to over-reporting.9

Although physical inactivity and sedentary time are associated with adverse effects on similar metabolic risk factors,10,11 the mechanisms of action may not be the same.12 Current universally adopted physical activity guidelines recommend ≥150 min/wk of MVPA in bouts of 10 min or more13 in order to reduce risk of premature mortality and various chronic diseases.14 However, even amongst those who meet these recommendations, the majority of people spend only 2-4% of their waking hours in MVPA.15,16 Because current guidelines offer no framework for the other ~96% of time, conventional physical activity surveillance has primarily focused on MVPA and leisure-time physical activity and largely overlooked a significant portion of daily activity energy expenditure (EE). Duvivier et al.17 recently observed that the acute effect of 13 h
of sitting activity on insulin and other metabolic markers was not offset by 1 h of vigorous exercise, highlighting the need for a more thorough exploration of the inter-relationship between sedentary time and MVPA.

Complicating the relationships between sedentary time, physical activity and metabolic health is the widespread use of subjective leisure-time physical activity data in Canadian health surveillance. In 2007, an estimated 65% of Canadian adults met guidelines (30–60 min of MVPA 4 days/wk) by self-reported leisure-time physical activity. In 2009, the inaugural Canadian Health Measures Survey (CHMS)—the first nationally representative study to calculate MVPA from total activity time using accelerometers—revealed that only 15% of Canadians were sufficiently active. Given that self-reported leisure-time information is subject to both healthy responder bias, recall bias and only captures a portion of total activity, objective total activity measures are vital to improve our understanding of the relationships between sedentary time, physical activity and metabolic health. Nevertheless, the overwhelming evidence of an epidemiological association between physical activity and health is based on traditional self-reported leisure-time activity, and likely to persist in national surveillance due to its relative ease of collection and cost-effectiveness.

The objective of this study was 2-fold: First, to examine the joint effects of physical activity and sedentary time on obesity and metabolic health, and second; to compare these relationships when using subjective (self-report) leisure-time or objective (accelerometer) total activity data.

Methods

Participants

Initiated in 2007, the CHMS is a cross-sectional study conducted biannually, designed to collect key surveillance information concerning the health of a nationally representative sample of Canadians aged 3–79. The survey collects information through household interviews, direct physical measures, physical activity monitors, blood and urine samples, and environmental measures. Approximately 96% of Canadians are represented. Excluded are full-time members of the Canadian Forces; residents of aboriginal settlements or reserves; select remote regions, and; institutionalized residents.

Two cycles of the CHMS were used in the present study; Cycle 1 (2007–9) and Cycle 2 (2009–11) were combined with an initial sample size of \( n = 11,387 \). The final analytical sample was \( n = 5,950 \) after only those \( \geq 18 \) years (range: 18–79 years) with valid accelerometer data (\( \geq 4 \) valid days) were included.

Objectively measured physical/sedentary activity

Data from Actical accelerometers were used to provide an objective assessment of total physical activity and sedentary time. In accordance with Colley et al., minimum adherence for inclusion in the study was 4 valid days of wear time, wherein 10 h of wear time was required for a valid day. One valid weekend day was not required. Wear time was calculated by subtracting non-wear time from 24 h. 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.

In order to capture intensity of activities, Actical monitors measure acceleration in all directions in 1 min epochs by summing total counts per minute (CPM). Each intensity level has a corresponding CPM cut-point, and the time spent in each intensity was summed and converted into total minutes per day. The cut-points applied in this study were previously published guidelines specific to the Actical monitors: 100 CPM (sedentary intensity); 100–1534 CPM (light intensity), and; >1534 CPM (MVPA). Physical activity guideline adherence was defined as accumulating 150 min or more of MVPA in bouts of 10 min or more in 7 days, denoted as ‘active’. Not meeting physical activity guidelines was denoted as ‘inactive’ (see Supplementary material online, Table S1). An allowance of 2 min of not meeting the cutpoint throughout the 10 consecutive minutes of MVPA was permitted. For participants with only 4–6 valid days of accelerometer wear, their average daily time in MVPA was calculated and multiplied by 7. Sedentary time was dichotomized into \( \geq 480 \) min/day (‘sedentary’) and \(< 480 \) min/day (‘non-sedentary’). Accelerometer measured groups were created by cross classifying by physical activity and sedentary time. The four groups were subsequently denoted (i) active/non-sedentary; (ii) active/sedentary; (iii) inactive/non-sedentary; and (iv) inactive/sedentary, with the active/non-sedentary group serving as the referent group.

Self-reported physical/sedentary activity

Self-reported leisure-time physical activity and sedentary time data were collected during the household interview. Information was collected on the type of activity (walking for exercise, gardening or yard work, swimming, bicycling, popular or social dance, home exercises, ice hockey, ice skating, in-line skating or rollerblading, jogging or running, golfing, exercise classes or aerobics, downhill skiing or snowboarding, bowling, baseball or softball, tennis, weight-training, fishing, volleyball, basketball, soccer or any other) duration and frequency. Pre-determined (average) MET (metabolic equivalent) levels were assigned to
each activity, expressed in kcal/kg/h. EE was converted from yearly EE to daily EE and all activities were summed, producing daily leisure-time EE in kcal/kg/day.\textsuperscript{9,23} This index has good reliability ($r = 0.90$) and criterion validity ($r = 0.36$) when compared to other questionnaire-based methods of physical activity ($r = 0.77$).\textsuperscript{26} Self-reported leisure-time physical activity was dichotomized into ‘active’ ($\geq 3$ kcal/kg/day) and ‘inactive’ ($<3$ kcal/kg/day) groups.

Self-reported leisure-time sedentary time 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.\textsuperscript{27,28} This composite measure of activities outside of work included response categories ranging from $<5$ h to 45 or more hours per week. Sedentary time was subsequently dichotomized as ‘sedentary’ ($\geq 20$ h/wk) or ‘non-sedentary’ ($<20$ h/wk) (Supplementary material online, Table S1). Analogous to accelerometer measured groups; four self-reported leisure-time groups were created: (i) active/non-sedentary; (ii) active/sedentary; (iii) inactive/non-sedentary; and (iv) 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 ($\geq 7.1$ mmol/L) or HbA1c levels ($\geq 6.5\%$).\textsuperscript{29} Cardiovascular disease (CVD), heart attack and stroke were self-reported. In order to have sufficient power for physical activity-by-sedentary time comparisons, diabetes, CVD, heart attack and stroke were collapsed into a single variable (‘1+ disease’). Obesity was defined by measured height and weight as a body mass index (BMI) $\geq 30$ kg/m$^2$.

Metabolic syndrome (MetS) was classified according to the harmonized definition\textsuperscript{30} as having three or more of: elevated blood pressure ($\geq 130/85$ mmHg) or hypertensive medication use; abdominal obesity (waist circumference (WC) $\geq 102$ cm (men) or $88$ cm (women)); elevated triglycerides (TG) ($\geq 1.69$ mmol/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.

Physical fitness
Aerobic fitness was determined using the Modified Canadian Aerobic Fitness Test\textsuperscript{31} step test, an indirect submaximal fitness test used to determine aerobic capacity.\textsuperscript{27,28} A composite musculoskeletal fitness score was derived from tests of grip strength, sit and reach, and partial curl ups.\textsuperscript{27,28} 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
To compare baseline demographics within the sample, $\chi^2$ and analysis of variance were used across to assess differences in frequency counts and mean values, respectively. Logistic regression was then applied to estimate the odds (OR, 95% confidence interval (CI)) of having 1+ disease, obesity, MetS and each individual MetS component, for each group (active/sedentary; inactive/non-sedentary; inactive/sedentary) compared to the active/non-sedentary referent group (OR = 1.00). This analysis was done twice, first with the self-reported leisure-time physical activity groups, and second with the objectively measured total activity groups. Models were adjusted for age, sex, education, ethnicity, income adequacy (total household income divided by number of residents), accelerometer 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 9.4 (SAS Institute Inc., Cary, NC, USA). The bootstrap technique\textsuperscript{32} was used to calculate 95% CIs and standard errors. Analyses with cell counts under 10 were suppressed and statistical significance was set at $\alpha < 0.05$ for all analyses.

Results
Characteristics of the sample are described in Table 1. Comparing across accelerometer measured total activity groups, the active/non-sedentary group was the youngest (40.3 years) and primarily male (59.6\%) while the inactive/sedentary group was the oldest (46.5 years) 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 overall significant differences between groups for income, SBP, DBP, Glucose, HDL, TG and Hba1c.

The mean time spent in MVPA (see Supplementary material online, Table S2) decreased systematically across accelerometer measured total activity groups. 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 self-report leisure-time groups, MVPA ranged from 18.3 to 33.0 min/day. Daily sedentary time ranged from 425.2 to 601.9 min/day and from...
| Table 1 Weighted characteristics by accelerometer measured total activity groups |
|---------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|
|                                | Active                       | Inactive                     | P-value                     |
|                                | Non-sedentary                | Sedentary                    | Non-sedentary               | Sedentary                    |                          |
| Age (years)                    | 40.3 (37.7–47.1)             | 43.0 (40.9–45.0)             | 43.4 (40.8–46.0)            | 46.5 (45.9–47.0)             | <0.0001                   |
| Sex                            | 59.6% (37.7–81.6)            | 51.4% (46.6–56.2)            | 58.5% (50.3–66.7)           | 45.6% (44.1–47.2)            | <0.05                     |
| Male                           | 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                      | 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                      | 13.8% (5.9–25.5)             | 9.1% (5.8–12.3)              | 12.5% (9.0–16.0)            | 11.8% (10.0–13.6)            |                           |
| Smoking                        | 49.9% (37.4–62.5)            | 26.0% (20.5–31.4)            | 31.6% (24.5–38.6)           | 30.5% (27.4–33.6)            |                           |
| Smoking                        | 26.3% (12.0–40.7)            | 56.0% (49.4–62.8)            | 49.5% (40.5–58.5)           | 51.4% (47.6–55.2)            |                           |
| 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                        | 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)            | <0.05                     |
|                                | 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 21.2% (1.9–40.4)     | 13.6% (8.5–18.7)             | 26.0% (18.4–33.7)           | 18.1% (16.1–20.2)            |                           |
|                                | Yes 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 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)            |                           |
| BMI (kg/m²)                    | 86.1 (82.9–89.3)             | 86.3 (84.5–88.2)             | 91.8 (90.0–93.6)            | 91.6 (90.3–92.9)             | <0.0001                   |
|                                | 25.4 (24.1–26.6)             | 25.5 (25.0–26.1)             | 27.4 (26.7–28.2)            | 27.2 (26.8–27.7)             | <0.0001                   |
|                                | 112.4 (109.7–115.1)          | 111.0 (108.8–113.3)          | 113.7 (112.0–115.3)         | 112.8 (111.6–114.0)          | <0.0001                   |
|                                | 72.5 (70.8–74.1)             | 70.7 (69.2–72.3)             | 73.8 (72.4–75.2)            | 71.8 (71.0–72.5)             | <0.05                     |
|                                | 4.9 (4.7–5.1)                | 4.9 (4.9–5.0)                | 4.9 (4.8–5.1)               | 5.1 (5.0–5.1)                | <0.05                     |
|                                | 1.4 (1.2–1.5)                | 1.4 (1.4–1.5)                | 1.4 (1.3–1.4)               | 1.4 (1.4–1.4)                | <0.05                     |
|                                | 1.1 (0.9–1.2)                | 1.1 (1.0–1.2)                | 1.2 (1.1–1.4)               | 1.3 (1.3–1.4)                | <0.0001                   |
|                                | 5.6 (5.4–5.7)                | 5.6 (5.5–5.7)                | 5.6 (5.5–5.7)               | 5.7 (5.6–5.8)                | <0.0001                   |

Mean or prevalence (%) and 95% confidence interval.

HS, high school; NS, not significant.

*Pregnant women excluded.

Significantly different from active/non-sedentary.

Significantly different from active/sedentary group.

Significantly different from inactive/non-sedentary group.
570.2 to 591.7 min/day in accelerometer measured groups and self-report groups, respectively. Prevalence of chronic disease and MetS components are shown in Fig. 1. Overall, only the self-reported leisure-time inactive/sedentary groups had a higher prevalence of every chronic disease. Within the accelerometer measured groups, obesity, abdominal obesity, elevated blood glucose, TG and HDL were significantly different across all groups ($P < 0.05$).

Fig. 1 Prevalence of chronic disease and metabolic syndrome components by accelerometer measured groups (Accel) and self-report groups (S-R). Prevalence (%) and 95% confidence intervals [N-Estimate suppressed. **Significant for overall $x^2$ for both Accel and S-R. *Significantly different from referent group (active/non-sedentary). (A) 1+ disease, (B) metabolic syndrome, (C) obesity, (D) abdominal obesity, (E) elevated blood pressure, (F) elevated blood glucose, (G) elevated triglycerides and (H) low HDL.
When compared to the referent group, the prevalence of abdominal obesity was significantly greater in the inactive/sedentary group (36.6 versus 15.2%) while the prevalence of elevated blood pressure was significantly greater in both sedentary groups (active: 23.1 versus 14.6%; inactive: 27.8 versus 14.6%). Within self-report leisure-time groups, all components of MetS varied across groups, and both sedentary groups had a significantly higher prevalence of abdominal obesity (active: 30.0 versus 20.6%; inactive: 43.2 versus 20.6%) and elevated blood pressure (active: 28.4 versus 16.9%; inactive: 32.5 versus 16.9%).

Aerobic fitness levels (Fig. 2) were similar between accelerometer measured total activity and self-reported leisure-time groups. When measured by accelerometer, 75.4% of the referent group had high aerobic fitness while 70.2% of the referent group did by self-report. Conversely, the prevalence of high musculoskeletal fitness was significantly lower in the inactive/sedentary group (51.2%) relative to the referent group (70.8%) in the self-report leisure-time groups.

The age and sex adjusted odds ratio (95% CI) for chronic disease and MetS revealed various significant relationships within accelerometer measured total activity and self-reported leisure-time groups. Upon including ethnicity, education, income, accelerometer wear time and BMI into the models, only two relationships retained significance within accelerometer measured groups (Table 2).

Discussion
Main finding of this study
The results of the present study demonstrate that, when measured objectively, not meeting physical activity guidelines in combination with being sedentary (≥480 min/day) is associated with greater odds of abdominal obesity and having a chronic disease. However, the associations differed when measured by self-reported leisure-time activity.

What is already known on this topic
Objectively measured physical activity/sedentary time and metabolic health
Numerous studies have noted the independent effects of sedentary time and MVPA on metabolic health and CVD. Similar to our study, Healy et al. noted significant associations between time spent in sedentary activities and MVPA with abdominal obesity, while Chomistek et al. noted the joint effect of low physical activity 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 four groups, 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 physical activity guidelines is consistent with previous research; however, the finding that the excess risk incurred by being inactive is offset by low sitting time for all outcomes is, to the authors’ knowledge, novel.

Although only two groups (active/non-sedentary; active/sedentary) in our study actually achieved the recommended level of physical activity, it is notable that three groups (active/non-sedentary; active/sedentary; and inactive/non-sedentary) all averaged ≥10 000 steps/day, a threshold proposed as a reasonable target to be categorized as ‘active’.

Fig. 2 Prevalence of ‘high’ fitness levels by accelerometer measured groups (Accel) and self-report groups (S-R). Prevalence (%) and 95% confidence interval. High musculoskeletal fitness—good’ rating or higher. **Significant for overall x² for both Accel and S-R. *Significantly different from referent group (active/non-sedentary). (A) Aerobic fitness and (B) musculoskeletal fitness.
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 from the referent.

**What this study adds**

**Accelerometers versus self-report**

Accelerometer measured total physical activity and sedentary time was associated with abdominal obesity and 1+ disease, 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-reported leisure-time activity. Similar to the accelerometer measured groups, self-reported leisure-time groups 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 in the self-report groups. These findings are in contrast to two previous studies which found stronger associations between objectively assessed physical activity and metabolic health as compared to self-report.

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**Table 2** Multivariable adjusted odds ratios of chronic disease and individual metabolic syndrome components by accelerometer measured total activity groups (Accel) and self-reported leisure-time groups (S-R)

<table>
<thead>
<tr>
<th>Chronic disease</th>
<th>Active</th>
<th>Inactive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-sedentary</td>
<td>Sedentary</td>
</tr>
<tr>
<td>1+ Disease</td>
<td>Accel 1.00</td>
<td>1.57 (0.71, 3.48)</td>
</tr>
<tr>
<td></td>
<td>S-R 1.00</td>
<td>0.72 (0.42, 1.23)</td>
</tr>
<tr>
<td>Obesitya</td>
<td>Accel 1.00</td>
<td>0.79 (0.20, 3.15)</td>
</tr>
<tr>
<td></td>
<td>S-R 1.00</td>
<td>1.52 (0.86, 2.67)</td>
</tr>
<tr>
<td>MetSb</td>
<td>Accel 1.00</td>
<td>1.65 (0.36, 7.47)</td>
</tr>
<tr>
<td></td>
<td>S-R 1.00</td>
<td>1.77 (0.88, 3.55)</td>
</tr>
<tr>
<td>MetS components</td>
<td>Abdominal obesityb</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accel 1.00</td>
<td>1.62 (0.69, 3.81)</td>
</tr>
<tr>
<td></td>
<td>S-R 1.00</td>
<td>1.59 (1.09, 2.31)</td>
</tr>
<tr>
<td>Blood pressure</td>
<td>Accel 1.00</td>
<td>1.38 (0.73, 2.62)</td>
</tr>
<tr>
<td></td>
<td>S-R 1.00</td>
<td>1.28 (0.79, 2.08)</td>
</tr>
<tr>
<td>Glucose</td>
<td>Accel 1.00</td>
<td>1.10 (0.52, 2.34)</td>
</tr>
<tr>
<td></td>
<td>S-R 1.00</td>
<td>0.92 (0.57, 1.48)</td>
</tr>
<tr>
<td>TG</td>
<td>Accel 1.00</td>
<td>1.65 (0.28, 9.73)</td>
</tr>
<tr>
<td></td>
<td>S-R 1.00</td>
<td>0.93 (0.44, 1.93)</td>
</tr>
<tr>
<td>HDL</td>
<td>Accel 1.00</td>
<td>2.44 (0.67, 8.88)</td>
</tr>
<tr>
<td></td>
<td>S-R 1.00</td>
<td>1.08 (0.76, 1.53)</td>
</tr>
</tbody>
</table>

Odds ratios and 95% confidence intervals. Adjusted for age, sex, ethnicity, education, income, wear time and BMI. Chronic disease—1+ disease: 1 or more of diabetes, myocardial infarction, stroke or cardiovascular disease; Obesity: BMI ≥ 30 kg/m²; MetS: ≥3 components. MetS components—abdominal obesity: ≥102 cm (men) and ≥88 cm (women); blood pressure: ≥130 mmHg (systolic) or ≥85 mmHg (diastolic); Glucose: ≥5.6 mM; triglycerides: ≥1.69 mM; HDL < 1.04 (men) and <1.29 (women). Self-report groups based on leisure-time activity/sedentary time cut-point. Bold indicates p < 0.05.

Accel, accelerometer measured group; S-R, self-reported group; TG, triglycerides; Abd. obesity, abdominal obesity.

aPregnant women excluded.
bNot adjusted for BMI.
activity did not capture occupational physical activity; however, they did not account for sedentary time. Celis-Morales et al. measured self-reported activity using the International physical activity questionnaire (IPAQ), which accounts for both sitting time and occupational activity. The extent to which differences in the measurement tools could have contributed to this divergent finding is unclear.

Atienza et al. proposed that muscular strength could account for the differences in metabolic risk between objective and self-reported physical activity due to its inverse association with metabolic risk. This may partially explain the weaker observed relationship between objectively measured activity and metabolic health. First, the sedentary cut-point of 100 CPM does not distinguish between different sedentary activities such as standing and sitting, meaning that important differences in total EE and blood glucose levels could be masked within our objectively measured sedentary groups. Other intensities are susceptible to misclassification due to cut-point ambiguity. CHMS cut-points were 100–1534 and ≥1535 CPM for light intensity activity and MVPA, respectively; however, previous studies have used different cut-points when using the same monitors. Therefore, it is possible the cut-points used in the CHMS do not capture intensity appropriately in all individuals, and may misclassify some participants. Indeed, the prevalence of MVPA was 21.8% by self-report and 12.2% by accelerometer, whereas, non-sedentary time was also much higher by self-report (41.5%) than objective measure (9.3%). The level of agreement in accelerometer versus self-report physical activity was κ = 0.22 and 0.038 in accelerometer versus self-report sedentary time, highlighting the difficulties in accurately capturing sedentary activities. Second, accelerometers are prone to the Hawthorne effect (reactivity), wherein participants who are aware of being observed (via accelerometer) may increase their physical activity level during the course of the study. Lastly, our self-reported activity measure only accounted for leisure-time physical activity and sedentary time and did not capture occupational sitting.

Limitations of this study

There are several limitations that warrant discussion. First, because the study is cross-sectional, causality cannot be inferred. Second, although a missing sample analysis revealed minimal differences between the full sample and those with valid accelerometer data, we cannot exclude the possibility of a healthy responder effect. Third, self-reported physical activity is also subject to recall bias and influence from social desirability, which may bias towards the null. Because aerobic fitness was measured using a submaximal step test, it may also underestimate actual VO2 for some participants, whereas BMI may not reflect the same body composition in younger and older adults. Lastly, dietary intake was not accounted for, and may differ between activity groups.

Implications

The main finding of this study was that self-report leisure-time physical activity and sedentary time demonstrate different associations with metabolic health compared to accelerometer measured activity. Using accelerometer data, the inactive/sedentary group was at higher risk for 1+ disease and abdominal obesity only, whereas the active/sedentary and inactive/non-sedentary groups were not at higher risk for any health outcome. Given that traditional self-reported and accelerometer-derived activity data may identify different aspects of health, complementary use of these methods may still provide value.

Supplementary data

Supplementary material is available at Journal of Public Health online.

Acknowledgements

This research was conducted at the Canadian Research Data Centre Network (CRDCN). Although the research and analysis are based on data from Statistics Canada, the opinions expressed are those of the authors alone.

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