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Comparison of self-reported and accelerometer-measured physical activity in Canadian adults

by Rachel C. Colley, Gregory Butler, Didier Garriguet, Stephanie A. Prince and Karen C. Roberts

Abstract

Background: Self-reported and accelerometer-measured physical activity levels generally exhibit low correlation and agreement. The objective of this study is to compare estimates of physical activity among adults from a newly developed Canadian questionnaire with those obtained objectively by accelerometry.

Data and methods: Data for 18- to 79-year-olds (N = 2,372) were collected in 2014 and 2015 as part of the Canadian Health Measures Survey (CHMS). Moderate-to-vigorous physical activity (MVPA) was reported on the household questionnaire by domain (transportation, recreation, and occupational or household) as part of the new Physical Activity Adult Questionnaire (PAAQ) and measured objectively using the Actical accelerometer. Correlation and mean difference analyses were used to assess the relationships between measured and reported physical activity variables. Linear regression was used to test the association between measured and reported physical activity and measures of obesity.

Results: On average, Canadian adults reported more physical activity than they accumulated on an accelerometer (49 minutes versus 23 minutes per day). The highest correlation observed was between accelerometer-measured MVPA and the sum of self-reported recreation and transportation activity (R = 0.36, $p < 0.0001$). The sum of activity from all domains (recreation + transportation + occupational or household) exhibited a lower correlation with measured variables because the occupational or household domain was negatively correlated with MVPA (R = -0.04). The occupational or household domain was positively correlated with light-intensity physical activity (R = 0.20, $p < 0.0001$). Respondents in the least active quintile were more likely than those in the most active quintile to report more activity than was measured by the accelerometer. On average, the most active quintile reported less activity than was measured by the accelerometer.

Interpretation: The newly developed Canadian physical activity questionnaire exhibited modest correlation and agreement with accelerometer-measured physical activity among adults. Accelerometers and questionnaires provide complementary information, about different aspects of physical activity (actual movement versus perceived time). Consequently, one should exercise caution in using estimates derived from these methods interchangeably.

Keywords: Data collection, direct measure, health surveys, movement, exercise

The Canadian Physical Activity Guidelines (PAG) for adults (≥ 150 minutes per week of moderate-to-vigorous physical activity [MVPA] in bouts of ≥ 10 minutes)[1] are supported by a large body of evidence, which indicates that physical activity is associated with a reduced risk of chronic disease and all-cause mortality.[2,3] The inclusion of devices to objectively measure physical activity as part of national population health surveys in Canada has broadened the scope of options for physical activity surveillance.[4] However, the lack of agreement between measured and self-reported estimates of physical activity[5-8] has created a surveillance challenge. Data from the 2016 Canadian Community Health Survey (CCHS) indicate that almost half of Canadian adults report that they were at least moderately active in their leisure time,[9] whereas accelerometer-measured data from the 2014-to-2015 Canadian Health Measures Survey (CHMS) indicate that only 17% meet the current PAG.[10] Differences in the presence of, and degree of association between, self-reported and accelerometer-measured physical activity as this relates to health add an additional challenge to reconciling the differences between methods.[11]

Questionnaires are relatively easier and cheaper to implement within a population health surveillance system than objective measurement tools and are therefore more commonly used. For this reason, it is important to develop and sustain valid and reliable questionnaires that capture this health behaviour. From 2007 to 2011, the CHMS used the Minnesota Leisure-Time Physical Activity Questionnaire (MLTPAQ). An analysis of CHMS data observed large differences between the MLTPAQ and the accelerometer in average daily minutes of physical activity, as well as in the classification with respect to meeting the PAG. For example, differences between methods were as high as 37.5 minutes per day in one direction or the other, and about 40% of the population met the PAG according to one method and not the other.[5]

The 2012-to-2013 CHMS adopted the International Physical Activity Questionnaire (IPAQ). The IPAQ addressed some of the key limitations of the MLTPAQ, accounting for the 10-minute-bout stipulation set out in the PAG and assessing MVPA across transportation, recreational, occupational and household domains in accordance with an emerging global consensus.[12] However, the IPAQ exhibited a low correlation with accelerometer data in the CHMS and classified almost all Canadians (90%) as meeting the PAG[6]; a finding consistent with a previous study.[13] In the 2012-to-2013 CHMS, a newly developed questionnaire module, the Physical Activity Adult Questionnaire (PAAQ), was tested alongside the IPAQ. A limited analysis on a sub-sample of the CHMS (n = 112) indicated that physical activity data from the PAAQ related more strongly to the acceler-

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ometer-measured data than did the IPAQ data (R=0.44 versus R=0.20) and yielded more plausible results for adherence to the current PAG (percentage meeting the PAG: 70% when all minutes of measured MVPA were used, 61% when self-reported data from the PAAQ were used, and 90% when self-reported data from the IPAQ were used).[6] Consequently, the PAAQ was fully implemented in both the CHMS (the 2014-to-2015 cycle) and the CCHS (2015 and 2016).

Resolving the differences between self-reported and objectively measured physical activity is an important surveillance challenge currently facing population health experts in Canada. The objective of this paper is to compare measured and reported physical activity data by using data from the 2014-to-2015 CHMS. A secondary objective is to compare associations with obesity markers between self-reported and accelerometer-measured physical activity. Finally, the self-reported estimates from the CHMS are compared with those obtained from the larger sample of respondents from the 2015 and 2016 CCHS.

Methods

Data sources

The Canadian Health Measures Survey (CHMS) is an ongoing survey conducted by Statistics Canada that collects reported and measured health information from a representative sample of the Canadian household-dwelling population aged 3 to 79 years. Residents of Indian reserves, institutions, certain remote regions, and the territories, and full-time members of the Canadian Forces were excluded. This analysis includes data on adults aged 18 to 79 years from Cycle 4 of the CHMS that were collected in 2014 and 2015. A total of 2,388 adult respondents had valid accelerometer and PAAQ data. A further 16 respondents were excluded on the basis of an outlier analysis. Specifically, respondents who reported more than 3.5 hours per day of recreation- (n=2) or transportation-based (n=8) physical activity or who reported more than 100 minutes per day of vigorous activity (n=6) were excluded. The excluded values were clear outliers as determined by means of a visual examination of the distributions and were all more than 6 standard deviations above the mean. These outlier rules were adapted from an approach employed in a previous analysis using CHMS data.[6] This analysis is therefore based on 2,372 respondents. CHMS respondents completed an interviewer-administered questionnaire in their home and visited a mobile examination centre (MEC) within the next six weeks to undergo a series of physical measurements. The questionnaire and accelerometer measurements were not taken during the exact same week. This therefore means that all analyses herein are making the assumption that both methods are capturing "typical" physical activity habits. Further detail about the CHMS, including ethics approval information, is available in previous publications.[14-16]

The Canadian Community Health Survey (CCHS) is an ongoing cross-sectional survey conducted by Statistics Canada that collects information related to health status, health care utilization and determinants of health for the Canadian population aged 12 and older. Physical activity is measured in the CCHS via the household questionnaire only (i.e., no accelerometer measurement) and is therefore included here to assess reliability of the estimates obtained from the questionnaire. The CCHS covers approximately 97% of the Canadian population aged 12 and older. Excluded from the survey's coverage are people living on reserves and other Aboriginal settlements, full-time members of the Canadian Forces, people living in institutions, and people living in the Quebec health regions of Nunavik and *Région des Terres-Cries-de-la-Baie-James*. This analysis includes data collected in 2015 and 2016 from a subsample aged 18 to 79 years (n = 90,080) to match the age of respondents from the CHMS. The same outlier exclusions were applied to the CCHS analysis as were used in the CHMS (n=1,425).

Physical activity measured by accelerometer (CHMS only)

Upon completion of the MEC visit, ambulatory respondents were asked to wear an Actical accelerometer (Philips Respironics, Oregon, United States) over their right hip on an elasticized belt during waking hours for seven consecutive days. All respondents were blind to the data while they wore the device. The Actical measures and records time-stamped acceleration in all directions, providing an index of physical activity intensity via a count value for each minute. A valid day was defined as having 10 or more hours of wear time, and a valid respondent was defined as having a minimum of four valid days.[17] Wear time was determined by subtracting nonwear time from 24 hours. Nonwear time was defined as at least 60 consecutive minutes of 0 counts, with allowance for one to two minutes of counts between 0 and 100.[17] Published movement intensity thresholds were applied to the data for the purpose of deriving time spent in light-intensity physical activity (LPA) and MVPA.[18] Analyses included two MVPA variables: one that included all minutes of MVPA ($MVPA_{ALL}$) and another that included only minutes accumulated in bouts of 10 minutes or more ($MVPA_{BOUTS}$). A complete description of the accelerometer data reduction procedures is available elsewhere.[4,15,17]

Physical activity measured by questionnaire (CHMS and CCHS)

As part of the household questionnaire, CHMS and CCHS respondents were asked to provide estimates of time spent in the last seven days engaged in transportation ($PAAQ_{TRA}$), recreational ($PAAQ_{REC}$), or occupational or household ($PAAQ_{OCC}$) physical activity (Appendix A). These values were summed to give total physical activity ($PAAQ_{TOTAL}$). Respondents were then asked to estimate the number of minutes in the last seven days during which they engaged in vigorous-intensity physical activity ($PAAQ_{VPA}$). Average daily values of each domain of physical

activity were calculated by dividing the total values by seven.

Obesity measures (CHMS only)

Body mass index (BMI) was calculated as measured weight in kilograms divided by measured height in metres squared (kilograms per metre squared; $kg \cdot m^{-2}$). A ProScale M150 digital stadiometer (Accurate Technology Inc., Fletcher, United States) was used to measure height to the nearest 0.1 centimetre, and a Mettler Toledo VLC with Panther Plus terminal scale (Mettler Toledo Canada, Mississauga, Canada) was used to measure weight to the nearest 0.1 kilogram. A flexible tape was used to measure waist circumference to the nearest 0.1 centimetre.

Statistical analysis

Descriptive statistics were used to calculate means, 95% confidence intervals, the standard error of the estimate, and the coefficient of variation. Pairwise contrasts were used to assess differences between sex and age groups. Pearson correlation coefficients were used to assess the relationship between measured and reported estimates of physical activity. To provide context, typical correlation coefficients obtained when comparing self-reported and accelerometer-measured physical activity are low-to-moderate and range from -0.71 to 0.96.[7] Weighted histograms were used to present the distribution of the mean difference (calculated as measured estimate – reported estimate) between measured and reported physical activity variables. Measured ($MVPA_{ALL}$ and $MVPA_{BOUTS}$) and reported variables ($PAAQ_{REC+TRA}$ and $PAAQ_{TOTAL}$) were used to assess the percentage of respondents meeting the current PAG (≥ 150 minutes of MVPA per week). A classification analysis was conducted to assess differences in how respondents were classified as meeting or not meeting the PAG. Given that seven complete days of accelerometer data were not available for all respondents (respondents were required to have four or more valid days of data to be included), respondents were deemed adherent if their **average daily MVPA** was greater than or equal to 21.43 minutes per day (150 minutes / 7 days). Association with obesity measures was assessed by means of linear regression controlling for age and sex.

To account for the complex survey design and non-response bias and to correctly estimate variance, all analyses were weighted by means of the survey weights generated by Statistics Canada for Cycle 4 of the CHMS[15] and the 2015 and 2016 CCHS.[19] The data were analyzed using SAS 9.3 (SAS Institute, Cary, United States) and SUDAAN 11.0 using denominator degrees of freedom (DDF=11) in the SUDAAN procedure statements for the CHMS analyses. To account for survey design effects, the bootstrap technique was used to estimate 95% confidence intervals.[15] Response rates were 40% for the CHMS (reflecting the analytical requirement of at least four valid days of accelerometer data) and 57.5% for the 2015 and 2016 CCHS.

Results

Descriptive statistics

Adults in the CHMS sample accumulated, on average, 23 minutes per day of measured $MVPA_{ALL}$, 11 minutes per day of $MVPA_{BOUTS}$, and 200 minutes per day of LPA (Table 1). Estimates were higher in males than in females for all types of physical activity, but these differences rarely reached statistical significance. Adults in the CHMS reported, on average, that they accumulated 15 minutes per day of transportation activity ($PAAQ_{TRA}$), 11 minutes per day of recreational activity ($PAAQ_{REC}$), and 22 minutes per day of occupational or household activity ($PAAQ_{OCC}$) (Table 2). Average daily vigorous physical activity (VPA) was low (< 5 $min \cdot d^{-1}$) according to both the measured and the reported data (Tables 1 and 2).

Correlation analysis

$MVPA_{ALL}$ and $MVPA_{BOUTS}$ were positively correlated with $PAAQ_{REC}$, $PAAQ_{TRA}$, $PAAQ_{REC+TRA}$ and $PAAQ_{TOTAL}$ (Figure 1). The highest correlation coefficient observed was between the accelerometer-measured variables ($MVPA_{ALL}$ and $MVPA_{BOUTS}$) and $PAAQ_{REC+TRA}$ ($R = 0.34/0.36$, $p < 0.0001$). The strength of the correlation between $PAAQ_{TOTAL}$ and the measured variables was weakened by the negative direction of the relationship between the accelerometer-measured variables and $PAAQ_{OCC}$ (R = -0.038 [not significant] for $MVPA_{ALL}$ and -0.094 [$p < 0.0001$] for $MVPA_{BOUTS}$) (Figure 1). Measured LPA was positively correlated with $PAAQ_{OCC}$ ($R = 0.20$, $p < 0.0001$) and $PAAQ_{TOTAL}$ ($R = 0.15$, $p < 0.0001$), but was negatively and weakly correlated with $PAAQ_{REC}$ and $PAAQ_{TRA}$. The correlation between some accelerometer-measured and self-reported variables was slightly stronger in males than in females (e.g., $MVPA_{BOUTS}$ and $PAAQ_{REC+TRA}$: R = 0.39 in males and R = 0.31 in females, both $p < 0.0001$). The strength of correlation between $MVPA_{BOUTS}$ and $PAAQ_{REC+TRA}$ was relatively stable across age groups for both males and females (data not shown).

Self-reported vigorous physical activity ($PAAQ_{VPA}$) and measured VPA were positively and weakly correlated (VPA_{ALL}: $R = 0.21$, $p < 0.0001$; VPA_{BOUTS}: R = 0.24, $p < 0.0001$) (data not shown). The correlation between measured and reported vigorous physical activity was stronger when using measured data accumulated in 10 minute bouts and was significant in 18 to 59 year olds (e.g., 18 to 39 year olds: R = 0.24, $p < 0.0001$; 40-59 year olds: R = 0.29, $p < 0.0001$) but not in respondents aged 60 and older. The strongest correlation for vigorous physical activity was observed in males aged 40 to 59 years ($R=0.35$, $p < 0.0001$).

Mean difference analysis

The mean difference between $MVPA_{ALL}$ and $PAAQ_{REC+TRA}$ was less (-4.4 $min \cdot d^{-1}$, 95% confidence interval [CI]: -7.5 to -1.3) than the difference between $MVPA_{BOUTS}$ and $PAAQ_{REC+TRA}$ (-16.3 $min \cdot d^{-1}$, 95% CI: -18.7 to -14.0) (data not shown). The mean difference between $MVPA_{ALL}$ and $PAAQ_{TOTAL}$ was less (-26.2 $min \cdot d^{-1}$, 95% CI: -33.0 to -19.4) than the difference between $MVPA_{BOUTS}$ and

Table 1
Average daily minutes of accelerometer-measured physical activity by age and sex, household population aged 18 to 79, Canada excluding territories, 2014 and 2015

		Moderate-to-vigorous physical activity$_{ALL}$			Moderate-to-vigorous physical activity$_{BOUTS}$			Vigorous physical activity			Light physical activity		
			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
	Sample size	Mean	from	to	Mean	from	to	Mean	from	to	Mean	from	to
18 to 79 years	2372	22.5	19.8	25.1	10.5	8.7	12.4	3.0	2.4	3.5	200.1	190.7	209.5
Males†	1174	25.3	21.0	29.6	11.7	9.0	14.4	3.7	2.7	4.7	201.5	190.3	212.7
Females	1198	19.8*	16.9	22.8	9.4	7.3	11.5	2.3*	1.8	2.8	198.7	188.7	208.7
18 to 39 years‡	832	26.6	22.6	30.5	11.6	8.4	14.9	3.7	2.5	4.8	203.6	188.8	218.4
Males	406	29.3	24.2	34.3	12.7	8.3	17.0	4.4[E]	2.3	6.5	199.7	184.4	214.9
Females	426	24.0	18.7	29.3	10.7	7.1	14.2	2.9	1.9	4.0	207.3	184.4	230.1
40 to 59 years	810	22.8	19.3	26.2	10.8	8.6	13.1	3.2[E]	2.0	4.4	212.0	205.2	218.8
Males	400	26.3	19.8	32.8	12.4	8.8	15.9	4.1[E]	2.0	6.2	216.0	202.2	229.9
Females	410	19.3	15.0	23.6	9.3	6.2	12.4	2.3	1.5	3.0	208.0	196.1	219.9
60 to 79 years	730	15.5*	13.0	18.0	8.3*	6.5	10.1	1.5*	1.0	2.1	175.7*	164.1	187.3
Males	368	17.1	13.9	20.3	9.0	6.5	11.6	1.9[E]	0.9	2.8	181.0	162.4	199.6
Females	362	14.0	10.6	17.3	7.6	5.9	9.3	1.2[E]	0.7	1.8	170.8	154.2	187.4

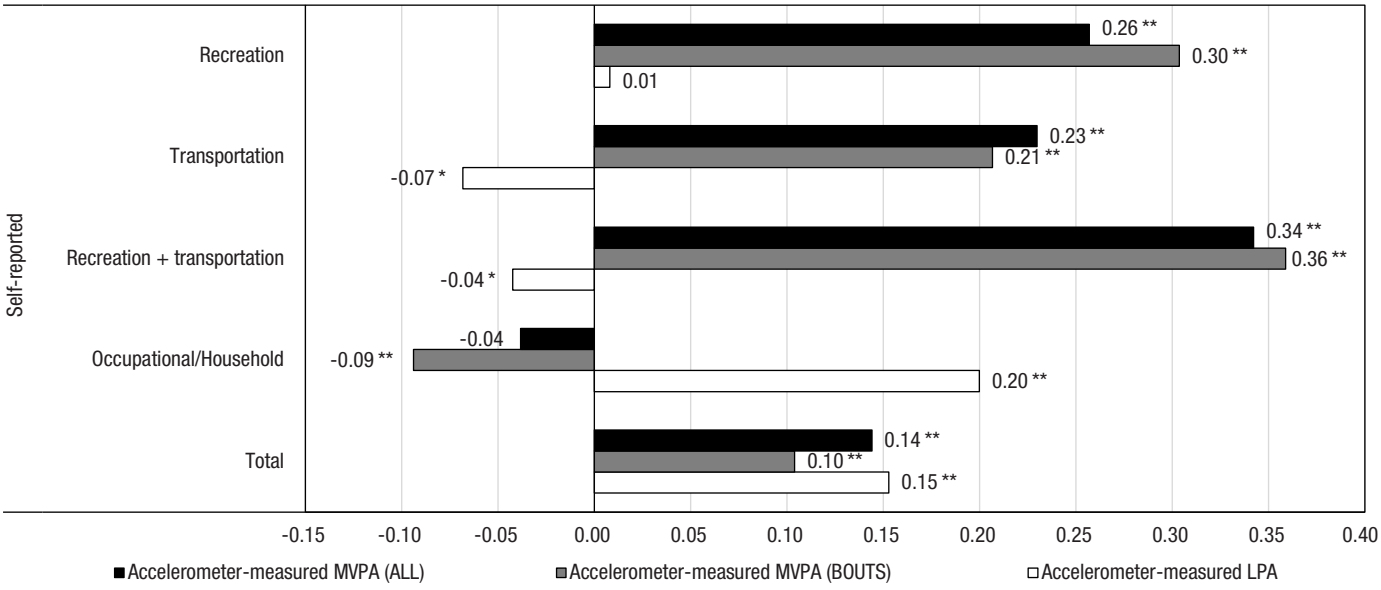
[E] use with caution
* significantly different from reference category ($p < 0.05$)
† reference sex group
‡ reference age group
ALL = all minutes of MVPA included
BOUTS = only minutes of MVPA accumulated in 10-minute bouts included
Note: Means and 95% confidence intervals are based on weighted estimates.
Source: Canadian Health Measures Survey, Cycle 4 (2014 and 2015).

Table 2
Average daily minutes of self-reported domains of physical activity by age and sex, household population aged 18 to 79, Canada excluding territories, 2014 and 2015

		Recreation physical activity			Transportation physical activity			Recreation + transportation physical activity			Occupational and household physical activity			Total physical activity			Vigorous physical activity		
			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
	Sample size	Mean	from	to	Mean	from	to	Mean	from	to	Mean	from	to	Mean	from	to	Mean	from	to
18 to 79 years	2372	11.4	9.2	13.7	15.4	13.6	17.2	26.9	23.6	30.1	21.8	16.3	27.3	48.7	41.8	55.6	4.6	3.5	5.7
Males†	1174	12.5	9.5	15.4	17.6	14.9	20.2	30.0	25.8	34.2	29.0	19.0	38.9	59.0	46.9	71.1	5.6	3.8	7.3
Females	1198	10.5*	7.9	13.1	13.4	10.8	16.0	23.9*	20.1	27.6	15.0*[E]	8.1	21.8	38.8*	30.6	47.1	3.6*	2.7	4.6
18 to 39 years‡	832	15.2	11.2	19.3	17.5	12.3	22.7	32.8	25.9	39.6	24.9[E]	14.0	35.8	57.6	44.1	71.1	6.3[E]	3.6	9.1
Males	406	15.1[E]	8.7	21.6	20.3[E]	12.4	28.2	35.4	25.0	45.8	F	F	F	69.0[E]	41.2	96.7	8.2[E]	4.5	12.0
Females	426	15.4[E]	8.8	21.9	14.9	10.6	19.2	30.2	21.2	39.2	16.7	11.3	22.0	46.9	36.3	57.4	4.5*[E]	2.0	7.0
40 to 59 years	810	10.7	7.2	14.2	14.9	11.7	18.1	25.6	21.4	29.8	23.2[E]	12.9	33.6	48.8	37.4	60.2	4.5	3.2	5.7
Males	400	13.2[E]	8.3	18.1	16.5	11.8	21.3	29.7	23.1	36.4	28.3	20.1	36.6	58.1	47.1	69.1	4.8[E]	2.5	7.1
Females	410	8.2[E]	5.0	11.4	13.3*	9.5	17.1	21.5*	16.6	26.3	F	F	F	39.7*[E]	23.8	55.6	4.1	2.7	5.5
60 to 79 years	730	6.5	4.8	8.2	13.0*	9.9	16.0	19.4*	15.9	23.0	14.6	10.4	18.8	34.1*	28.3	39.9	2.0*[E]	1.2	2.8
Males	368	6.9	4.0	9.8	14.8	10.0	19.5	21.7	15.7	27.6	22.5	14.4	30.6	44.2	34.1	54.3	2.5[E]	1.5	3.5
Females	362	6.1	3.9	8.3	11.2	8.4	14.1	17.4	13.9	20.9	7.3*[E]	4.5	10.1	24.6*	20.9	28.4	F	F	F

[E] use with caution
F too unreliable to be published
* significantly different from reference category ($p < 0.05$)
† reference sex group
‡ reference age group
Total = recreation + transportation + occupational/household
Note: Means and 95% confidence intervals are based on weighted estimates.
Source: Canadian Health Measures Survey, Cycle 4 (2014 and 2015).

Figure 1
Pearson correlations between accelerometer-measured and questionnaire-reported physical activity variables, household population aged 18 to 79, Canada excluding territories, 2014 and 2015



* significantly different from reference category ($p < 0.05$)
** significant different from reference category ($p < 0.001$)
ALL = all minutes of MVPA included
BOUTS = only minutes of MVPA accumulated in 10-minute bouts included
LPA = light physical activity
MVPA = moderate-to-vigorous physical activity
Source: Canadian Health Measures Survey, Cycle 4 (2014 and 2015).

$PAAQ_{TOTAL}$ (-38.2 min·d^{-1}, 95% CI: -44.6 to -31.7) (data not shown). The mean difference (accelerometer-measured minus self-reported) in minutes for $PAAQ_{TOTAL}$ was within +/- 12.5 minutes in 50% of respondents when $MVPA_{ALL}$ was used (Figure 2) and 55% of respondents when $MVPA_{BOUTS}$ was used (data not shown). The mean difference (accelerometer-measured minus self-reported) in minutes for $PAAQ_{REC+TRA}$ was within +/- 12.5 minutes in 43% of respondents when $MVPA_{ALL}$ was used (Figure 2) and 44% of respondents when $MVPA_{BOUTS}$ was used (data not shown). The mean difference between self-reported VPA was -1.6 minutes per day [95% CI: -2.7 to -0.5] for VPA_{ALL} and -3.0 minutes per day [95% CI: -3.96 to -1.96] for VPA_{BOUTS}. The difference between measured (VPA_{ALL}) and reported vigorous physical activity was within +/- 5 minutes in 77% of people (data not shown). No notable differences in mean difference existed for age, sex and obesity status (underweight and healthy weight versus overweight or obese); however, differences were evident by quintile of accelerometer-measured minutes of $MVPA_{ALL}$ (Figure 3). Less active people were more likely than the most active people to report greater physical activity than accumulated on the accelerometer (i.e., mean difference was a negative number). On average, the most active people reported less activity than was measured on the accelerometer (i.e., mean difference was a positive value). The contrast in mean difference between $MVPA_{ALL}$ and $PAAQ_{REC+TRA}$ between the lowest and highest quintiles was significant (-9.2 min·d^{-1} [95% CI: -12.9 to -5.5] for the lowest quintile, versus +5.1 min·d^{-1} [95% CI: -4.5 to +14.7] for the highest quintile) (Figure 3).

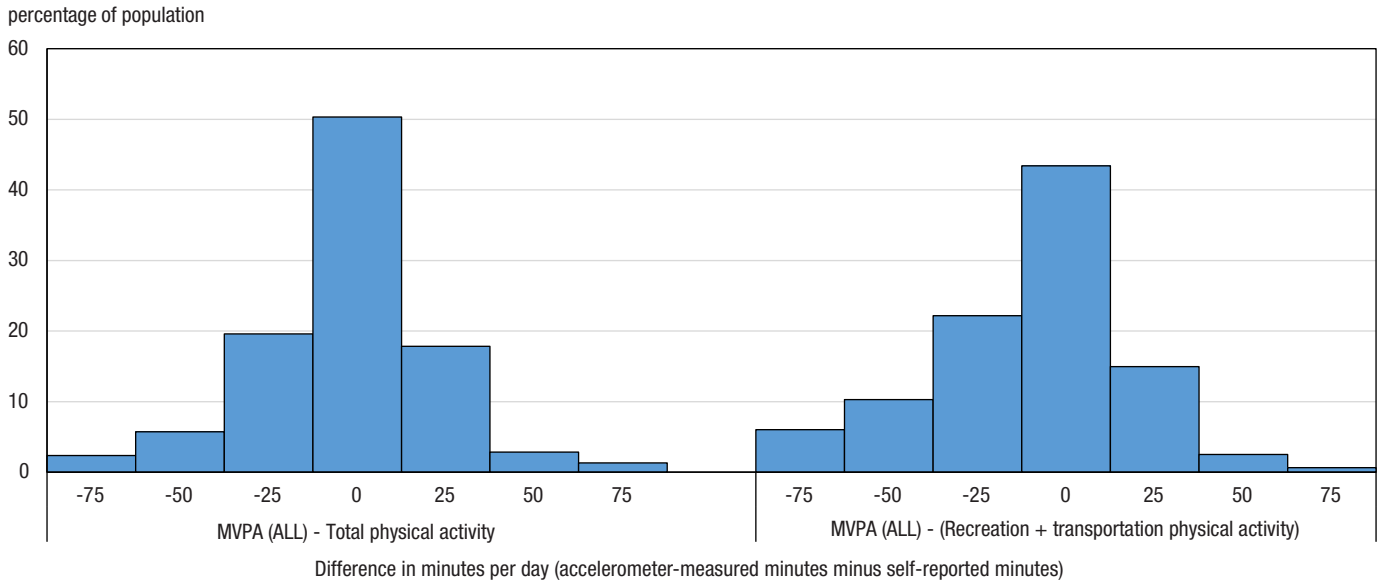
Adherence to physical activity guidelines

Percentage adherence to the current PAG (≥ 150 minutes of MVPA per week) varied according to which variable was used. The percentage was lower for the accelerometer-measured variables (17% for $MVPA_{BOUTS}$ and 39% for $MVPA_{ALL}$) than for the self-reported variables (46% for $PAAQ_{REC+TRA}$ and 60% for $PAAQ_{TOTAL}$) (Figure 4). A classification analysis showed that accelerometer-measured $MVPA_{ALL}$ and self-reported ($PAAQ_{REC+TRA}$) were in agreement 67% of the time (i.e., both classifying respondents as either meeting or not meeting the PAG) (Figure 5). The remaining 33% was split between the accelerometer classifying respondents as meeting the PAG but not the PAAQ (20%), and the PAAQ classifying respondents as meeting the PAG but not the accelerometer (13%).

Association with obesity markers

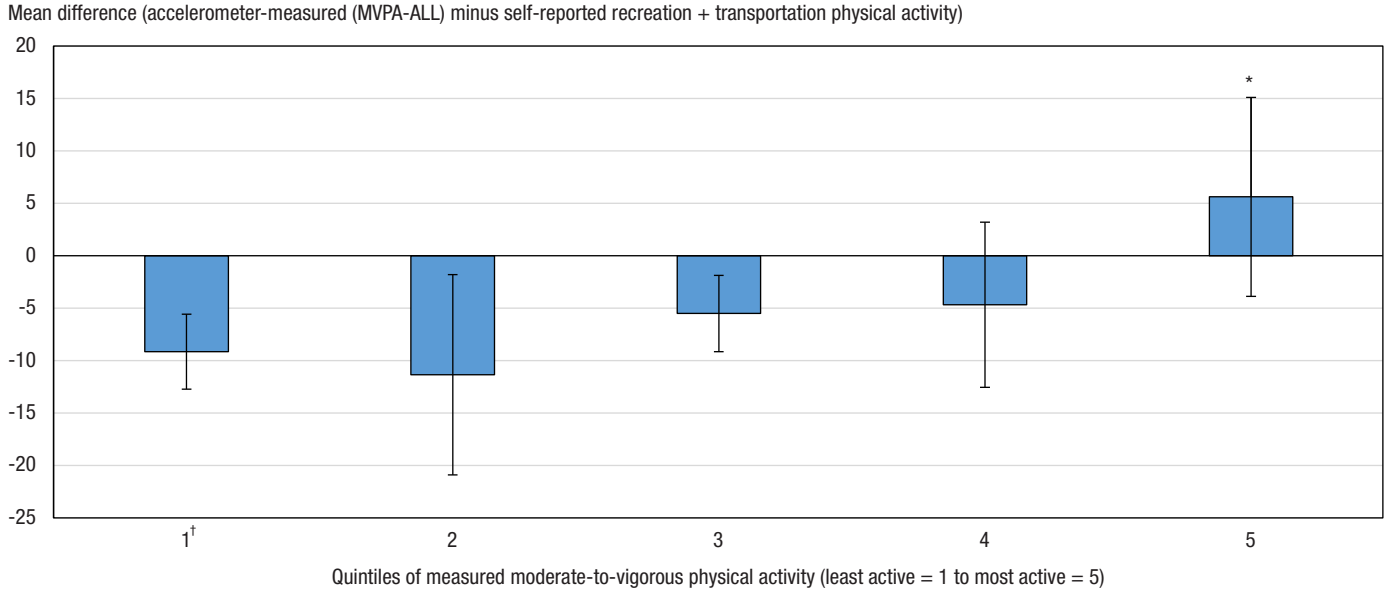
According to linear regression models adjusted for age and sex, $MVPA_{ALL}$, $MVPA_{BOUTS}$, $PAAQ_{REC}$, $PAAQ_{TRA}$ and $PAAQ_{REC+TRA}$ were all negatively associated with BMI and WC, while measured LPA and $PAAQ_{OCC}$ were not associated with either obesity measure (Figure 6). The effect size (beta) for the

Figure 2
Distribution of difference in mean minutes per day between accelerometer-measured moderate-to-vigorous physical activity and self-reported physical activity, household population aged 18 to 79, Canada, 2014 and 2015



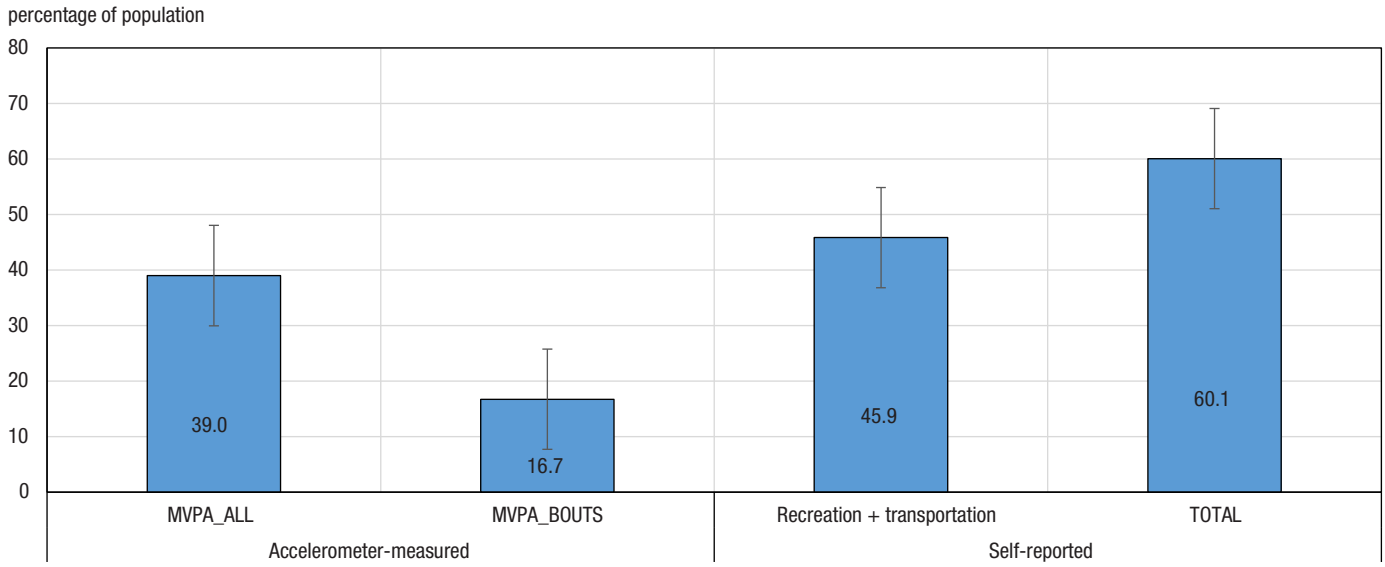
MVPA = moderate-to-vigorous physical activity
ALL = all minutes of MVPA included
Total = recreation + transportation + occupational/household
Source: Canadian Health Measures Survey, Cycle 4 (2014 and 2015).

Figure 3
Mean difference between accelerometer-meaured and self-reported physical activity, presented by quintile of physical activity level, household population aged 18 to 79, Canada excluding territories, 2014 and 2015



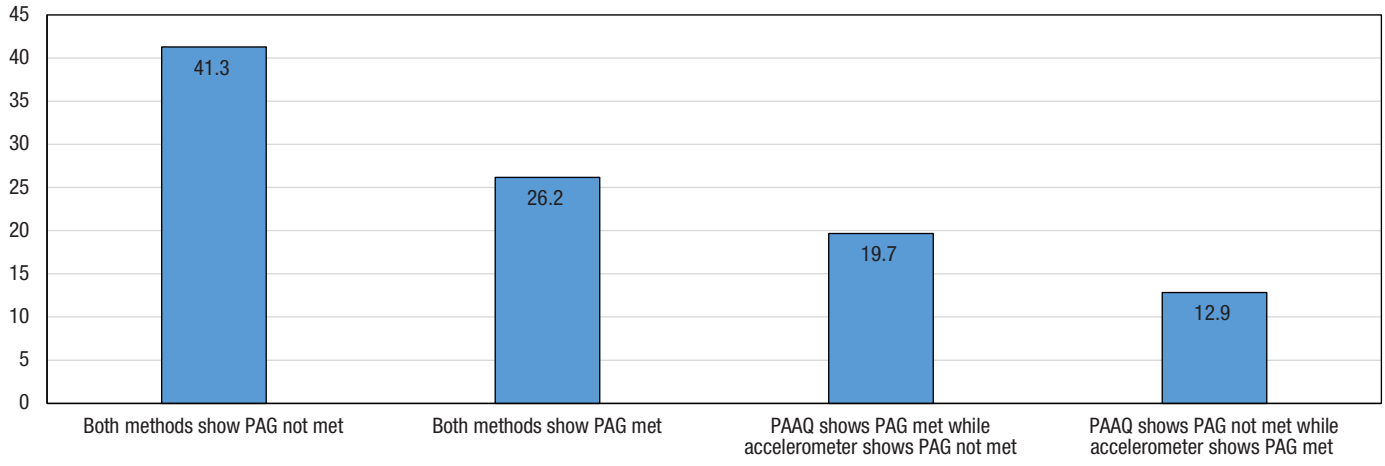
* significantly different from reference category ($p < 0.05$)
† reference category
MVPA = moderate-to-vigorous physical activity
ALL = all minutes of MVPA included
Source: Canadian Health Measures Survey, Cycle 4 (2014 and 2015).

Figure 4
Adherence to the physical activity guideline by physical activity variable, household population aged 18 to 79, Canada excluding territories, 2014 and 2015



MVPA = moderate-to-vigorous physical activity
ALL = all minutes of MVPA included
BOUTS = only minutes of MVPA accumulated in 10-minute bouts included
Total = recreation + transportation + occupational/household
Source: Canadian Health Measures Survey, Cycle 4 (2014 and 2015).

Figure 5
Percentage of population where the physical activity guideline was met by both the questionnaire and the accelerometer, neither the questionnaire nor the accelerometer, the questionnaire only, and the accelerometer only, household population aged 18 to 79, Canada excluding territories, 2014 and 2015



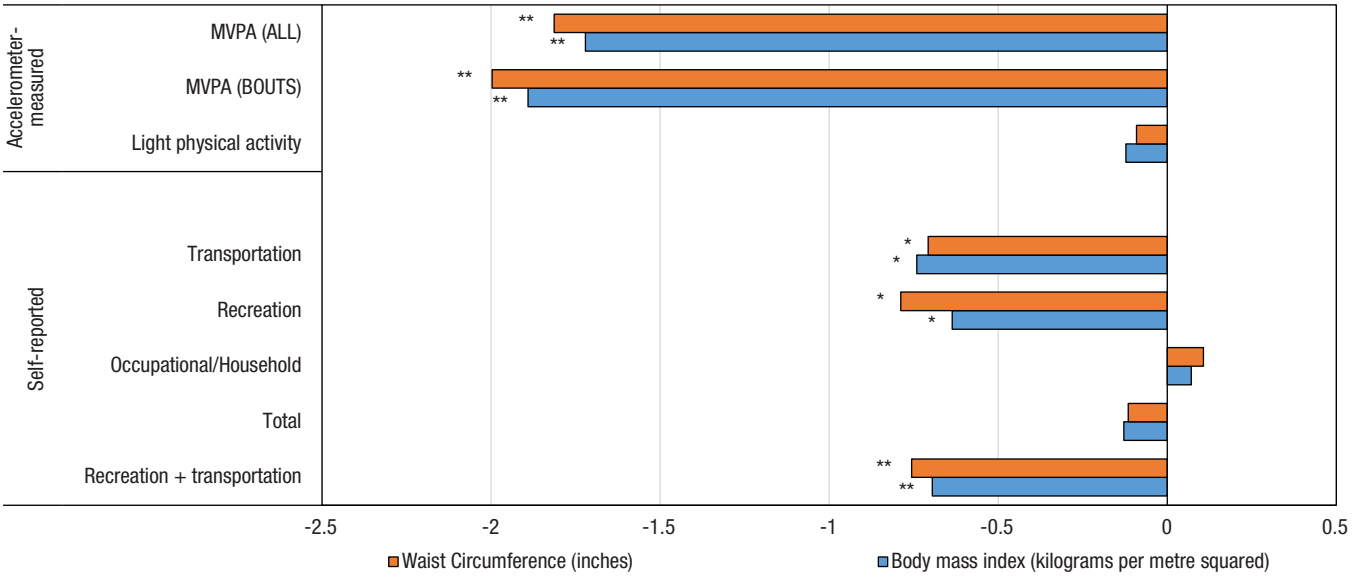
PAG = physical activity guidelines
PAAQ = physical activity adult questionnaire
Source: Canadian Health Measures Survey, Cycle 4 (2014 and 2015).

association was greater for the measured variables than for the self-reported variables. While the level of significance for $PAAQ_{REC+TRA}$ (p = 0.0005 for BMI and p = 0.0006 for WC) was greater than for either $PAAQ_{REC}$ (p = 0.016 for BMI and p = 0.01 for WC) or $PAAQ_{TRA}$ (p = 0.046 for BMI and p = 0.040 for WC) on their own, the effect size (beta) was not any greater for $PAAQ_{REC+TRA.}$ This was explained by wider confidence intervals around the association for the individual variables than for the combination of recreation and transportation (data not shown).

Discussion

This study observed large differences in physical activity estimates and modest correlation between self-reported and accelerometer-measured physical activity. The highest strength of correlation between accelerometer-measured and self-reported data in this study was observed between the sum of self-reported recreation and transportation physical activity and measured minutes of MVPA (Figure 1). Associations with health markers existed between both measured and reported physical activity variables, but were stronger when measured variables were used. Differences in the percentage of Canadians meeting the PAG were observed between measured and reported methods. This therefore presents a surveillance reporting challenge. While the results suggest that accelerometer-measured and self-reported physical activity estimates should not be used interchangeably, the two methods provided PAG adherence values at the population level that were somewhat aligned (39% versus 46%, Figure 4), and there was also some consistency in the direction of association with markers of obesity. Collectively, the results of this study highlight the importance for data users to understand the differences between methods and to exercise caution in using estimates derived from these methods interchangeably. The level of correlation observed in this study is similar to that obtained in a previous analysis using the same questionnaire in a preliminary CHMS sample[6] and stronger than previously observed with other questionnaire tools used in the CHMS, such as the IPAQ (R = 0.20)[6] or MLTPAQ (R = 0.22 to 0.26).[5] The previous analysis of a preliminary CHMS sample (n = 112) lacked the sample size to investigate correlations by domain, but reported that $PAAQ_{TOTAL}$ was moderately correlated with measured $MVPA_{BOUTS}$ at a level of R = 0.44.[6] The degree of correlation between the same variables in the present study was weaker (R = 0.14) and likely a reflection of some bias in the small sample used in the preliminary study. The present study did observe higher correlations (e.g., R = 0.42) between $PAAQ_{REC+TRA}$ and MVPA

Figure 6
Association between measured and reported physical activity variables and body mass index and waist circumference, presented as the beta coefficient from linear regression models multiplied by 30 minutes, household population aged 18 to 79, Canada excluding territories, 2014 and 2015



* significantly different from reference category (p < 0.05)
** significantly different from reference category (p < 0.001)
MVPA = moderate-to-vigorous physical activity
ALL = all minutes of MVPA included
BOUTS = only minutes of MVPA accumulated in 10-minute bouts included
Total = recreation + transportation + occupational/household
Note: Models controlled for age and sex.
Source: Canadian Health Measures Survey, Cycle 4 (2014 and 2015).

in 40- to 59-year-old men. $PAAQ_{REC}$ and $PAAQ_{TRA}$ were positively correlated, while $PAAQ_{OCC}$ was negatively correlated with measured MVPA. This resulted in a weakening of the level of correlation observed between $PAAQ_{TOTAL}$ and accelerometer-measured MVPA.

A comparison between self-reported and accelerometer-measured physical activity in the 2005 and 2006 National Health and Nutrition Examination Survey (NHANES)[20] reported similar correlation coefficients by domain: overall total (R = 0.27 in NHANES and R = 0.22 in CHMS), recreational activity (R = 0.29 in NHANES and R = 0.26 in CHMS), transportation activity (R = 0.20 in NHANES and R = 0.23 in CHMS), and occupational or household activity (R = 0.08 in NHANES and R = -0.04 in CHMS). The questionnaires used in the NHANES and present analyses were different (Tucker and colleagues assigned metabolic equivalent values to activities from the Compendium of Physical Activities[21]), but both were designed to provide an estimate of time spent in the various domains of physical activity. The NHANES results also suggest that questions about household and occupational physical activity are likely capturing a combination of LPA and MVPA. Systematic reviews have reported wide variation between studies in the degree and direction of correlation between measured and reported physical activity.[7,8] Further, the strength of correlation varies within studies by age and sex,[7,13] obesity status[22] and physical activity level.[23] The present study observed only modest differences in correlation and mean difference by age, sex and obesity status; however, a pattern was evident by level of physical activity. Less active people were more likely than the most active quintile of respondents to report more activity than they accumulated on the accelerometer. This may be a reflection that more active respondents were more likely to report energetic activities that are easier to recall accurately (e.g., sport participation or exercise class) and are likely to be predominantly MVPA, while less active respondents may have reported less energetic activities (e.g., gardening, chores or incidental walking) that are harder to recall accurately and are likely to comprise both LPA and MVPA. Previous research has shown that more energetic or intense activities relate better to accelerometer-measured data.[23] The agreement between measured and reported vigorous physical activity was quite good in this study (the mean difference was within +/- 5 minutes per day in 77% of respondents) and may provide further evidence of more accurate reporting by the most active people in the study.

The relatively low correlation and large mean differences between accelerometer-measured and self-reported data observed in this study as well as in others is not surprising given that they **do not measure the same constructs**. Questionnaires capture **behaviour** or perceived time spent in specific activities or domains (e.g., work or school, play or leisure, or transport) while objective measurement devices capture movement or continuous measures of bodily acceleration above a defined threshold.[24] Leading experts are now asserting that direct comparisons between estimates from reported and measured methods are unsuitable[24] and that researchers should stop asking which method is "correct" and rather focus on the richness and complementary information that both methods can offer.[25] While the present study did use traditional approaches to compare accelerometer-measured and self-reported estimates, such as correlation and mean difference analyses, it also examined whether the differences observed were logical and whether there was any evidence that the two approaches told a similar story. The finding that $PAAQ_{REC+TRA}$, and not $PAAQ_{OCC}$, was correlated with measured MVPA is notable, particularly because occupational or household activity was correlated with measured LPA. While the strength of association with BMI and WC was weaker when self-reported physical activity was used, the presence and direction of associations were similar for measured MVPA and $PAAQ_{REC+TRA}$.

What is already known on this subject?

- Self-reported and accelerometer-measured physical activity levels generally exhibit low correlation and agreement.
- Previous comparisons between self-reported and accelerometer-measured physical activity using Canadian Health Measures Survey (CHMS) data have exhibited low correlation between methods and large differences in the number of minutes of physical activity accumulated per day and in adherence to physical activity guidelines.
- A new physical activity questionnaire module was adopted in the 2014-to-2015 CHMS with the aim of overcoming some of the limitations observed with previous questionnaire modules.

What does this study add?

- On average, Canadian adults reported more physical activity than they accumulated on the accelerometer.
- The correlation between self-reported data from the new questionnaire module and accelerometer-measured physical activity was low. This finding is consistent with results observed for other questionnaire modules.
- The sum of recreation- and transportation-based physical activity was most closely aligned with accelerometer-measured data.
- This study confirms previous reports that questionnaires and accelerometers measure different aspects of physical activity and therefore should not be used interchangeably.

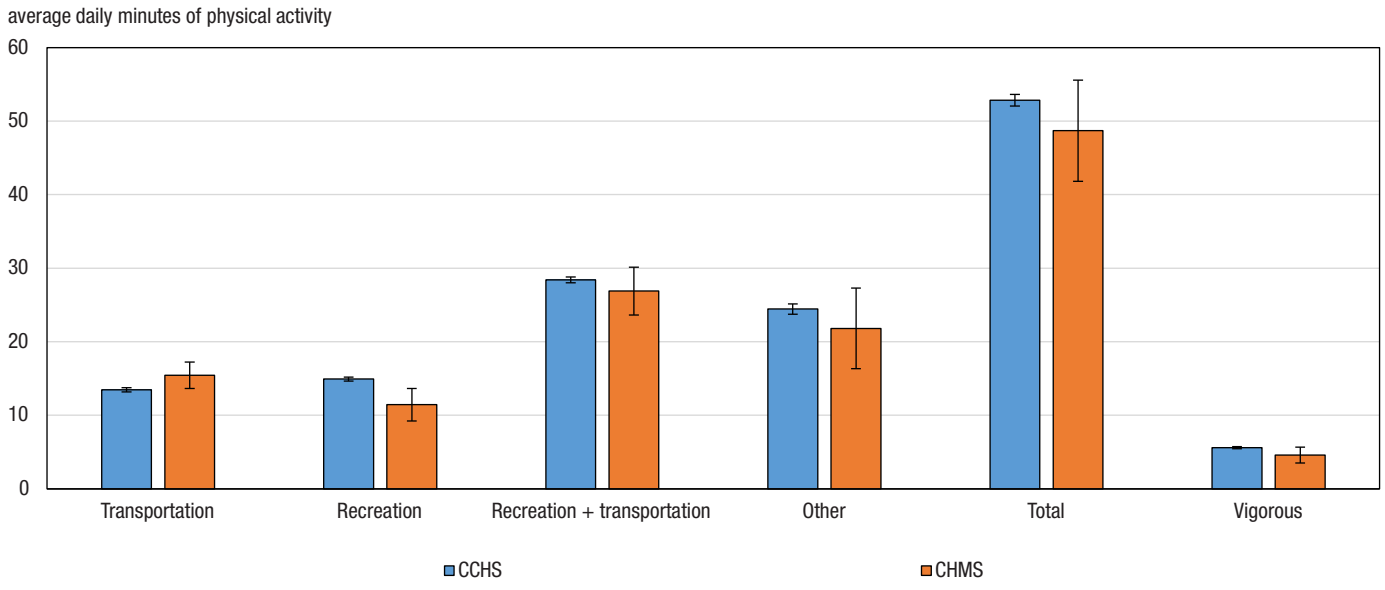
This finding is consistent with the literature.[2,3,26] The strength of association between reported variables and BMI and WC was higher for $PAAQ_{REC+TRA}$ than for either domain alone or for $PAAQ_{TOTAL}$ (table 3). It appears that $PAAQ_{OCC}$ was weakening the association between $PAAQ_{TOTAL}$ and the obesity markers. This finding is consistent with the correlation analysis.

This study has important limitations that could explain, in part, the lack of agreement and low correlation between methods. Firstly, the seven days of accelerometer wear time did not match directly with the self-report response timeframe (i.e., the accelerometer and questionnaire measures occurred during different weeks). Intra-individual variability in activity habits between different days and weeks can be quite high.[27] Therefore, this analysis is relying on an assumption that both measures are capturing a reflection of a given respondent's "typical" physical activity habits. This unfortunate mismatch in timing of measurement also means that the correlation strength observed in this study is likely lower than what would have resulted if the two difference measurements occurred simultaneously. Secondly, the inclusion of cycling as an example in the questionnaire for both recreation- and transportation-based activity bears noting, in light of the fact that accelerometry generally does not capture cycling accurately. Finally, asking respondents to report only activities that **"make you sweat at least a little and breathe harder"** may be interpreted differently by different people, and may not always exclusively capture MVPA. The correlation between LPA and the occupational or household domain suggests that respondents were reporting a combination of LPA and MVPA for this domain.

Both accelerometer-measured physical activity and self-reported measures have been shown by the literature to have beneficial associations with health. However, the cost of accelerometers limits the sample size of surveys that employ them. In Canada, currently, self-reported modules are the best option for reporting across all provincial and territorial jurisdictions. Furthermore, because of their cost, accelerometer data are not collected in many countries. As a result, international comparisons are dependent on self-reported data. In Canada, accelerometers are used to measure physical activity in the CHMS (about 5,000 to 6,000 respondents every two years) but not in the much larger CCHS (about 65,000 respondents every year). The difference is important, as the smaller sample size and clustered sampling frame of the CHMS mean that it is possible to report only national-level estimates every two years while the CCHS data can be reported at the provincial and territorial and health region levels. The ability to examine disparities across the country is an important advantage offered by the self-reported physical activity outcomes obtained via the CCHS. The physical activity estimates by domain and overall were similar between the CHMS and a larger sample from the CCHS (Figure 7). This suggests good reproducibility of the questionnaire module.

Accelerometers are not practical in all settings; however, the richness of accelerometer data cannot be understated. In addition to mitigating concerns about social desirability bias and recall difficulty, the per-minute resolution of actual movement across a seven-day period has led to important contributions to the understanding of how movement relates to health. As the evidence base

Figure 7
Average daily minutes of physical activity, by domain and data source, household population aged 18 to 79, Canada excluding territories, 2014 and 2015 (CHMS) and 2015 and 2016 (CCHS)



Total = recreation + transportation + occupational/household
Source: Canadian Health Measures Survey (CHMS), Cycle 4 (2014 and 2015), and Canadian Community Health Survey (CCHS), 2015 and 2016.

linking accelerometer-measured physical activity and health grows, the research community may develop complementary PAGs based on device-measured movement.[24] In the future, these devices may become more readily available and efficient, and consequently facilitate national tracking of adherence to guidelines by means of objective measures.[24] Schuna and colleagues reported that respondents meeting the PAG according to reported data accumulated only 56 minutes per week of $MVPA_{BOUTS}$ when an accelerometer was used.[28] When data from the present study are used, the corresponding average $MVPA_{BOUTS}$ value for respondents who met the PAG according to $PAAQ_{REC+TRA}$ was 116 minutes per week (data not shown). The average $PAAQ_{REC+TRA}$ reported by respondents accumulating ≥ 150 minutes per week of $MVPA_{BOUTS}$ was 355 minutes per week. More detailed analyses are needed to clarify whether having different PAGs for objective versus self-reported measures is realistic.

The recently published 2018 Physical Activity Guidelines Advisory Committee Scientific Report[29] indicates that physical activity accumulated in bouts of any length is associated with health benefits (i.e., bouts need not be 10 minutes long). Interestingly, the present study found that the inclusion of all minutes of measured MVPA was more closely aligned with self-reported activity. Further, researchers are increasingly arguing against threshold-based guidelines, given that any dose of physical activity (particularly moving from none to a little) is associated with the greatest health benefit.[2,30] This evolution in the evidence base linking physical activity and health in adults will be used to inform the revision of PAG in Canada and around the world. Future versions of the PAAQ and any resultant analyses similar to the present one will have to adapt accordingly.

The newly developed Canadian PAAQ was successfully implemented into two large Canadian health surveillance surveys, overcomes key limitations of previous self-report tools used, and aligns with the current focus on capturing activity across the various domains. This study found that MVPA captured by the newly developed Canadian PAAQ module achieved low correlation and agreement with physical activity measured by accelerometry. The study also found some agreement in population-level adherence to the PAG and in associations with markers of obesity. These findings provide further evidence to support the idea that self-reported and objectively measured physical activity levels should not be used interchangeably. Rather, greater focus should be placed on maximizing the richness and potential that **both** methods offer to help increase the understanding of how behaviour and movement relate to health. ■

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Appendix A

Physical Activity Adult Questionnaire (PAAQ)

Adapted from Canadian Health Measures Survey documentation available at http://www23.statcan.gc.ca/imdb-bmdi/instrument/5071_Q1_V5-eng.pdf.

Preamble: The following questions are about various types of physical activities done in the last seven days. I want you to only think of activities you did for a minimum of 10 continuous minutes.

1. **Transportation**
   a. In the last seven days, did you use active ways like walking or cycling to get to places such as work, school, the bus stop, the shopping centre or to visit friends?
      Interviewer's note: Do not include walking, cycling or other activities done purely for leisure. These activities will be asked about later.
      i. Yes/No
   b. In the last seven days, on which days did you do these activities?
      i. Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Sunday
   c. How much time in total, in the last seven days, did you spend doing these activities? Please only include activities that lasted a minimum of 10 continuous minutes.
      i. ___minutes or hours (min: 0, max: 168)
2. **Recreation**
   a. Not including activities you just reported, in the last seven days, did you do sports, fitness or recreational physical activities, organized or non-organized, that lasted a minimum of 10 continuous minutes?
      Interviewer's note: Examples are walking, home or gym exercise, swimming, cycling, running, skiing, dancing and all team sports.
      i. Yes/No
   b. Did any of these recreational physical activities make you sweat at least a little and breathe harder?
      i. Yes/No
   c. In the last seven days, on which days did you do these recreational activities that made you sweat at least a little and breathe harder?
      i. Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Sunday
   d. In the last seven days, how much time in total did you spend doing these activities that made you sweat at least a little and breathe harder?
      i. ___minutes or hours (min: 0, max: 168)
3. **Occupational or household**
   a. In the last seven days, did you do any other physical activities while at work, in or around your home or while volunteering?
      Interviewer's note: Examples include carrying heavy loads, shoveling, and household chores such as vacuuming or washing windows. Please remember to only include activities that lasted a minimum of 10 continuous minutes.
      i. Yes/No
   b. Did any of these other physical activities make you sweat at least a little and breathe harder?
      i. Yes/No
   c. In the last seven days, on which days did you do these other activities that made you sweat at least a little and breathe harder?
      i. Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Sunday
   d. In the last seven days, how much time in total did you spend doing these activities that made you sweat at least a little and breathe harder?
      i. ___minutes or hours (min: 0, max: 168)
4. **Vigorous physical activity**
   a. You have reported a total of ___minutes of physical activity (insert sum of transportation, recreation and occupational or household physical activity). Of these activities, were there any of vigorous intensity, meaning they caused you to be out of breath?
      i. Yes/No
   b. In the last seven days, how much time in total did you spend doing vigorous activities that caused you to be out of breath? Please only include activities that lasted a minimum of 10 continuous minutes.
      i. ___minutes or hours (min: 0, max: 168)