Component of Statistics Canada Catalogue no. 82-003-X
Health Reports

Article

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April 2012

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Abstract

Background
The accurate measurement of time devoted to physical activity, sedentary pursuits and sleep is difficult and varies considerably between surveys. This has implications for population surveillance and understanding how these variables relate to health.

Methods
This sample of children (n = 878) was from the 2007 to 2009 Canadian Health Measures Survey. Moderate- to-vigorous physical activity (MVPA), sedentary behaviour and sleep duration were assessed using both a questionnaire and an accelerometer. This article compared parent-reported and directly measured physical activity, sedentary behaviour and sleep, and examined their associations, alone or in combination, with selected health markers in children aged 6 to 11.

Results
According to parent reports, the children in this study had an average of 105 minutes of MVPA, 2.5 hours of screen time and 9.7 hours of sleep per day; accelerometers recorded 63 minutes of MVPA, 7.6 hours of sedentary time and 10.1 hours of sleep per day. MVPA, measured by parent-report or accelerometry, was significantly associated with body mass index. In a regression model, directly measured MVPA and sleep were significantly associated with body mass index, and directly measured MVPA was significantly associated with waist circumference. Parent-reported screen time approached a significant association with body mass index.

Interpretation
Time estimates and associations with health markers varied between parent-reported and directly measured physical activity, sedentary behaviour and sleep in children. These differences are important to understand before the two measurement techniques can be used interchangeably in research and health surveillance.

Keywords
Blood pressure, body mass index, cholesterol, data collection, health surveys, movement, obesity

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Among Canadian children, obesity rates are high,[1] physical fitness has decreased,[2] and few meet current physical activity recommendations.[3] Research focused on organized, purposeful moderate-to-vigorous physical activity (MVPA) has tended to ignore sedentary behaviour and sleep,[4] which are independently associated with obesity and other aspects of health.[5-7]

Accurate assessment of children's physical activity, sedentary behaviour and sleep is needed for health surveillance, evaluation of interventions, and understanding of the determinants of health. Inconsistencies in choice of measurement methodology over time have made it difficult for researchers, practitioners and policy-makers to track and understand the health impact of physical activity at the population level.[8]

Physical activity is associated with a reduced risk of cardiovascular disease, some types of cancer, diabetes, obesity, high blood pressure, depression, stress and anxiety.[9-12] These links with health have led to growing interest in how physical activity is measured. A systematic review comparing self-reported and direct measures in children and youth found low correlations and a tendency for self-reports to overestimate activity levels.[13]

Sedentary behaviour—low-energy-expenditure pursuits (less than or equal to 1.5 metabolic equivalents)—is also strongly associated with adverse health markers, independent of those attributed to a lack of MVPA.[6] Accurate measurement, however, is a challenge. Self- or parent-reports capture only limited aspects of sedentary behaviour (for example, screen time).[14] On the other hand, direct measures can determine the overall quantity of sedentary time, but they do not provide the contextual information that is available from self-reports. Consequently, a combination of measurement techniques may be warranted.[15]

The increase in the prevalence of childhood obesity has coincided with a decline in sleep duration.[16] Numerous cross-sectional studies have found significant associations between short sleep duration and higher obesity among children and youth.[5,7,17] While sleep duration is often assessed by self-reports, the quantity and quality of sleep have been successfully measured via direct observation and actigraphy.[18,19] A combination of self-report and direct measurement has been recommended to gain a complete profile of sleep health.[20]

The 2007 to 2009 Canadian Health Measures Survey (CHMS) collected both parent-reported and directly measured (accelerometry) data about children's activity. This analysis uses that information to examine MVPA, sedentary behaviour and sleep duration in children aged 6 to 11. The objective was to compare and contrast findings from these data collection methods, and explore differences in their associations with health markers in children.

Methods

Data source

Cycle 1 of the CHMS collected data from a nationally representative sample of the population aged 6 to 79 living in private households. Residents of Indian Reserves, Crown lands, institutions and certain remote regions, and full-time members of the Canadian Forces, were excluded. Data were collected at 15 sites across the country from March 2007 through February 2009. Approximately 96.3% of Canadians were represented. The survey involved an interview in the respondent's home and a visit to a mobile examination centre for a series of physical measurements.

Ethics approval to conduct the survey was obtained from Health Canada's Research Ethics Board.[21] For children aged 6 to 11, written informed consent was obtained from a parent or legal guardian, in addition to written informed assent from the child. Participation was voluntary; respondents could opt out of any part of the survey at any time.

The response rate for selected households was 69.6%, meaning that in 69.6% of the households, a resident provided the sex and date of birth of all household members. One or two members of each responding household were chosen to participate in the survey. Details about the CHMS are available elsewhere.[22,23]

Accelerometry data reduction

Upon completion of the mobile examination centre visit, ambulatory respondents were asked to wear an Actical accelerometer (Phillips – Respironics, Oregon, USA) over their right hip on an elasticized belt during their waking hours for seven consecutive days. The Actical (dimensions: 2.8 x 2.7 x 1.0 centimetres; weight: 17 grams) measures and records time-stamped acceleration in all directions, providing an index of physical activity intensity. The digitized values are summed over a user-specified interval of one minute, resulting in a count value per minute (cpm). Accelerometer signals are also recorded as steps per minute. The Actical has been validated to measure physical activity in adults and children.[24-27]

The monitors were initialized to start collecting data in one-minute epochs at midnight following the mobile examination centre appointment. All data were blind to respondents while they wore the device. Respondents were given a prepaid envelope in which to return the monitors to Statistics Canada, where the data were downloaded and the monitor was checked to determine if it was still within the manufacturer's calibration specifications.[28]

Respondents aged 6 to 11 with four or more valid days of accelerometer wear-time[25] were included in this analysis (n = 878). Of the children who agreed to wear an accelerometer and who returned the device, 90.0% had at least one valid day of data, and 83.5% had at least four valid days. When adjustments were made for the sampling strategy, the final response rate for having a minimum of four valid days was 45.8% (69.6% x 90.9% x 86.6% x 83.5%).

A valid day was defined as 10 or more hours of wear-time. Wear-time was determined by subtracting nonwear-time from 24 hours. Nonwear-time was defined as at least 60 consecutive minutes of zero counts, with allowance for two minutes of counts between 0 and 100. For each minute, the level of movement intensity (sedentary, light, and MVPA) was based on cut-points: sedentary = wear-time zeros + cpm less than 100[29]; MVPA = cpm 1,500 or more.[25] For each child, minutes at each intensity level were summed for each day and averaged for valid days.

Because wear-time can markedly affect physical activity variables (for instance, time spent in sedentary behaviour), accelerometer analyses often adjust for wear-time. This would have been redundant in the present analysis because the directly measured sleep duration variable is derived from monitor nonwear-time (24 hours minus wear-time).

Details of how the MVPA, sedentary behaviour and sleep variables were derived from the accelerometers and from the questionnaire are presented in Table 1.[30]

Health markers

Obesity

Height was measured to the nearest 0.1 cm using a ProScale M150 digital stadiometer (Accurate Technology Inc., Fletcher, USA). Weight was measured to the nearest 0.1 kg with a Mettler Toledo VLC with Panther Plus terminal scale (Mettler Toledo Canada, Mississauga, Canada). Body mass index (BMI) was calculated as weight (kg) divided by height in metres squared (m^2). Waist circumference was measured with a stretch-resistant anthropometric tape at the end of a normal expiration to the nearest 0.1 cm at the mid-point between the last rib and the top of the iliac crest.[31]

Blood pressure

Blood pressure was measured with the BpTRU™ BP-300 device (BpTRU Medical Devices Ltd., Coquitlam, British Columbia), an automated electronic monitor that uses an upper arm cuff. Six measurements were taken at one-minute intervals, with the last five used to calculate average blood pressure and heart rate.[32] The device automatically inflates and deflates the cuff and uses an oscillometric technique to calculate systolic and diastolic blood pressure.

Table 1
Definitions of parent-reported and directly measured moderate-to-vigorous physical activity (MVPA), sedentary behaviour and sleep

	Parent-reported		Directly measured
	Questions asked to parent	Derived variable	Derived variable from accelerometry data
MVPA	**About how many hours a week does he/she usually take part in physical activity that makes him/her out of breath or warmer than usual:** … in his/her free time at school (for example, lunch)? … in his/her class time at school? … outside of school while participating in lessons or league or team sports? … outside of school while participating in unorganized activities, either on his/her own or with friends?	Physical activity participation (hours per week) = sum of four questions at left; converted into average minutes per day.	MVPA was derived from the accelerometry data using a cut-point of 1,500 cpm.[25] All minutes above this cut-point were summed across each valid day and then averaged for each child on valid days.
Sedentary behaviour/ Screen time	**On average, about how many hours a day does your child:** … watch TV or videos or play video games? … spend on a computer (working, playing games, e-mailing, chatting, surfing the internet, etc.)?	Total screen time (hours per day) = sum of two questions at left	Sedentary time was defined as time spent below 100 cpm (including zero counts) accumulated during wear-time.[29] All wear-time minutes below this cut-point were summed across each valid day and averaged for each child on valid days.
Sleep	**How many hours does your child usually spend sleeping in a 24-hour period, excluding time spent resting?**	Sleep duration (hours per day)	Proxy estimates of sleep duration were derived from the accelerometry data as the longest period of nonwear-time in a 24-hour period between two valid days and averaged for each child.

Non-HDL-cholesterol

Non-HDL-cholesterol was calculated by subtracting HDL cholesterol, measured using a non-HDL precipitation method on the Vitros 5,1FS (Ortho Clinical Diagnostics), from total cholesterol.[33] Non-HDL cholesterol consists of very-low-density, low-density, and intermediate-density lipoprotein cholesterol, and, therefore, reflects the cholesterol content of all apo-B-containing lipoproteins. Non-HDL cholesterol is an indicator of cardiovascular and diabetes risk among children and adolescents and is not reliant on a fasted blood sample.[34] Blood samples were taken by a certified phlebotomist and were analyzed at the Health Canada Laboratory (Bureau of Nutritional Sciences, Nutrition Research Division). Other blood markers are available in the CHMS, but the fasting requirement would have sharply reduced sample size. To ensure sufficient power for this analysis, non-HDL-cholesterol was used as the sole blood marker.

Statistical analysis

Descriptive statistics were used to present results and mean differences between parent-reported and directly measured MVPA, sedentary behaviour and sleep duration. The generic term, "movement variables," is used to describe MVPA, sedentary/screen time, and sleep duration collectively. Pearson correlations were completed between each valid day pairing of parent-reported and directly measured movement variables. Regression analysis was used to assess significant associations between parent-reported and accelerometer data for each variable (MVPA, sedentary behaviour, sleep duration) and health markers (BMI, waist circumference, blood pressure, non-HDL cholesterol). Multivariate regression was used to examine the association between multiple movement variables and health markers. All regression models were adjusted for age (continuous) and sex and tested for collinearity. Parent-reported and directly measured movement variables were weakly correlated, thereby justifying the inclusion of both in the same model. Directly measured sedentary time was highly correlated with directly measured MVPA and sleep duration; therefore, the "full model" includes parent-reported and directly measured MVPA and sleep, but only parent-reported screen time (that is, directly measured sedentary time was excluded). Statistical significance was set at a p value of 0.05. All statistical analyses were performed using SAS v9.1 (SAS Institute, Cary, NC) and were based on weighted data for respondents with at least four valid days. To account for survey design effects, standard errors, coefficients of variation, and 95% confidence intervals were estimated using the bootstrap technique.[23,35,36]

Results

The average age of the 878 children in the sample was 8.7 years (Table 2). Just over half of them (51.2%) were boys. Nearly one-quarter (23%) were overweight/ obese. The average waist circumference of this group of children was 61.0 cm. Their average systolic blood pressure was 93.2 mmHg, and their average diastolic blood pressure, 60.7 mmHg. Their mean non-HDL cholesterol was 2.9 mmol/L.

Parent-reported versus directly measured movement variables

On average, parents reported that their children engaged in considerably more MVPA than was recorded by accelerometer: 104.5 minutes versus 63.3 minutes, a difference of about 40 minutes a day (Table 2). As expected, directly measured sedentary time (7.6 hours a day) substantially exceeded

Table 2
Age, health markers, parent-reported and directly measured variables, by sex, household population aged 6 to 11, Canada, 2007 to 2009

	Total			Boys			Girls		
		95% confidence interval			95% confidence interval			95% confidence interval	
	Average	from	to	Average	from	to	Average	from	to
Age and health markers									
Age	8.7	8.5	8.9	8.7	8.4	9.0	8.8	8.5	9.1
Body mass index (kg/m^2)	17.8	17.5	18.1	17.9	17.4	18.4	17.6	17.1	18.1
Overweight/Obese (%)	22.7	18.8	26.6	24.6	18.8	30.4	20.6	15.7	25.5
Waist circumference (cm)	61.0	59.9	62.2	61.8	60.3	63.3	60.2	58.7	61.7
Systolic blood pressure (mmHg)	93.2	92.4	94.0	93.1	92.2	94.0	93.3	92.4	94.2
Diastolic blood pressure (mmHg)	60.7	59.9	61.5	60.6	59.7	61.5	60.7	59.8	61.6
Non-HDL cholesterol (mmol/L)	2.9	2.8	2.9	2.8	2.7	2.9	2.9	2.8	3.0
Parent-reported variables									
Usual moderate-to-vigorous physical activity (minutes per day)	104.5	101.8	107.2	109.0	105.8	112.2	100.0	97.0	103.0
Total screen time (hours per day)	2.5	2.4	2.7	2.5	2.3	2.8	2.6	2.4	2.7
Television and video time (hours per day)	1.8	1.7	2.0	1.8	1.6	2.0	1.9	1.7	2.0
Computer time (hours per day)	0.7	0.6	0.8	0.7	0.6	0.8	0.7	0.6	0.8
Sleep (hours per day)	9.7	9.6	9.8	9.7	9.6	9.8	9.7	9.5	9.8
Directly measured variables									
Moderate-to-vigorous physical activity (minutes per day)	63.3	60.1	66.4	69.4	65.4	73.4	56.9	54.3	59.5
Sedentary time (hours per day)	7.6	7.5	7.7	7.5	7.3	7.7	7.7	7.6	7.8
Sleep (hours per day)	10.1	10.0	10.2	10.0	9.9	10.1	10.2	10.1	10.3

N=878
Source: 2007 to 2009 Canadian Health Measures Survey.

parent-reported screen time (2.5 hours a day). Screen time, of course, is only one aspect of sedentary behaviour. Directly measured sleep duration averaged 24 minutes a day more than parent-reported sleep time: 10.1 hours versus 9.7 hours. Parent-reported and directly measured movement variables were weakly correlated: MVPA (rho = 0.29), sedentary/screen time (rho = 0.17), and sleep duration (rho = 0.25).

Obesity

Parent-reported and directly measured MVPA were each independently associated with BMI (Table 3). Parent-reported screen time and directly measured sleep approached a statistically significant association with BMI ($p = .06$ for each) in the model adjusted for age and sex only (Table 3) and in the model adjusted for other movement variables ($p = .05$ for each) (Table 4). The percentage of the variance in BMI explained by the full model (18%) was higher than that explained by any variable alone (13% to 15%) (Table 4). Based on the full model, an increase of one hour a day in directly measured MVPA was associated with a 1.2 kg/m^2 decrease in BMI (-0.020 x 60 minutes = 1.2). An increase of one hour a day in directly measured sleep duration was associated with a 0.32 kg/m^2 decrease in BMI.

The pattern of findings for waist circumference was similar to that for BMI, but the overall variance explained was higher—26% in the full model (Table 4). An increase of 1 hour a day in directly measured MVPA was associated with a 3.2 cm (-0.054 x 60 minutes) decrease in waist circumference.

Blood pressure and cholesterol

Directly measured MVPA was significantly associated with systolic blood pressure (beta = -0.023; $p < .05$) (data not shown). Diastolic blood pressure was not associated with any of the movement variables. The total variance explained by the full model was 4% for systolic blood pressure and 2% for non-HDL cholesterol (data not shown), indicating weak associations with these health markers.

Discussion

The primary aim of this study was to compare how parent-reported and directly measured MVPA, sedentary behaviour and sleep duration, alone and in combination, relate to health risk in children aged 6 to 11. The measurement method affected the presence and strength of association with the health markers. For instance, both parent-reported and directly measured MVPA were significantly associated with BMI, but only directly measured MVPA was associated with waist circumference. By contrast, directly measured sedentary behaviour was not associated with BMI or waist circumference, but the association between parent-reported screen time and BMI approached significance.

Parent-reported MVPA was markedly higher than MVPA obtained by accelerometry (105 versus 63 minutes per day). This is consistent with a review that

Table 3
Univariate regression coefficients relating movement variables to body mass index and waist circumference, household population aged 6 to 11, Canada, 2007 to 2009

Movement variables	Body mass index (kg/m^2) beta	Body mass index (kg/m^2) R^2	Waist circumference (cm) beta	Waist circumference (cm) R^2
Parent-reported				
Moderate-to-vigorous physical activity (minutes per day)	-0.006*	0.14	-0.019	0.24
Screen time (hours per day)	0.225	0.14	0.434	0.23
Sleep (hours per day)	-0.006	0.13	-0.161	0.23
Directly measured				
Moderate-to-vigorous physical activity (minutes per day)	-0.018*	0.15	-0.053*	0.25
Sedentary time (hours per day)	0.224	0.13	0.608	0.23
Sleep (hours per day)	-0.287	0.14	-0.685	0.23

* significant at $p < 0.05$
Note: Adjusted for age and sex.
Source: 2007 to 2009 Canadian Health Measures Survey.

Table 4
Multivariate regression coefficients relating movement variables to body mass index and waist circumference, household population aged 6 to 11, Canada, 2007 to 2009

	Full model	
Movement variables	Body mass index (kg/m^2) beta	Waist circumference (cm) beta
Parent-reported		
Moderate-to-vigorous physical activity (minutes per day)	-0.0002	-0.004
Screen time (hours per day)	0.225	0.425
Sleep (hours per day)	0.085	0.061
Directly measured		
Moderate-to-vigorous physical activity (minutes per day)	-0.020*	-0.054*
Sedentary time (hours per day)	†	†
Sleep (hours per day)	-0.318*	-0.782
Variance explained (R^2)	**0.18**	**0.26**

† not included in full model because of collinearity
* significant at $p < 0.05$
Notes: Adjusted for age and sex, parent-reported and directly measured MVPA and sleep, and parent-reported screen time.
Source: 2007 to 2009 Canadian Health Measures Survey.

compared indirect and direct measures of MVPA in children; the majority (72%) of papers showed parent- or self-reported MVPA values to be higher than direct measures.[13]

The low correlation between parent reports and direct measures is not unexpected. While the two methods measure the same variables, they assess different aspects of these behaviours. For instance, participation in an hour-long soccer game (which a parent might report as MVPA) would not be recorded as a full 60 minutes of MVPA on an accelerometer, because the child does not move at that intensity for the entire game. This example highlights a fundamental difference between the methods: parent reports capture *time spent doing a specific activity*, while accelerometry captures *actual movement* at a defined intensity.

Similarly, parent-reported screen time captures only a portion of the total sedentary time that can be measured by an accelerometer. Failure to distinguish between screen time and total sedentary behaviour may lead to misinterpretation of the respective links between these two constructs and health. In this analysis, average accelerometer-recorded sedentary time was about three times more than parent-reported screen time. The lack of correlation and the clear conceptual differences between the two measures allowed the inclusion of both in the full

What is already known on this subject?

- Among Canadian children, obesity rates are high, physical fitness has decreased, and few meet current physical activity recommendations.
- Moderate-to-vigorous physical activity (MVPA), sedentary behaviour and sleep duration are independently associated with obesity and other aspects of health.
- Measurement of physical activity, sedentary behaviour and sleep has been inconsistent.

What does this study add?

- The Canadian Health Measures Survey (CHMS) collected parent-reported and measured (accelerometry) data about physical activity, sedentary behaviour and sleep duration from a nationally representative sample of 6- to 11-year-olds.
- The CHMS makes it possible to compare data collected by these different methods and explore the impact on associations with health markers.
- Parent-reported and directly measured movement variables were both associated with health in children.
- The differences in estimates of MVPA, sedentary behaviour and sleep duration between measurement methods are substantial and have implications for understanding how these behaviours relate to health risk.

model, and demonstrate the impossibility of one replacing the other in health surveillance.

In earlier studies, associations between directly measured sedentary time and health risk have not been consistent. For example, Carson and Janssen[37] found that directly measured sedentary behaviour was not predictive of cardio-metabolic risk factors in children and adolescents. However, they did find that high self-reported television time (at least four hours a day) was a predictor of elevated cardio-metabolic risk factors. In the present analysis, the association between parent-reported screen time and BMI approached significance, but no independent association emerged between directly measured sedentary time and any of the health markers tested. This lack of association may be due to a lack of inter-individual variation in total sedentary time.[3] In light of this finding, researchers have explored more complex aspects of directly measured sedentary behavior; for instance, breaks in sedentary time have been shown to be predictive of health in adults.[38] While Carson and Janssen[37] did not find the same trend in children and adolescents, this represents an understudied area of research.

Limitations

The most common method of measuring movement and sleep at the population level is self-report in questionnaires, diaries/logs, and interviews. This approach has advantages (low cost, low participant burden, practicality), but the limitations, including social desirability bias and recall challenges, are substantial.[13]

Limitations of accelerometry include the inability to accurately capture the true movement and energy expenditure of activities such as cycling, swimming and carrying loads. Moreover, among researchers who measure movement in children with accelerometers, consensus is lacking on the device to use, the appropriate epoch length,[39] the importance of bouts of movement,[37] and minimum data requirements.[40]

Another problem with accelerometer data is non-response bias. To avoid it in this analysis, only participants with at least four valid days of data were included. However, in this study, accelerometry non-respondents tended to be older and more obese.[3] Thus, they might be less active, and, therefore, MVPA may be slightly overestimated here.

Although each method used in this study has shortcomings, the limitations differ. This lends support to the use of both indirect and direct measures. For example, the swimming and cycling not captured by an accelerometer would be picked up in questions geared to obtaining information about specific activities.

Problems can arise, however, when different measurement methods yield different results. One problem relates to associations between the movement variables and health markers. When one method reveals an association, but the other does not, it is difficult, if not impossible, to interpret and use the findings to guide policy.

Furthermore, a given dose of directly measured MVPA that is associated with a health marker will be different from the corresponding dose of parent-reported MVPA needed to obtain the same health benefit. The implications of this discrepancy for how physical activity guidelines are developed and assessed in the population are not well understood.

Another problem is misclassification errors. It is unlikely that the difference between measurement methods is systematic. For example, some parents may dramatically overestimate their children's physical activity, while others' assessments may be quite accurate. In the first case, children would be misclassified as active, but in the second, they would be correctly classified. The extent and impact of misclassification errors can be profound, as has been demonstrated in relation to estimates of obesity in children.[41]

The weak association between the movement variables and some health markers (blood pressure, non-HDL cholesterol) may have been the result of a small sample size, the cross-sectional design, low prevalence of adverse values of these markers at this young age, or a true lack of association.

Interpretation of the results is also hampered by the cross-sectional, single-measurement period design of this study. Longitudinal examinations of the same behaviours might yield different results.

Conclusion

Accurate assessment of children's activity is required for health surveillance and for devising and evaluating interventions. The formulation of guidelines is strongly influenced by the method of assessment. Thus, an understanding of the implications of using a particular method is needed.

Values of children's MVPA, sedentary behaviour and sleep duration derived from the CHMS vary between parent reports and accelerometry. This finding has implications for surveillance of adherence to guidelines and for furthering the understanding of how these variables relate to health. As well, parent-reported and directly measured movement variables are associated with health in different ways. The results of this analysis demonstrate the benefits of using both approaches in health surveillance, while highlighting the need to understand the sometimes large differences between these metrics. One measurement method cannot replace the other, and the differences and limitations of each must be understood before they can be effectively used in a complementary fashion. ■

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