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Research articles

Health matters

Methodological insights

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Abdominal obesity and cardiovascular disease risk factors within body mass index categories

by Margot Shields, Mark S. Tremblay, Sarah Connor Gorber and Ian Janssen

Abstract

Background
Several organizations recommend the use of measures of abdominal obesity in conjunction with body mass index (BMI) to assess obesity-related health risk. Recent evidence suggests that waist circumference (WC), waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) are increasing within BMI categories. This shift may have affected the usefulness of abdominal obesity measures.

Data and methods
Data are from respondents aged 18 to 79 to the 2007 to 2009 Canadian Health Measures Survey. Using logistic regression, this paper examines cardiovascular disease (CVD) risk factors in relation to WC, WHR and WHtR *within* BMI health-risk categories. CVD risk factors considered include components of the metabolic syndrome.

Results
Among men in the normal and overweight BMI categories, WHR and WHtR were positively associated with having at least two CVD risk factors. All three abdominal obesity measures were associated with increased odds of having at least two CVD risk factors among normal-weight women. Abdominal obesity was not associated with CVD risk factors for people in obese class I.

Interpretation
Among men and women in the normal BMI category, measures of abdominal obesity are associated with increased odds of CVD risk factors. This underscores the importance of measuring and monitoring abdominal obesity in normal-weight men and women.

Keywords
Body composition, central obesity, metabolic syndrome, waist circumference, waist-to-height ratio, waist-to-hip ratio

Authors
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E levated body mass index (BMI) is a well-established contributor to the aetiology of cardiovascular disease (CVD).[1] But while BMI is widely used to monitor the prevalence of obesity, it provides no information about the distribution of body fat. Some studies, have found that measures of abdominal obesity, principally, waist circumference (WC), waist-to-hip ratio (WHR), and more recently, waist-to-height ratio (WHtR), are more closely related to CVD morbidity and mortality than is BMI.[2-5] However, reviews of the literature conducted to assess which measure of adiposity is most strongly associated with CVD have yielded inconsistent conclusions.[2-4,6-11]

While a BMI classification system has been developed and used extensively to place adults in weight categories based on health risk,[1,12,13] a recent report by the World Health Organization concluded that, where possible, abdominal obesity should also be measured and used in conjunction with BMI to assess and predict disease risk.[14] Indeed, several organizations have recommended that a WC measure be used *within* BMI categories to classify obesity-related health risk.[1,12,13,15] Specifically, WC cut-points of 102 cm (40.2 inches) in men and 88 cm (34.6 inches) in women are used to denote high health risk within normal-weight, overweight, and obese BMI categories.

Recent evidence[16] suggests that the obesity phenotype among Canadians has changed over the past three decades— the distributions of WC, WHR and WHtR *within* BMI categories have shifted toward higher values.[17] This may have affected the degree to which measures of abdominal obesity are associated with CVD risk factors within BMI categories, particularly, normal-weight and obese.

For example, the percentage of normal-weight Canadian women at high health risk based on WC increased over the past three decades from almost nil to 3.8%.[17] Among people in obese class I, WC has increased to such an extent that almost all (84% of men and 94% of women) are now at high health risk according to WC.

Based on data from the 2007-2009 Canadian Health Measures Survey, this study examines associations between measures of abdominal obesity and CVD risk factors within the BMI categories for adults aged 18 to 79. The abdominal obesity measures considered are WC, WHR and WHtR. The CVD risk factors are components of the metabolic syndrome (a group of risk factors that predispose individuals to cardiovascular disease and type 2 diabetes): elevated blood pressure, elevated triglycerides, elevated glucose, and reduced high-density lipoprotein (HDL) cholesterol.

Methods

Data source

The Canadian Health Measures Survey (CHMS) is a nationally representative survey of the household population.[18-20] Data for cycle 1 were collected from March 2007 through February 2009 at 15 sites across the country for respondents aged 6 to 79. Full-time members of the Canadian Forces and residents of Crown lands, Indian reserves, institutions and certain remote regions were excluded. The sample represented approximately 96% of the population.[21]

The survey involved a household interview, during which information about socio-demographic characteristics, health and lifestyle was gathered, and a visit to a mobile examination centre where direct measurements (including body composition, blood pressure, and blood samples) were taken.

Of the households selected for the survey, 69.6% agreed to participate. In each responding household, one or two members were selected; 88.3% of selected household members completed the household interview, and 84.9% of the responding household members participated in the subsequent mobile examination centre component. The final response rate, adjusting for the sampling strategy, was 51.7%.[21]

Blood samples were collected at the mobile examination centre. Approximately half of respondents were selected at random to fast before blood samples were taken. Because some of the CVD risk factors considered in this study require fasting blood samples, it was necessary to base estimates on the subsample who fasted. The overall combined response rate for this subsample was 46.3%. Sampling weights for the fasted subsample were provided, which incorporated an adjustment for the probability of being selected into the subsample, a non-response adjustment (based on characteristics available for respondents versus non-respondents to this component of the survey), and calibration to ensure that estimates based on the weights were representative of the Canadian population by sex, age group and geographical region.[21]

This study pertains to respondents aged 18 to 79 who were part of the fasted subsample. Although the relationship between measures of adiposity and CVD risk factors is attenuated with advancing age, a significant association remains,[22] and therefore, the analyses included 65- to 79-year-olds. Pregnant women and respondents classified as underweight based on BMI (less than 18.5 kg/m^2) were excluded. Twelve records were dropped because of missing values for the anthropometric or CVD risk factor variables. This left 1,760 participants (846 men and 914 women).

Measures

Adiposity health risk variables

Weight was measured to the nearest 0.1 kg, and height, to the nearest 0.1 cm. Waist circumference (WC) was measured at the end of a normal expiration to the nearest 0.1 cm at the mid-point between the last floating rib and the top of the iliac crest.[1,23] Hip circumference was measured at the level of the symphysis pubis and the greatest gluteal protuberance.[23]

Body mass index (BMI) was calculated by dividing weight in kilograms (kg) by height in meters squared (m^2); waist-to-hip ratio (WHR), as WC in cm divided by hip circumference in cm; and waist-to-height ratio (WHtR), as WC in cm divided by height in cm.

Based on cut-points recommended by the World Health Organization,[1] Health Canada[12] and Obesity Canada,[13] the 1,760 CHMS respondents included in this analysis were divided into five health-risk categories based on BMI (kg/m^2):

- normal weight (18.5 to 24.9)
- overweight (25.0 to 29.9)
- obese class I (30.0 to 34.9)
- obese class II (35.0 to 39.9)
- obese class III (40.0 or more)

and three health-risk categories based on WC (cm):

- low risk (men, 93.9 or less; women, 79.9 or less),
- increased risk (men, 94.0 to 101.9; women, 80.0 to 87.9)
- high risk (men, 102.0 or more; women, 88.0 cm or more).

Respondents were also classified as being at increased/high risk based on WHR (men, 0.9 or more; women, 0.85 or more)[14] and WHtR (0.5 or more for both sexes).[6]

Sample sizes for the adiposity health risk variables are presented in Table 1.

CVD risk variables

The CVD risk factors are components of the metabolic syndrome based on the new harmonized definition.[24] This definition requires the presence of three or more of the following:

- elevated blood pressure (systolic 130 mmHg or more, or diastolic 85 mmHg or more)
- elevated triglycerides (1.7 mmol/L or more)
- reduced high-density lipoprotein (HDL) cholesterol (less than 1.0 mmol/L for men, and less than 1.3 mmol/L for women)
- elevated fasting blood glucose (5.6 mmol/L or more)
- abdominal obesity (WC 102 cm or more for men and 88 cm or more for women)

Table 1
Sample sizes for adiposity health risk variables, by sex, household population aged 18 to 79 years, Canada, 2007-2009

	Men	Women
Total	**846**	**914**
Body mass index		
Normal	265	394
Overweight	384	294
Obese class I	132	131
Obese class II or III	65	95
Waist circumference health risk		
Low	363	316
Increased	208	204
High	275	394
Waist-to-hip ratio health risk		
Low	274	519
Increased/High	572	395
Waist-to-height ratio health risk		
Low	235	359
Increased/High	611	555

Source: 2007-2009 Canadian Health Measures Survey (fasted sample).

Abdominal obesity was omitted, since the purpose of the study is to examine CVD risk factors in relation to abdominal obesity.

In addition to the measured values, respondents who reported taking specific CVD-related medications in the past month were considered to have the CVD risk factor. Respondents reported the Drug Identification Numbers (DIN) of all prescription medications they were taking. These were coded using the Anatomical Therapeutic Chemical (ATC) classification system.[25] The following ATC codes were used in defining the CVD risk factors:

- elevated blood pressure (all C02, all C03, C04AA02, C04AB01, all C07, all C08, all C09)
- elevated triglycerides (C04AC01, C04AC03, C10AB01, C10AB02, C10AB04, C10AB05, C10AC01, C10AC02, C10AX02, C10AX06)
- low HDL cholesterol (C04AC01, C04AC03, C10AB01, C10AB02, C10AB04, C10AB05, C10AC01, C10AC02, C10AX02)
- elevated fasting blood glucose (all A10 drugs)

A summary variable was constructed to identify respondents with at least two (of the four) CVD risk factors. Although the definition of the metabolic syndrome requires three factors, almost all respondents identified as having the metabolic syndrome (88%) had abdominal obesity (data not shown).

Control variables

Age was used as a continuous variable. Dichotomous variables were created for highest level of *education* (postsecondary graduation yes/no) and *smoking* status (current daily smoker yes/no). With self-reported data on *leisure-time physical activity*, a derived variable based on metabolic energy costs[26] was created to classify respondents as inactive versus active/moderately active. Three categories were used to describe *alcohol consumption*: *heavy drinker* (at least five drinks in one occasion on a weekly basis during the past year and/or heavy drinking in the previous week—15 or more drinks for men; 10 or more for women); *moderate/light drinker* (at least one drink in the past year); or *non-drinker* (did not drink in the past year). Use of *hormone replacement therapy* among women, was defined as taking prescription drugs in the past month with an ATC code G03.

Analysis

Descriptive statistics were used to profile the adiposity variables (means, standard deviations and correlations) and the CVD risk factors (percentages). With logistic regression models, the adiposity variables were examined in relation to CVD risk factors, controlling for age, education, smoking status, alcohol consumption, leisure-time physical activity, and for women, use of hormone replacement therapy. Because of high correlations among the adiposity variables, it was not possible to include them in the same regression models.

Regressions were first run using categorical variables based on health-risk cut-points for each adiposity variable. Regressions were then run using continuous measures for the adiposity variables (overall and within BMI categories). This second set of regressions was not run within the obese class II and III category because measures of abdominal obesity do not provide additional information about health risk for people with BMIs in this range.[12] To facilitate comparisons among the adiposity variables, the second set of regressions was also run based on standardized adiposity variables (the four adiposity variables were standardized to have a mean of 0 and a standard deviation of 1).

All analyses were weighted with the sampling weights for the fasted subsample in order to obtain estimates representative of the Canadian population. Statistical analyses were performed using SAS and SUDAAN software. Standard errors, coefficients of variation, and 95% confidence intervals were calculated with the bootstrap technique.[27,28] The number of degrees of freedom was specified as 11 to account for the CHMS sample design.[21] Significance levels were set at $p < 0.05$.

Results

Means and standard deviations for BMI and the three abdominal obesity variables (WC, WHR and WHtR) among people aged 18 to 79 are presented in Table 2. For both sexes, correlations among BMI, WC and WHtR were very high (r values greater than 0.9).

About one in four Canadians aged 18 to 79 had at least two CVD risk factors: 29% of men and 24% of women (Table 3).

Using logistic regression models, CVD risk factors were examined in relation to the health risk categories for the four adiposity variables (Table 4). Regardless of the variable, people in the increased/high health risk categories generally had higher odds of having CVD risk factors. The exception was WHtR, where the association did not attain statistical significance for elevated glucose (both sexes) or for elevated blood pressure (men). For BMI, a dose-response relationship emerged: people

Table 2
Descriptive statistics for adiposity variables, by sex, household population aged 18 to 79 years, Canada, 2007-2009

| | Body mass index (kg/m²) | | | Waist circumference (cm) | | | Waist-to-hip ratio (%) | | | Waist-to-height ratio (%) | | |
| | | 95% confidence interval | | | 95% confidence interval | | | 95% confidence interval | | | 95% confidence interval | |
	Estimate	from	to	Estimate	from	to	Estimate	from	to	Estimate	from	to
Men												
Mean	27.3	26.8	27.8	95.0	93.4	96.6	92.0	91.3	92.8	54.1	53.3	55.0
Standard deviation	4.8	...	...	13.9	...	...	7.9	...	...	8.1	...	...
Correlations												
Body mass index (kg/m²)	...	...	...	0.92	...	...	0.62	...	...	0.91	...	...
Waist circumference (cm)	...	...	...	...	...	...	0.82	...	...	0.96	...	...
Waist-to-hip ratio	...	...	...	...	...	...	...	...	...	0.84	...	...
Women												
Mean	26.8	25.9	27.7	87.2	84.7	89.7	83.0	82.0	84.0	53.8	52.3	55.2
Standard deviation	5.9	...	...	15.3	...	...	8.0	...	...	9.7	...	...
Correlations												
Body mass index (kg/m²)	...	...	...	0.91	...	...	0.55	...	...	0.92	...	...
Waist circumference (cm)	...	...	...	...	...	...	0.79	...	...	0.97	...	...
Waist-to-hip ratio	...	...	...	...	...	...	...	...	...	0.79	...	...

... not applicable
Note: Excludes respondents classified as underweight based on body mass index (less than 18.5).
Source: 2007-2009 Canadian Health Measures Survey (fasted sample).

Table 3
Prevalence of cardiovascular disease (CVD) risk factors, by sex, household population aged 18 to 79 years, Canada, 2007-2009

| | Elevated blood pressure | | | Elevated triglycerides | | | Elevated glucose | | | Reduced HDL cholesterol | | | At least two CVD risk factors | | |
| | | 95% confidence interval | | | 95% confidence interval | | | 95% confidence interval | | | 95% confidence interval | | | 95% confidence interval | |
	Estimate	from	to	Estimate	from	to	Estimate	from	to	Estimate	from	to	Estimate	from	to
Men															
Overall† (%)	28.0	24.1	32.2	28.8	22.5	35.9	19.6	16.4	23.2	24.5	19.4	30.6	29.1	25.9	32.5
Based on lab measurement only	17.0	13.5	21.3	28.5	22.4	35.6	19.1	16.1	22.7	24.2	18.9	30.4	...	...	...
Based on medication use only	14.4	12.6	16.3	F	...	...	2.0	1.4	2.7	F	...	...	...	...	...
Sample size with risk factor†	292	...	...	249	...	...	207	...	...	203	...	...	302	...	...
Women															
Overall† (%)	24.9	21.1	29.1	20.1	15.7	25.3	13.0	10.1	16.6	36.8	28.5	45.9	23.9	20.1	28.2
Based on lab measurement only	13.2	9.6	17.9	20.0	15.6	25.2	12.4	9.6	15.9	36.5	28.1	45.8	...	...	...
Based on medication use only	17.5	15.3	20.0	F	...	...	3.2ᴱ	1.8	5.4	F	...	...	...	...	...
Sample size with risk factor†	261	...	...	193	...	...	138	...	...	314	...	...	238	...	...

† based on lab measurement/medication use
... not applicable
ᴱ use with caution
F too unreliable to be published
Note: Excludes respondents classified as underweight (body mass index less than 18.5).
Source: 2007-2009 Canadian Health Measures Survey (fasted sample).

Table 4
Adjusted odds ratios relating adiposity health risk variables to cardiovascular disease (CVD) risk factors, by sex, household population aged 18 to 79 years, Canada, 2007-2009

	Elevated blood pressure			Elevated triglycerides			Elevated glucose			Reduced HDL cholesterol			At least two CVD risk factors		
	Estimate	95% confidence interval		Estimate	95% confidence interval		Estimate	95% confidence interval		Estimate	95% confidence interval		Estimate	95% confidence interval	
		from	to		from	to		from	to		from	to		from	to
Men															
Body mass index category															
Normal†	1.0	…	…	1.0	…	…	1.0	…	…	1.0	…	…	1.0	…	…
Overweight	1.6	0.8	3.3	3.4*	2.0	5.9	1.4	0.7	2.7	4.8*	2.0	11.4	3.9*	1.9	8.1
Obese class I	2.0	0.7	5.8	5.5*	2.4	12.8	4.3*	1.6	11.4	6.4*	2.0	19.8	9.2*	3.7	22.9
Obese class II or III	8.4*	3.3	21.8	5.5*	1.4	21.7	5.9*	2.1	16.6	7.2*	2.5	20.3	17.5*	5.1	59.9
Waist circumference health risk															
Low†	1.0	…	…	1.0	…	…	1.0	…	…	1.0	…	…	1.0	…	…
Increased	2.2*	1.2	4.0	2.6*	1.1	5.9	1.6	0.7	3.7	2.4	0.9	6.5	3.6*	1.9	6.8
High	3.6*	1.7	7.7	3.8*	1.7	8.5	2.4*	1.3	4.6	3.8*	1.7	8.2	6.4*	2.9	13.7
Waist-to-hip ratio health risk															
Low†	1.0	…	…	1.0	…	…	1.0	…	…	1.0	…	…	1.0	…	…
Increased/High	2.6*	1.3	5.2	4.3*	1.8	10.1	2.3*	1.1	5.1	2.9*	1.3	6.7	5.2*	2.7	9.8
Waist-to-height ratio health risk															
Low†	1.0	…	…	1.0	…	…	1.0	…	…	1.0	…	…	1.0	…	…
Increased/High	2.0	0.9	4.5	7.9*	2.0	30.8	1.9	0.8	4.6	5.7*	2.3	14.0	13.0*	4.9	34.2
Women															
Body mass index category															
Normal†	1.0	…	…	1.0	…	…	1.0	…	…	1.0	…	…	1.0	…	…
Overweight	2.0*	1.1	3.6	4.0*	1.9	8.7	0.9	0.3	3.2	2.9*	1.6	5.2	2.9*	1.4	6.2
Obese class I	3.0*	1.2	7.5	8.2*	4.1	16.4	4.8*	1.4	17.0	5.0*	3.2	7.8	9.9*	3.5	28.1
Obese class II or III	5.6*	2.2	14.5	7.9*	2.9	21.5	3.7*	1.4	10.1	8.9*	4.2	18.9	13.3*	4.3	40.9
Waist circumference health risk															
Low†	1.0	…	…	1.0	…	…	1.0	…	…	1.0	…	…	1.0	…	…
Increased	2.8*	1.1	7.4	2.9	1.0	8.7	1.4	0.6	3.3	2.5*	1.0	6.1	3.9*	1.8	8.2
High	3.7*	1.6	8.5	9.4*	3.5	25.8	3.7*	1.6	8.7	4.7*	2.7	8.2	13.8*	6.6	28.8
Waist-to-hip ratio health risk															
Low†	1.0	…	…	1.0	…	…	1.0	…	…	1.0	…	…	1.0	…	…
Increased/High	2.3*	1.3	4.0	5.9*	2.3	15.1	4.6*	2.2	9.4	3.3*	1.9	5.8	6.0*	3.3	11.0
Waist-to-height ratio health risk															
Low†	1.0	…	…	1.0	…	…	1.0	…	…	1.0	…	…	1.0	…	…
Increased/High	2.7*	1.3	5.8	7.8*	3.5	17.5	3.4	0.9	12.3	3.9*	2.3	6.7	11.8*	4.9	28.4

† reference category
* significantly different from reference category (p<0.05)
Notes: Excludes respondents classified as underweight (body mass index less than 18.5). Adjusted for age, education, smoking status, alcohol consumption, physical activity level and hormone replacement use (women). Separate models were run for each adiposity variable.
Source: 2007-2009 Canadian Health Measures Survey (fasted sample).

in the combined obese class II and III category had considerably higher odds (17.5 for men and 13.3 for women) of having at least two CVD risk factors than did those in the normal-weight category.

Based on continuous measures, all four adiposity variables were strongly associated with having at least two CVD risk factors (Table 5). For example, on average, among both men and women,

each 1 cm increase in WC was associated with a 1.07 increase in the odds of having at least two CVD risk factors.

To facilitate comparisons, regressions were also run based on standardized adiposity variables. A one-standard-deviation-increase in BMI (4.8 kg/m^2 for men; 5.9 kg/m^2 for women) was, on average, associated with a 2.40 increase in the odds of having at least two CVD

risk factors for men, and a 2.56 increase for women. Based on standardized variables, the odds ratios for the three abdominal obesity measures were slightly higher than those for BMI (WC: 2.63 for men and 2.97 for women; WHR: 2.80 for men and 2.64 for women; WHtR: 2.85 for men and 3.21 for women), although the confidence intervals of the four variables overlapped for both sexes.

Table 5
Adjusted odds ratios relating adiposity variables to having at least two cardiovascular disease (CVD) risk factors, by sex and BMI category, household population aged 18 to 79 years, Canada, 2007-2009

	At least two CVD risk factors			At least two CVD risk factors (standardized adiposity variables)		
	Adjusted odds ratios	95% confidence interval		Adjusted odds ratios	95% confidence interval	
		from	to		from	to
Men						
Total†						
Body mass index (kg/m²)	1.20*	1.12	1.29	2.40*	1.71	3.37
Waist circumference (cm)	1.07*	1.05	1.10	2.63*	1.93	3.60
Waist-to-hip ratio (%)	1.14*	1.10	1.18	2.80*	2.08	3.76
Waist-to-height ratio (%)	1.14*	1.09	1.19	2.85*	2.04	3.99
Normal weight						
Body mass index (kg/m²)	1.38	0.71	2.68	1.70	0.57	5.12
Waist circumference (cm)	1.06	0.98	1.15	1.56	0.87	2.82
Waist-to-hip ratio (%)	1.18*	1.06	1.32	2.98*	1.45	6.12
Waist-to-height ratio (%)	1.22*	1.01	1.49	2.38*	1.02	5.55
Overweight						
Body mass index (kg/m²)	1.39*	1.02	1.90	1.63*	1.03	2.57
Waist circumference (cm)	1.09	1.00	1.18	1.71	1.00	2.94
Waist-to-hip ratio (%)	1.10*	1.05	1.15	1.74*	1.32	2.29
Waist-to-height ratio (%)	1.19*	1.09	1.30	1.96*	1.41	2.72
Obese class I						
Body mass index (kg/m²)	0.87	0.55	1.35	0.82	0.44	1.52
Waist circumference (cm)	0.92	0.84	1.02	0.65	0.39	1.09
Waist-to-hip ratio (%)	0.98	0.81	1.17	0.90	0.40	2.04
Waist-to-height ratio (%)	1.02	0.78	1.33	1.07	0.44	2.61
Women						
Total†						
Body mass index (kg/m²)	1.17*	1.10	1.25	2.56*	1.74	3.76
Waist circumference (cm)	1.07*	1.05	1.09	2.97*	2.23	3.95
Waist-to-hip ratio (%)	1.13*	1.08	1.18	2.64*	1.89	3.69
Waist-to-height ratio (%)	1.13*	1.09	1.17	3.21*	2.33	4.43
Normal weight						
Body mass index (kg/m²)	1.51*	1.04	2.20	2.05*	1.07	3.92
Waist circumference (cm)	1.15*	1.03	1.30	2.68*	1.20	6.00
Waist-to-hip ratio (%)	1.19*	1.01	1.40	2.87*	1.06	7.74
Waist-to-height ratio (%)	1.30*	1.05	1.61	2.90*	1.21	6.93
Overweight						
Body mass index (kg/m²)	1.10	0.81	1.48	1.14	0.74	1.76
Waist circumference (cm)	1.04	0.98	1.11	1.36	0.86	2.14
Waist-to-hip ratio (%)	1.07	0.99	1.15	1.59	0.96	2.65
Waist-to-height ratio (%)	1.11	0.99	1.23	1.60	0.96	2.66
Obese class I						
Body mass index (kg/m²)	0.79	0.42	1.49	0.74	0.33	1.67
Waist circumference (cm)	1.01	0.89	1.15	1.08	0.40	2.89
Waist-to-hip ratio (%)	1.05	0.90	1.23	1.45	0.45	4.65
Waist-to-height ratio (%)	1.06	0.87	1.28	1.33	0.51	3.47

† excludes respondents classified as underweight (body mass index less than 18.5)
* significantly different from 1.0 ($p < 0.05$)
Notes: Adjusted for age, education, smoking status, alcohol consumption, physical activity level and hormone replacement use (women). Adiposity variables were entered into regression models as continuous variables. Separate models were run for each adiposity variable.
Source: 2007-2009 Canadian Health Measures Survey (fasted sample).

What is already known on this subject?

- Elevated body mass index (BMI) and abdominal obesity are associated with increased risk of cardiovascular disease.

- Several health organizations recommend the use of measures of waist circumference within BMI categories to assess obesity-related health risk, but reviews of the literature to determine which adiposity measure is most strongly associated with CVD have yielded inconsistent conclusions.

- A Canadian study based on data collected 20 years ago found that higher waist circumference (WC) was associated with increased prevalence of CVD risk factors among women in the overweight and obese class I categories; among men, WC was not associated with increased prevalence of CVD risk factors in any BMI category.

- For a given BMI, Canadians have higher measures of abdominal obesity than they did 30 years ago.

What does this study add?

- Among men in the normal-weight and overweight categories, waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) were associated with increased odds of CVD risk factors.

- Among women in the normal-weight category, WC, WHR, and WHtR were associated with increased odds of CVD risk factors.

- For men and women in obese class I, measures of abdominal obesity were not associated with increased odds of CVD risk factors.

When the odds of having at least two CVD risk factors were examined *within* BMI categories, significant associations were observed for WHR and WHtR among men in the normal-weight (2.98 for WHR and 2.38 for WHtR based on standardized variables) and overweight (1.74 for WHR and 1.96 for WHtR based on standardized variables) categories. The odds (1.71) for WC approached significance (p=0.06) for overweight men. For men in obese class I, none of the adiposity variables was associated with having at least two CVD risk factors.

Among normal-weight women, all three abdominal obesity variables and BMI were associated with increased odds of having at least two CVD risk factors (2.68 for WC, 2.87 for WHR, 2.90 for WHtR, and 2.05 for BMI based on standardized variables). But among women in the overweight and obese class I categories, none of the variables was associated with having at least two CVD risk factors, although the odds approached significance (p=0.07) for WHR (1.59) and WHtR (1.60) among women who were overweight.

Discussion

Based on nationally representative data, the results of this study provide evidence that measures of BMI and abdominal obesity are associated with increased prevalence of CVD risk factors. Moreover, *within* certain BMI categories, measures of abdominal obesity are associated with an increased risk of having at least two CVD risk factors. Among normal-weight and overweight men, WHR and WHtR were associated with CVD risk factors. Among normal-weight women, all three measures of abdominal obesity were related to CVD risk factors. However, among overweight women, none of the abdominal obesity measures was significantly related to CVD risk factors, although associations with WHR and WHtR approached significance. Among men and women in obese class I, measures of abdominal obesity were not associated with CVD risk factors.

A study based on data from the Canada Heart Health Surveys (1986 to 1992), which had a design and approach similar to the present analysis, found that among women, but not men, in the overweight and obese class I categories, elevated WC was associated with increases in CVD risk factors.[29] This earlier study excluded normal-weight people because of the small number who had a large WC, and did not assess WHtR and WHR. An American analysis of data from the Third National Health and Examination Survey (1988 to 1994) found that elevated WC was associated with increased CVD risk factors among women in the normal, overweight and obese class I categories, and among men in the overweight and obese class I categories.[30]

Differences between the results of the current analysis and these earlier studies may, in part, reflect recent changes in the obesity phenotype in Canada[16] and other countries.[31,32] Larger increases in WC than in BMI resulted in a shift toward higher WC values *within* BMI categories.[17] Almost all men and women in obese class I are now at high health risk based on WC, as are the majority of overweight women (more than a threefold increase since 1981).[17] The finding that WC (as a continuous variable) within these sex-BMI categories was not associated with increases in CVD risk factors suggests that WC measures may no longer be useful in assessing CVD risk within these sex-BMI categories. Whether this is true for other obesity-related health risks is unclear.

In the earlier Canadian study,[29] sample size was insufficient to consider WC among normal-weight women. However, by 2007-2009, close to one-quarter of normal-weight women were classified at increased/high health risk based on their WC,[17] and results from the current study show that WC is now associated with increases in CVD risk factors for normal-weight women.

Elevated odds of CVD risk factors were observed for WC among normal-weight and overweight men, but associations did not attain statistical significance. However, in these BMI categories,

WHR and WHtR were significantly associated with CVD risk factors. As well, for women in the normal-weight and overweight BMI categories, based on the standardized coefficients, the odds ratios for WHR and WHtR were higher than for WC, although the confidence intervals overlapped. Among overweight women, associations with CVD risk factors for WHR and WHtR approached significance.

The INTERHEART case-control study, which had the benefit of a very large sample size (12,000 myocardial infarction cases and 15,000 controls), found that the risk of myocardial infarction was more strongly associated with WHR than with WC.[5] It was suggested that the advantage of WHR over WC in assessing health risk is due to the protective effect of larger hip circumference.[5] Other studies have found independent associations between WC (positive) and hip circumference (negative) with obesity-related diseases and mortality.[33-35] However, the value of WHR in clinical practice is limited because of difficulties in interpretation—is an individual's risk greater because of a high WC and/or a low hip circumference? Furthermore, loss in abdominal fat due to weight reduction will not be reflected in changes in WHR (both WC and hip circumference will decrease), making WHR an inadequate tool for use in weight loss management.[36] Finally, contrary to the findings of the INTERHEART case-control study, a recent meta-analysis of 58 cohort studies concluded that BMI, WC and WHR had similar strengths of association with CVD risk.[37]

Associations between WHtR and health outcomes have been studied less extensively. A systematic review of the literature examining associations with CVD and diabetes concluded that WHtR is an effective screening tool in assessing health risk, probably better than WC.[6] This may be due to the protective effect of height.[38]

Canadian clinical practice guidelines recommend that to monitor and assess obesity-related health risks among adults, WC should be measured in addition to

BMI.[13] But because of the complexity of collecting measures of abdominal obesity, most large population-based surveys conducted by Statistics Canada rely exclusively on BMI. The strong gradient observed in CVD risk factors by BMI category in the current study supports this practice. Although it would be useful to routinely collect measures of abdominal obesity in addition to BMI, the high correlation between BMI and WC (more than 0.9) in this study suggests that BMI is an excellent proxy in assessing obesity-related CVD risk when it is not feasible to measure abdominal obesity.

Limitations

Important limitations of this study include the response rate, the size of the fasting subsample, restrictions on the availability and number of control variables in the analysis, the cross-sectional design of the study, and the inherent limitations of the accepted thresholds for increased health risk associated with each indicator.

The fasting subsample response rate was 46.3%. Although sampling weights were adjusted to compensate for all four levels of non-response (household roster, household interview, mobile examination center visit, and fasting blood sample), estimates may be biased if individuals with certain characteristics were less likely to participate. The degree to which this may have affected associations with CVD risk factors is unknown.

Nonetheless, a study that examined whether the characteristics of those who responded to the household questionnaire differ from the characteristics of those who completed the mobile examination component found no significant differences in estimates when the non-response adjustment was applied.[21]

The relatively small fasting sample size and the clustered nature of the sample design resulted in fairly wide confidence intervals for the odds ratios relating obesity measures to CVD risk factors. Larger sample sizes would improve the ability to compare the effectiveness of risk assessment among the various adiposity measures. As well, the limited sample size prevented examination of categorical abdominal obesity variables (based on health risk) in relation to CVD risk factors *within* BMI categories.

In the regression models examining adiposity variables in relation to CVD risk factors, a maximum of 10 control variables could be entered because of the 11 degrees of freedom available in the CHMS sample design. In supplementary analyses that considered ethnicity and family history of CVD as potential confounders, associations between the adiposity variables and CVD risk factors were not altered.

Although it was not possible to control for women's menopause status (such information was not included in the CHMS), this is addressed to some extent by the inclusion of age, which is correlated with menopause.

The cross-sectional nature of the CHMS precludes an assessment of temporal ordering of excess weight and the onset of CVD risk factors.

Finally, the results of this study cannot be generalized to other health outcomes such as heart disease, stroke and diabetes.

Conclusion

The current analysis indicates that BMI is associated with increases in CVD risk factors, and therefore, can be used to measure obesity-related health risk in the context of population-based surveys. The study also supports the Canadian clinical practice guideline that, in addition to BMI, WC should be measured to assess obesity-related health risk in adults.[13] Unlike past research based on Canadian data,[29] this analysis found that measures of abdominal obesity were associated with increased risk for overweight men, and for normal-weight men and women, who, based on their BMI, are not considered to be at elevated risk of obesity-related disease. As more cycles of CHMS data are collected and sample sizes increase, future research will be able to compare the relative usefulness of WC, WHR and WHtR within BMI categories in identifying additional health risk. ■

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Urban sprawl and its relationship with active transportation, physical activity and obesity in Canadian youth • Research article

17

Urban sprawl and its relationship with active transportation, physical activity and obesity in Canadian youth

by Laura Seliske, William Pickett and Ian Janssen

Abstract

Background

Urban sprawl is a potential environmental influence on youth overweight/obesity. However, little is known about the association between urban sprawl and behaviours that influence obesity such as active transportation and physical activity.

Methods

The study population consisted of 7,017 respondents aged 12 to 19 to the 2007/2008 Canadian Community Health Survey, living in Canada's 33 census metropolitan areas (CMAs). Factor analysis was used to obtain an urban sprawl score for each CMA, incorporating dwelling density, percentage of single or detached dwelling units, and percentage of the population living in the urban core. Multi-level logistic regression examined whether urban sprawl was associated with frequent active transportation (30 or more minutes a day), moderate-to-vigorous physical activity (MVPA) (60 or more minutes a day), and overweight/obesity.

Results

Urban sprawl was associated with active transportation among 12- to 15-year-olds, with the relative odds of engaging in at least 30 minutes of active transportation per day increasing by 24% (95% CI: 10-39%) for each standard deviation (SD) increase in the urban sprawl score. For the entire sample aged 12 to 19, higher urban sprawl was associated with MVPA (odds ratio per SD increase = 1.10, 95% CI: 1.01-1.20), but not with overweight/obesity (odds ratio per SD increase = 1.06, 95% CI: 0.94-1.18).

Interpretation

Urban sprawl was associated with active transportation and MVPA in Canadian youth, although in the opposite direction to what has been reported in the literature for adults.

Keywords

adolescent behaviour, body mass index, built environment, exercise, residence characteristics, urban planning

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O ver the past 30 years, the prevalence of overweight and obesity has nearly tripled among Canadian youth aged 12 to 17,[1] thereby potentially increasing the physical, mental and social problems associated with obesity in young people.[2-6] Furthermore, obesity tends to persist, with 60% to 90% of obese adolescents remaining obese into adulthood.[7] To develop effective public health strategies, an understanding of the determinants of obesity is important. Because lack of moderate-to-vigorous physical activity (MVPA) is acknowledged to be one of those determinants,[8-11] researchers are interested in features of the surrounding environment that promote or inhibit physical activity.[12]

Urban sprawl is a pattern of development whereby metropolitan areas extend over a large geographic region.[13] This can make it difficult to walk or cycle between destinations, and can result in more driving, longer commute times, and less physical activity.[14,15] Evidence from two American studies suggests an association between urban sprawl and obesity and its behavioural determinants among adolescents. Ewing et al.[16] found that 12- to 17- year-olds in counties with greater-than-average urban sprawl were more likely to be overweight or obese than were those in counties with less-than-average urban sprawl. In a study of Grade 8 and 10 students, Slater et al.[17] found a lower prevalence of obesity among those in areas with less-than-average urban sprawl, but no association with MVPA.

Because reliance on automobiles may influence obesity, it is important to consider the role of driving on the association between urban sprawl and the behavioural determinants of obesity. Trowbridge et al.[18] reported that, in the United States, the likelihood of driving

more than 32 km per day was twice as great among youth in sprawling counties, compared with those in compact counties. This supports the possibility of an association between urban sprawl and driving patterns. However, the influence may not be the same for youth who lack a driver's license, and therefore, depend on active transportation such as cycling and walking. Few studies of urban sprawl and obesity-related behaviours among young people have examined the potential moderating role of driving age.

Studies of the association between urban sprawl and obesity in youth are not extensive and have typically been limited to the United States. The inclusion of active transportation as an outcome may help gain a better understanding of whether urban sprawl affects the use of physically active means of transportation, which, in turn, may also influence MVPA and youth obesity.

The primary objective of this analysis was to examine associations between urban sprawl and (1) active transportation, (2) MVPA, and (3) obesity in a large sample of Canadian youth residing in Census Metropolitan Areas (CMAs). A secondary objective was to consider driving age as a possible moderator of these associations. As well as interventions aimed at changing an individual's behaviour,[19-21] the possibility of modifying surrounding environments to facilitate healthy behaviour should be recognized. Two-thirds (68%) of Canadians live in CMAs[22] (urban centres with a population of 100,000 or more). Therefore, even small changes in features of the built environment in CMAs have the potential to affect many people.

Methods

Study design

The study consisted of a multi-level cross-sectional analysis and examined associations between urban sprawl, obesity-related behaviours, and obesity among 12- to 19-year-olds in Canada's 33 CMAs. Individual-level data on active transportation, MVPA, obesity, and socio-demographic characteristics

were obtained from a general health survey. Area-level data—urban sprawl scores and climate averages—were obtained for each CMA from the 2006 Census and from Environment Canada, respectively. The individual- and area-level data were linked based on the CMA identifier for each survey respondent.

Study sample

The study sample was from the 2007/2008 Canadian Community Health Survey (CCHS), a large, nationally representative cross-sectional survey that collects information about the health of Canadians aged 12 or older.[23] A complex sampling strategy ensured that the sample was representative of the health regions in all provinces and territories.

The present analysis was restricted to respondents aged 12 to 19. Because urban sprawl primarily applies to larger urban areas,[12] only CMA residents were included .

Outcomes

CCHS respondents were asked to report the number of times they participated in common physical activities in the past three months (90 days) and the appropriate duration category. The midpoint of the duration category was used to estimate the number of minutes of physical activity.[24] The average daily duration of the activity was calculated by multiplying the frequency and duration and dividing this by 90.

Total MVPA was comprised of all activities, whereas active transportation was limited to walking, cycling and rollerblading to work or to school or for leisure. Respondents were placed in two groups, based on whether they met the current guideline of 60 minutes of MVPA a day.[25] In the absence of guidelines for the duration of active transportation, a 30-minute-a-day cut-point was used to place participants into two groups. This cut-point corresponded to the top quartile of active transportation, and the percentage of study participants who met this active transportation threshold was similar to the percentage who met the 60-minute-a-day MVPA cut-point.

Because vehicle use may moderate the association between urban sprawl and physical activity, an interaction term between urban sprawl and age group was introduced into the analysis, distinguishing those who were of driving age (16 to 19) from those who were not (12 to 15).

Self-reported height and weight were used to calculate the body mass index (BMI) (weight in kg / height in m^2) of each respondent. The weight status of 18- and 19-year-olds was based on adult BMI thresholds of less than 25 kg/m^2 (non-overweight), 25 to 29.9 kg/m^2 (overweight), and 30 or more kg/m^2 (obese); for 12- to 17-year-olds, the age- and sex-specific International Obesity Task Force pediatric BMI thresholds[26] were used. Overweight and obese categories were combined for regression analyses.

Exposure

Urban sprawl was measured for each CMA, using an adaptation of the Canadian urban sprawl index developed by Ross et al.[27] that incorporated total dwelling density, percentage of single or detached dwellings, and percentage of the population living in the urban core of each CMA. Total dwelling density and density of single or detached dwelling units in each CMA were obtained using PCensus (2006 Census of Canada Profile Data; Tetrad Computer Applications Inc., Vancouver BC) The percentage of the population in the urban core was obtained from Statistics Canada.[28] Instead of weighting the three urban sprawl components equally to create a summary urban sprawl score (as is done by Ross et al.[27]), a principal components factor analysis was performed. Results showed that the three components comprised a single factor, and Cronbach's alpha for this factor was 0.89. The factor loadings were 0.95 for dwelling density, 0.96 for density of single or detached dwellings, and 0.82 for percentage of the population in the urban core of the CMAs. The three components were used to create a standardized urban sprawl score, with a mean of 0 and a standard deviation of 1.

Statistics Canada, Catalogue no. 82-003-XPE • Health Reports, Vol. 23, no. 2, June 2012

Urban sprawl and its relationship with active transportation, physical activity
and obesity in Canadian youth • Research article

19

Confounders

Potential individual-level confounders obtained from the CCHS were age,[7,29,30] sex,[31] socio-economic status,[32] and the season[33] in which the interview was conducted. Household education categories ranged from less than secondary graduation to postsecondary graduation. Household income was determined by a ratio of the income to a low-income threshold for a given household and community size.[24]

Area-level confounders, specifically, climate averages,[34] were also considered. They comprised daily temperature, annual rainfall and annual snowfall. The climate data for each CMA were obtained from Environment Canada, and were based on averages from 1972 to 2000 at the international airport or the municipal airport in each CMA.[35]

Statistical analysis

All analyses were conducted using SAS software version 9.2 (SAS Institute, Cary, NC). The complex sampling procedures for the CCHS resulted in individuals in the target population having unequal probabilities of being sampled. To account for this, 500 bootstrap replications were performed using Statistics Canada's bootstrap weights for the descriptive and regression analyses.[36,37] Multi-level logistic regressions were carried out using *proc glimmix* and used a multi-step process to estimate the odds ratio (OR) of reporting: (1) 30 minutes of active transportation a day; (2) 60 minutes of MVPA a day; and (3) an overweight/obese BMI, in association with estimated levels of urban sprawl.

An empty model was used to determine the intra-class correlation (ICC) statistic for logistic regression. The ICC value indicates the percentage of the total variation in the outcomes that was due to differences across CMAs. Bivariate associations between the outcomes and each potential confounder were then examined. The multivariate model-building process began with the introduction of the individual-level variables and the interaction term (driving age), and proceeded using a backwards elimination approach. The urban sprawl variable was forced into all models. The interaction term was included at the beginning of the model-building process to test the *a priori* hypothesis that driving age modified the association between urban sprawl and the outcome variables. For active transportation and MVPA, the CMA climate variables were entered into the model using backwards elimination.

Season and climate variables were not included for overweight/obesity, because no evidence suggests an association. To account for the possibility that the relationship between urban sprawl and the outcomes may be heavily influenced by respondents in the three largest CMAs (Montreal, Toronto and Vancouver), the analysis was repeated with these respondents removed.

Table 1
Distribution of selected demographic and health characteristics, household population aged 12 to 19 in Census Metropolitan Areas, Canada, 2007/2008

Characteristic	Unweighted number	Weighted %	95% confidence interval from	to
Total	**7,017**	**100.0**	...	...
Sex				
Male	3,587	51.3	50.9	51.8
Female	3,430	48.7	48.3	49.1
Age group				
12 to 15	3,522	51.0	49.4	52.6
16 to 19	3,495	49.0	47.4	50.6
Highest household education				
Less than secondary graduation	180	2.8	2.3	3.4
Secondary graduation	659	9.0	8.0	10.0
Postsecondary graduation	4,666	68.6	67.1	70.1
Not stated	1,512	19.6	18.4	20.8
Household income decile				
1 to 3	1,729	27.4	25.9	28.9
4 to 6	1,747	24.3	22.9	25.6
7 to 10	1,890	23.7	22.4	25.0
Not stated	1,651	24.6	23.3	26.0
Season of survey interview				
Winter (December to February)	1,527	23.2	21.9	24.5
Spring (March to May)	1,955	27.4	25.9	28.9
Summer (June to August)	1,489	22.4	21.1	23.8
Fall (September to November)	2,046	27.0	25.6	28.4
Active transportation (30 or more minutes a day)				
Yes	1,669	22.2	20.9	23.5
No	4,715	68.6	67.1	70.1
Not stated	633	9.2	8.3	10.2
Moderate-to-vigorous physical activity (60 or more minutes a day)				
Yes	2,402	32.8	31.3	34.3
No	3,812	56.2	54.6	57.7
Not stated	803	11.0	10.0	12.0
Weight				
Not overweight	4,975	71.7	70.3	73.2
Overweight	933	12.1	11.2	13.0
Obese	307	4.2	3.5	4.9
Not stated	802	11.9	10.9	13.0

... not applicable
Source: 2007/2008 Canadian Community Health Survey.

Results

A total of 7,017 respondents to the 2007/2008 CCHS met the inclusion criteria for the study. Respondents were equally distributed between the two age groups (12 to 15 and 16 to 19) (Table 1). One in four respondents engaged in active transportation for at least 30 minutes day. One in three met the MVPA guidelines. Of those who reported their height and weight, one in four were overweight or obese.

Table 2 provides the urban sprawl scores and the climate characteristics for each CMA. Positive scores indicate higher levels of urban sprawl. Toronto, Montreal and Vancouver—the three largest CMAs—had the lowest scores.

The ICC value for active transportation (30 or more minutes a day) indicated that only 0.21% of the variation in this outcome was explained at the CMA level. In the bivariate analysis, no association was apparent between urban sprawl and active transportation in the total sample (Table 3). However, because the interaction term between age and urban sprawl was statistically significant (β= -0.20, p<0.01), separate odds ratios were calculated for the two age groups. When adjustments for the individual- and area-level confounders were made, urban sprawl was related to an increased likelihood of active transportation among 12- to 15-year-olds (OR per SD increase = 1.24, 95% CI: 1.10-1.39), but not among 16- to 19-year-olds (OR per SD increase = 1.02, 95% CI: 0.88-1.17).

The ICC value for MVPA (60 or more minutes a day) indicated that only 0.28% of the variation in this outcome was explained at the CMA level. Because the interaction term between the urban sprawl score and MVPA was not significant (β= -0.01, p-value=0.90), the odds ratio was calculated for the entire study population, rather than by age group (Table 4). The bivariate analysis suggested no statistically significant association between urban sprawl and MVPA. However, when the individual- and area-level confounders were added to the model, a positive association emerged between urban sprawl and MVPA (OR per SD increase = 1.10, 95%: 1.01-1.20). Sex, the season when the interview was conducted, and average daily temperature were also significantly related to MVPA.

The ICC value for overweight/obesity was 0.90%. The bivariate analyses revealed no association between urban sprawl and overweight/obesity (Table 5). Addition of the confounders to the model did not change this result. The age interaction term was not statistically significant (β= -0.02, p-value=0.81).

When respondents in the three largest CMAs (Montreal, Toronto and Vancouver) were removed from the analysis, the interaction term was no longer statistically significant for active transportation (β= 0.16, p-value=0.13), suggesting that there was no difference in relationships for the two age groups (data not shown). Furthermore, the association between urban sprawl and active transportation changed directions (OR per SD increase = 0.93, 95% CI: 0.82-1.05). For MVPA, the relationship was no longer statistically significant (OR per SD increase = 0.98, 95% CI: 0.88-1.09). However, removal of these respondents did not substantially affect the relationship with overweight/obesity (OR per SD increase = 0.97, 95% CI: 0.86-1.11).

Table 2
Urban sprawl scores and climate characteristics, by Census Metropolitan Area

| | | 1972-to-2000 average | | |
Census Metropolitan Area	Standardized urban sprawl score	Daily temperature (ºC)	Annual rainfall (mm)	Annual snowfall (cm)
Montreal, QC	-2.28	6.2	764	216
Toronto, ON	-2.15	7.5	685	115
Vancouver, BC	-1.65	10.1	1,155	48
Kitchener-Cambridge-Waterloo, ON	-1.51	6.7	765	160
Hamilton, ON	-1.43	7.6	765	162
Victoria, BC	-1.21	9.7	841	44
Windsor, ON	-0.73	9.4	805	127
Guelph, ON	-0.65	6.5	771	161
Oshawa, ON	-0.45	7.7	760	118
Calgary, AB	-0.35	4.1	321	127
St. Catharines-Niagara, ON	-0.31	8.8	746	137
Quebec City, QC	-0.21	4.0	924	316
Barrie, ON	-0.09	6.7	700	238
Abbotsford-Mission, BC	-0.04	10.0	1,508	64
Winnipeg, MB	0.05	2.6	416	111
London, ON	0.05	7.5	818	202
St. John's, NF	0.07	4.7	1,191	322
Trois-Rivières, QC	0.20	4.9	859	241
Regina, SK	0.37	2.8	304	106
Edmonton, AB	0.38	2.4	375	121
Sherbrooke, QC	0.41	4.1	874	294
Ottawa ON-Gatineau QC	0.51	6.0	732	236
Saskatoon, SK	0.65	2.2	265	97
Thunder Bay, ON	0.70	2.5	559	188
Brantford, ON	0.86	8.0	780	113
Kelowna, BC	0.93	7.7	298	102
Halifax, NS	0.96	6.3	1,239	231
Moncton, NB	0.98	5.1	865	350
Kingston, ON	1.05	6.7	795	181
Saguenay, QC	1.11	2.3	661	342
Saint John, NB	1.17	5.0	1,148	257
Peterborough, ON	1.24	5.9	682	162
Greater Sudbury, ON	1.35	3.7	657	274

Source: 2006 Census of Canada; Environment Canada.

Statistics Canada, Catalogue no. 82-003-XPE • Health Reports, Vol. 23, no. 2, June 2012

Urban sprawl and its relationship with active transportation, physical activity
and obesity in Canadian youth • Research article

21

Table 3
Unadjusted and adjusted odds ratios relating selected characteristics to active transportation, household population aged 12 to 19 in Census Metropolitan Areas, Canada, 2007/2008

	Bivariate model			Individual-level model			Area-level model		
	Unadjusted odds ratio	**95% confidence interval**		**Adjusted odds ratio**	**95% confidence interval**		**Adjusted odds ratio**	**95% confidence interval**	
		from	to		from	to		from	to
Urban sprawl									
1 standard deviation in sprawl score	1.03	0.94	1.12	....	...	...	....	...	...
12- to 15-year-olds	....	...	...	1.15*	1.03	1.27	1.24*	1.10	1.39
16- to 19-year-olds	....	...	...	0.94	0.77	1.15	1.02	0.88	1.17
Individual-level variables									
Sex									
Male†	1.00	...	...	1.00	...	...	1.00	...	...
Female	0.74*	0.64	0.87	0.73*	0.63	0.86	0.73*	0.63	0.86
Age group									
12 to 15†	1.00	...	...	1.00	...	...	1.00	...	...
16 to 19	1.03	0.88	1.19	0.84	0.70	1.00	0.84	0.70	1.00
Highest household education									
Less than secondary graduation†	1.00	...	...	....	...	...	....	...	...
Secondary graduation	1.62	0.94	2.80	....	...	...	....	...	...
Postsecondary graduation	1.32	0.80	2.20	....	...	...	....	...	...
Not stated	1.80*	1.10	2.97	....	...	...	....	...	...
Household income decile									
1 to 3†	1.00	...	...	1.00	...	...	1.00	...	...
4 to 6	0.80*	0.65	0.99	0.77*	0.62	0.95	0.77*	0.62	0.95
7 to 10	0.72*	0.58	0.90	0.69*	0.56	0.86	0.69*	0.56	0.86
Not stated	0.94	0.76	1.17	0.90	0.72	1.13	0.90	0.72	1.13
Season of survey interview									
Winter (December to February)†	1.00	...	...	1.00	...	...	1.00	...	...
Spring (March to May)	0.92	0.72	1.17	0.92	0.72	1.17	0.92	0.72	1.17
Summer (June to August)	1.39*	1.10	1.74	1.40*	1.11	1.76	1.40*	1.11	1.76
Fall (September to November)	1.16	0.94	1.44	1.16	0.94	1.45	1.16	0.94	1.45
Area-level variables									
Average temperature (1 standard deviation increase)	1.12*	1.02	1.23	....	...	...	1.18*	1.06	1.32
Average rainfall (1 standard deviation increase)	1.07	0.97	1.17	....	...	...	....	...	...
Average snowfall (1 standard deviation increase)	0.97	0.88	1.06	....	...	...	....	...	...

N = 6,384
† reference category
* significantly different from reference category (p<0.05)
... not applicable
Note: Active transportation is 30 or more minutes a day.
Source: 2007/2008 Canadian Community Health Survey.

Discussion

Adolescents aged 12 to 15 in CMAs with a high degree of urban sprawl were more likely than those in relatively compact CMAs to engage in active transportation. And for the 12-to-19 age group overall, high urban sprawl was associated with elevated odds of MVPA. Although the strength of these associations was relatively modest, the impact on the physical activity levels of young people may still be meaningful for the population as a whole. The CMAs with the lowest sprawl scores—Toronto, Montreal and Vancouver—were also the most populated. Therefore, alterations of the surrounding environment aimed at increasing active transportation could potentially affect a large number of young people.

The lack of a relationship between urban sprawl and overweight/obesity in this analysis differs from the results of Ewing et al.[16] and Slater et al.[17] who found that increased urban sprawl was associated with a higher prevalence of overweight/obesity in American youth. A possible reason for the difference may be that the sprawl index used by those researchers pertained to counties, whereas the measure in this analysis pertained to CMAs. The large size of CMAs may have masked differences in the prevalence of overweight/obesity.

Table 4
Unadjusted and adjusted odds ratios relating selected characteristics to moderate-to-vigorous physical activity, household population aged 12 to 19 in Census Metropolitan Areas, Canada, 2007/2008

	Bivariate model			Individual-level model			Area-level model		
	Unadjusted odds ratio	95% confidence interval		Adjusted odds ratio	95% confidence interval		Adjusted odds ratio	95% confidence interval	
		from	to		from	to		from	to
Urban sprawl									
1 standard deviation in sprawl score	1.01	0.94	1.09	1.02	0.94	1.10	1.10*	1.01	1.20
Individual-level variables									
Sex									
Male†	1.00	...	...	...	...	...	1.00	...	...
Female	0.56*	0.49	0.64	0.56*	0.49	0.64	0.56*	0.49	0.64
Age group									
12 to 15†	1.00	...	...	...	...	...	...	...	...
16 to 19	0.93	0.81	1.71	...	...	...	...	...	...
Highest household education									
Less than secondary graduation†	1.00	...	...	...	...	...	...	...	...
Secondary graduation	1.32	0.74	2.35	...	...	...	...	...	...
Postsecondary graduation	1.46	0.87	2.46	...	...	...	...	...	...
Not stated	1.63	0.97	2.73	...	...	...	...	...	...
Household income decile									
1 to 3†	1.00	...	...	...	...	...	...	...	...
4 to 6	0.99	0.81	1.22	...	...	...	...	...	...
7 to 10	1.26*	1.04	1.52	...	...	...	...	...	...
Not stated	1.05	0.85	1.29	...	...	...	...	...	...
Season of survey interview									
Winter (December to February)†	1.00	...	...	1.00	...	...	1.00	...	...
Spring (March to May)	0.89	0.73	1.10	0.89	0.73	1.10	0.89	0.73	1.10
Summer (June to August)	1.34*	1.09	1.65	1.33*	1.08	1.64	1.33*	1.08	1.64
Fall (September to November)	1.10	0.90	1.35	1.09	0.89	1.33	1.09	0.89	1.33
Area-level variables									
Average temperature (1 standard deviation increase)	1.13*	1.05	1.23	...	...	...	1.18*	1.08	1.30
Average rainfall (1 standard deviation increase)	1.11*	1.02	1.20	...	...	...	...	...	...
Average snowfall (1 standard deviation increase)	1.00	0.91	1.10	...	...	...	...	...	...

N = 6,384
† reference category
* significantly different from reference category (p<0.05)
... not applicable
Note: Moderate-to-vigorous physical activity is 60 or more minutes a day.
Source: 2007/2008 Canadian Community Health Survey.

Another possibility is that information about neighbourhood and traffic safety was included in the earlier studies, [16,17] but was not available from the CCHS. Concerns about traffic and crime tend to have a dampening effect on active transportation among young people.[38,39] In the present study, the three largest CMAs, where traffic concerns may be more common, had the least urban sprawl. In fact, when respondents in these three CMAs were removed from the analysis, the strength of the relationships

was diminished. As well, the interaction term for active transportation was no longer significant, and the direction of the relationship changed. This suggests that the positive association between active transportation and urban sprawl primarily affected residents of large cities. Therefore, it is possible that traffic safety concerns may have deterred younger adolescents in the largest CMAs from engaging in active transportation.

In contrast to its influence on adults,[27,40-42] urban sprawl may encourage

physical activity in young people. Slater et al.[17] found that adolescents in sprawling counties had higher rates of sports participation. And according to Mecredy et al.,[43] Canadian youth exposed to less densely connected streets were more likely to be active outside of school for at least four hours a week, compared with young people exposed to more densely connected streets.

Initiatives to reduce urban sprawl in Canadian cities[44,45] and worldwide[46] are based, in part, on evidence demonstrating

Statistics Canada, Catalogue no. 82-003-XPE • Health Reports, Vol. 23, no. 2, June 2012

*Urban sprawl and its relationship with active transportation, physical activity
and obesity in Canadian youth • Research article*

23

Table 5

Unadjusted and adjusted odds ratios relating selected characteristics to overweight/obesity, household population aged 12 to 19 in Census Metropolitan Areas, Canada, 2007/2008

	Bivariate model			Individual-level model		
	Unadjusted odds ratio	95% confidence interval		Adjusted odds ratio	95% confidence interval	
		from	to		from	to
Urban sprawl						
1 standard deviation in sprawl score	1.04	0.94	1.16	1.06	0.94	1.18
Individual-level variables						
Sex						
Male[†]	1.00	...	...	1.00	...	...
Female	0.52*	0.44	0.62	0.51*	0.43	0.61
Age group						
12 to 15[†]	1.00	...	...	1.00	...	...
16 to 19	1.23*	1.04	1.46	1.25*	1.05	1.49
Highest household education						
Less than secondary graduation[†]	1.00	...	...	...	...	...
Secondary graduation	0.54*	0.31	0.95	...	...	...
Postsecondary graduation	0.42*	0.25	0.71	...	...	...
Not stated	0.48*	0.28	0.83	...	...	...
Household income decile						
1 to 3[†]	1.00	...	...	1.00	...	...
4 to 6	0.88	0.69	1.12	0.85	0.66	1.08
7 to 10	0.70*	0.55	0.89	0.67*	0.52	0.85
Not stated	0.93	0.72	1.19	0.88	0.68	1.14

N = 6,215
[†] reference category
* significantly different from reference category (p<0.05)
... not applicable
Source: 2007/2008 Canadian Community Health Survey.

What is already known on this subject?

- Given the rapidly increasing obesity prevalence among young people, researchers are interested in how aspects of the surrounding environment may contribute to obesity-related outcomes.

- American studies have demonstrated that urban sprawl, a component of the surrounding environment, is related to higher levels of obesity in young people.

What does this study add?

- A positive association emerged between urban sprawl and active transportation and moderate-to-vigorous physical activity, which contradicts other findings for youth and adult populations.

- The association between urban sprawl and active transportation prevailed only among 12- to 15-year-olds, indicating that driving age was a potential modifier. This highlighted the importance of considering associations among younger and older adolescents separately.

- Small variations in the outcomes across CMAs suggest that refinements of the current measure of urban sprawl might capture more variability across geographic areas.

negative effects, such as increased time spent in cars[47] and greater air pollution.[48] Among adults, urban sprawl has been negatively associated with physical activity and active transportation.[40,42,49] However, some urban planners recognize advantages of a suburban lifestyle, including more affordable housing,[50] aesthetically pleasing green space,[51] and lower crime rates.[52]

Limitations

A limitation of this study was that the ICC values for the outcomes were small, possibly because the large geographic area covered by the CMAs resulted in little variation in outcomes among them.

A small percentage of the CMAs consisted of rural land. Because it was not possible to exclude these areas, some study participants were not influenced by the patterns of development associated with urban sprawl.

An additional limitation was that the BMI and physical activity measures were based on self-reports, which likely resulted in an underestimate of BMI values[53] and an overestimate of physical activity levels,[54] which may have influenced the strength of the observed associations.

Finally, information on potentially important confounders was unavailable. For example, although it was possible to determine if participants were of driving age, whether they had a driver's license and access to a vehicle was not known.

Conclusion

Clearly, urban sprawl is a complex public health issue, with both positive and negative outcomes. This study contributes to the evidence of positive health outcomes associated with urban sprawl among Canadian youth. Urban sprawl was not related to overweight/obesity per se, but it was related to moderate-to-vigorous physical activity, and among 12- to 15-year-olds, to active transportation. These findings differed from those for adults.[43,48] Therefore, age should be considered when developing strategies relating to the built environment that are intended to increase physical activity, and ultimately, reduce obesity among Canadians. ∎

24 Health Reports, Vol. 23, no. 2, June 2012 • Statistics Canada, Catalogue no. 82-003-XPE

Urban sprawl and its relationship with active transportation, physical activity and obesity in Canadian youth • Research article

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Statistics Canada, Catalogue no. 82-003-XPE • Health Reports, Vol. 23, no. 2, June 2012
Urban sprawl and its relationship with active transportation, physical activity and obesity in Canadian youth • Research article

25

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Daily patterns of physical activity among Canadians • **Health matters**

27

Daily patterns of physical activity among Canadians

by Didier Garriguet and Rachel C. Colley

Abstract

The 2007 to 2009 Canadian Health Measures Survey (CHMS) collected directly measured physical activity on seven consecutive days for a representative sample of the population aged 6 to 79. Based on the CHMS, half of the active minutes in a day are accumulated between 11:00 a.m. and 5:00 p.m. For children, the most active period is lunch-time (11:00 a.m. to 1:00 p.m.), and for teenagers aged 15 to 19, the after-school period (3:00 p.m. to 5:00 p.m.). Children and youth are more active on weekdays than on weekends. Active children and youth tend to accumulate more minutes of moderate-to-vigorous physical activity after school, whereas active adults do so at lunch time.

Key words

Accelerometer, Actical, activity monitor, body mass index, body weight, exercise

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Canadian children and youth are more active on weekdays than on weekends, while adults have relatively consistent levels of physical activity regardless of the day of the week. At all ages, but particularly among children and youth, most physical activity occurs between 11:00 a.m. and 5:00 p.m., with distinct peaks at lunch time and in the afternoon just after school or work. Time-stamped objective measurement tools allow researchers to determine not only who is doing enough to meet physical activity guidelines, but also when that activity is occurring.

Until recently, population-level trends in physical activity were estimated using self-report surveys and questionnaires, an approach that is subject to recall error and bias.[1-3] By contrast, the 2007 to 2009 Canadian Health Measures Survey (CHMS) used accelerometers to obtain objective measures of physical activity and sedentary behaviour.[4-6] Accelerometers provide minute-by-minute data about steps taken and movement intensity (sedentary to vigorous).

This article identifies the times during the day when people engage in moderate-to-vigorous physical activity (MVPA), based on accelerometer measures over seven consecutive days (see *The data*). Minutes of MVPA are reported for two-hour intervals from 7:00 a.m. to 9:00 p.m., by age group and sex for weekdays and weekends. Patterns of physical activity among the most and least active in the population are also described.

Daily pattern of physical activity

For children and youth, weekdays during lunch hour and after school have been identified as periods when physical activity is high, based on self-reports,[7] pedometers,[8] and accelerometers.[9] Sex differences in the timing of physical activity have also been observed.[10]

Regardless of the person's age, half of all active minutes (at least moderately active) are accumulated between 11:00 a.m. and 5:00 p.m. (Table 1). MVPA accumulation is minimal at night

Table 1
Average daily minutes of moderate-to-vigorous physical activity, by age group, sex and time of day, household population aged 6 to 79, Canada, 2007 to 2009

Age group and sex	Time of day							
	7:00 a.m. to 8:59 a.m.	9:00 a.m. to 10:59 a.m.	11:00 a.m. to 12:59 p.m.	1:00 p.m. to 2:59 p.m.	3:00 p.m. to 4:59 p.m.	5:00 p.m. to 6:59 p.m.	7:00 p.m. to 8:59 p.m.	9:00 p.m. to 6:59 a.m.
6 to 10								
Boys	4.0	9.0*	13.1	11.5	11.4	10.3	8.1[E]	F
Girls	3.1	7.1	11.4	9.4	9.8	8.6	6.8	1.8[E]
11 to 14								
Boys	4.1	5.1	11.1	9.0	10.8	9.0	7.3	3.0
Girls	3.2	4.6	7.6	7.4	9.2	6.4	6.2	2.5[E]
15 to 19								
Men	4.4	5.1*	7.9*	7.5	9.6	6.8	5.7	6.1
Women	3.4	3.2	5.6	6.2	7.8	4.4	4.4	4.2
20 to 39								
Men	2.7	3.3	4.9*	4.6	4.7	4.8	3.7*	3.8
Women	2.3[E]	2.9	3.4	3.5	3.6	3.3	2.5	2.9
40 to 59								
Men	2.7	3.6	4.4	3.8	3.8	3.1	2.4	2.8
Women	1.9[E]	2.9	3.7	3.3	3.0	2.8	2.1	1.8
60 to 79								
Men	1.6	2.5	3.0[E]	2.9[E]	2.5[E]	1.7[E]	1.3[E]	1.5*
Women	1.5[E]	2.2	2.2	2.3	1.5	1.1	1.0	0.5[E]

* significantly different from females in same age group (p<0.05)
[E] use with caution
F too unreliable to be published
Source: 2007 to 2009 Canadian Health Measures Survey.

The data

The data are from the 2007 to 2009 Canadian Health Measures Survey (CHMS), which collected physical measurements for the household population aged 6 to 79. The survey excluded residents of Indian Reserves, Crown lands, institutions and certain remote regions, and full-time members of the Canadian Forces. Approximately 96% of Canadians were represented. Data were collected at 15 sites across Canada from March 2007 through February 2009. Ethics approval to conduct the survey was obtained from Health Canada's Research Ethics Board.[11] Details about the CHMS are available elsewhere.[3]

Participants were interviewed at home before visiting a mobile examination centre for a series of physical measurements. Upon completion of that 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 1 minute, resulting in a count value per minute. Accelerometer signals are also recorded as steps per minute. The Actical has been validated for measuring physical activity in adults[12] and children,[13,14] and step counts in adults and children.[15]

The monitors were initialized to start collecting data at midnight following the mobile examination centre visit. The data being recorded were not accessible by the respondents who were wearing the devices. The monitors were returned to Statistics Canada in a prepaid envelope, where the data were downloaded and the monitor was checked to determine if it was still within the manufacturer's calibration specifications.[4]

A total of 4,440 respondents returned the accelerometer with at least four valid days. A valid day was defined as having 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 2 minutes of counts between 0 and 100. For each minute, the level of movement intensity—sedentary, light, and moderate-to-vigorous (MVPA)—was based on cut-points corresponding to intensity level. The MVPA threshold was set at 1,500 for children and youth aged 6 to 19,[13] and at 1,535 for adults aged 20 to 79.[16] Minutes were summed by time period, defined as 7:00 to 8:59 a.m., 9:00 to 10:59 a.m., 11:00 a.m. to 12:59 p.m., 1:00 to 2:59 p.m., 3:00 to 4:59 p.m., 5:00 to 6:59 p.m., 7:00 to 8:59 p.m. and 9:00 p.m. to 6:59 a.m. and averaged over the number of valid days. The final response rate for having a minimum of four valid days was 41.8% (69.6% for selected household x 88.1% for selected person x 84.2% for mobile examination centre visit x 80.8% for valid accelerometer results).

Weekend estimates result from average minutes of MVPA on valid Saturday and Sunday, and weekday estimates, from average minutes of MVPA on valid Monday through Friday. Terciles of MVPA represent the weighted 33.3% and 66.6% of daily average of MVPA. Terciles were calculated by age group and sex.

Height was measured to the nearest 0.1 cm using a ProScale M150 digital stadiometer (Accurate Technology Inc., Fletcher, USA), and weight was measured to the nearest 0.1 kg with a Mettler Toledo VLC with Panther Plus terminal scale (Mettler Toledo Canada, Mississauga, Canada).[17] Body mass index (BMI) was calculated as weight (kg) divided by squared height (m) and was classified according to published BMI thresholds: normal (18.5 to 24.9 kg/m^2), overweight (25.0 to 29.9 kg/m^2), and obese (30.0 kg/m^2 or more) for adults.[18,19]

To account for survey design effects of the CHMS, standard errors, coefficients of variation, and 95% confidence intervals were estimated using the *bootstrap* technique.[17,20,21] Statistical significance was set at a *p* value of 0.05. Bonferroni adjustments were performed when comparing the different time periods. The number of degrees of freedom was specified as 11 to account for the CHMS sample design.[17]

(9:00 p.m. to 7:00 a.m.), ranging from 30 seconds to 6 minutes.

On average, males accumulate more MVPA than do females,[5,6] a difference that generally persists throughout the day. Among children aged 6 to 10 and teens aged 15 to 19, boys are significantly more active than girls during the mid-morning period (9:00 to 11:00 a.m.). At ages 15 to 39, men are significantly more active than women at lunch time (11:00 a.m. to 1:00 p.m.). And at ages 20 to 39, men are significantly more active than women in the early evening (7:00 to 9:00 p.m.).

For children aged 6 to 10, the most active period of the day is lunch time, while for adolescents and older teenagers, physical activity peaks from 3:00 to 5:00 p.m., particularly among 15- to 19-year-olds (Figure 1). Compared with the younger age groups, adults accumulate fewer minutes of MVPA in every time period.

Weekends and weekdays

On average, children and youth aged 6 to 19 spend more time in MVPA on weekdays than on weekends (57 versus 47 minutes per day; data not shown). This difference largely reflects more MVPA between 7:00 a.m. and 1:00 p.m. on weekdays (Figure 2). Even based on the percentage of time devoted to MVPA, weekdays are still more active than weekends, meaning that the differences are not due to less time wearing the accelerometer on weekends (data not shown).

Despite a popular assumption that adults are "weekend warriors" (accumulate the bulk of their MVPA on weekends, but are sedentary throughout the week), studies in the United States indicate that only 1% to 3% of adults fall into this category.[22,23] As well, in the CHMS results, no significant difference emerged in the average time adults spend in MVPA on weekdays versus weekends for the entire day (25 minutes on weekdays, 22 minutes on weekends; data not shown) or for any part of it.

Figure 1

Average daily minutes of moderate-to-vigorous physical activity, by age group and time of day, household population aged 6 to 79, Canada, 2007 to 2009
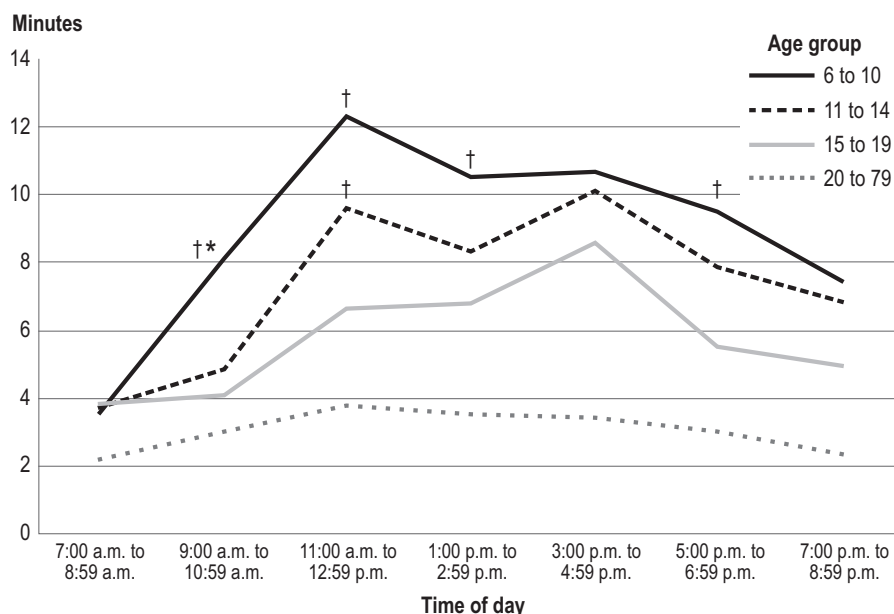
* significantly different from 11- to 14-year olds (p<0.05)
† significantly different from 15- to 19-year olds (p<0.05)
Source: 2007 to 2009 Canadian Health Measures Survey.

Figure 2

Average daily minutes of moderate-to-vigorous physical activity, by weekday/weekend and time of day, household population aged 6 to 79, Canada, 2007 to 2009

* significantly different from weekends (p<0.05)
E use with caution
Source: 2007 to 2009 Canadian Health Measures Survey.

Figure 3
Average daily minutes of moderate-to-vigorous physical activity, by activity tercile and time of day, household population aged 6 to 19 and 20 to 79, Canada, 2007 to 2009
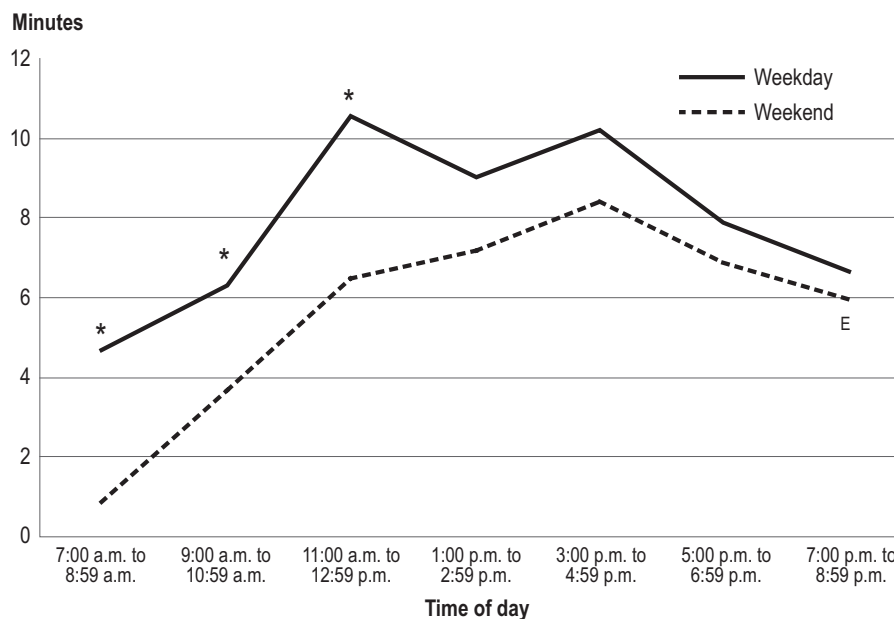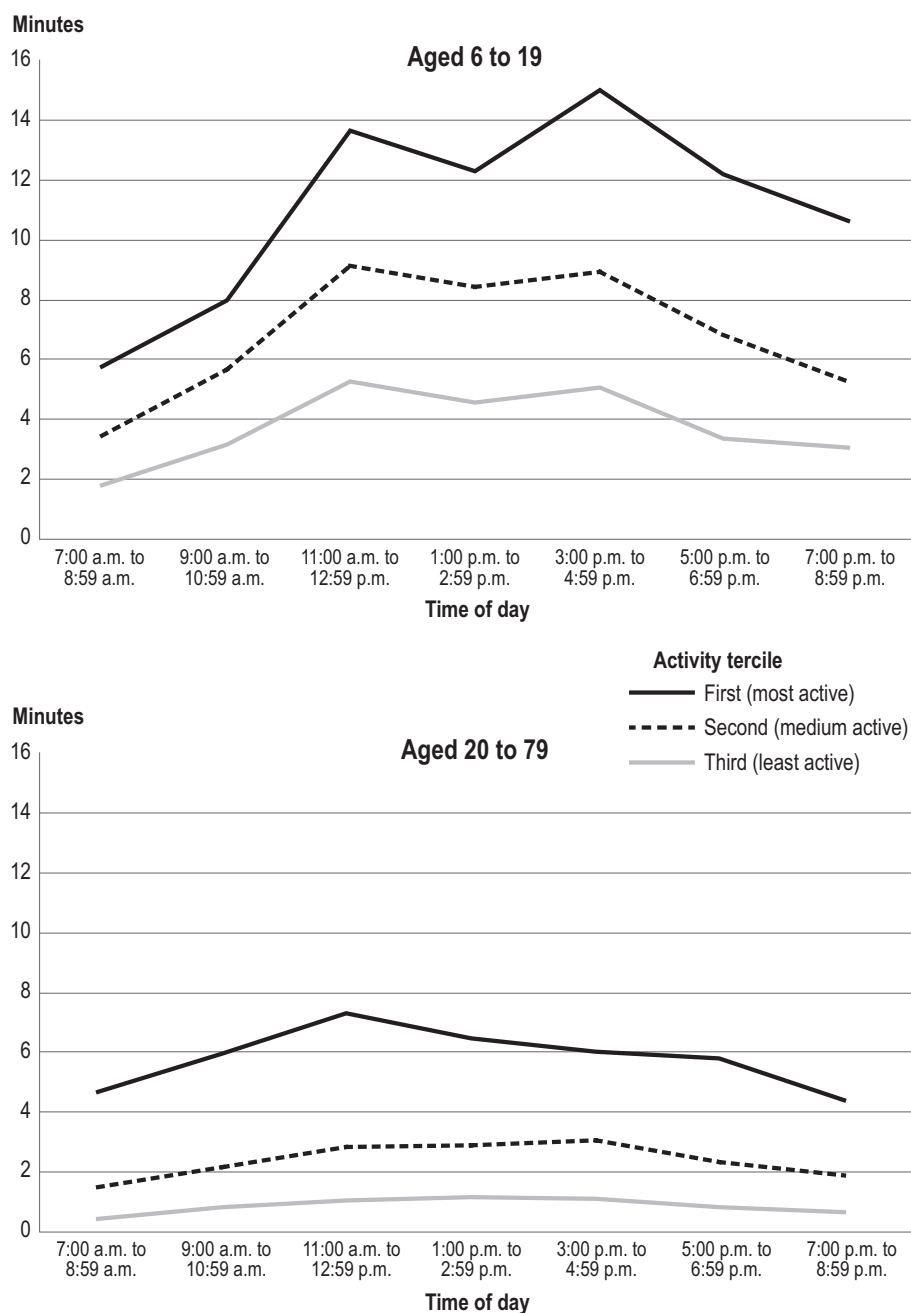

Note: All results for a given activity level differ significantly from the other two activity levels.
Source: 2007 to 2009 Canadian Health Measures Survey.

Most and least active

Fewer than 10% of children and youth meet the current guideline of 60 minutes of MVPA a day.[6] Physical activity levels are also low in adults, with 15% of them accumulating 150 minutes of MVPA in 10-minute bouts per week.[5]

For each age group and by sex, the population was divided into terciles according to MVPA: "least active" (the third with the lowest daily average minutes of MVPA); "most active" (the third with the highest daily average minutes of MVPA); and "medium active" (the third falling in between). For example, among boys aged 6 to 10, the least active accumulate less than 54 minutes of MVPA a day, and the most active, more than 79 minutes. For women aged 60 to 79, the least active accumulate less than 2.5 minutes of MVPA a day, and the most active, more than 12 minutes.

The most active group is not necessarily representative of people meeting physical activity guidelines. For instance, among children and youth aged 6 to 19, 18% of those in the most active group adhere to the guidelines (at least 60 minutes of MVPA a day on at least 6 days out of 7); less than 2% in the medium active and least active groups meet the guidelines. The trend is similar for more modest physical activity targets: close to half (46%) of the most active children and youth accumulate 30 minutes of MVPA a day 6 days a week, compared with 24% of the medium active group, and 5% of the least active group. For adults aged 20 to 79, 42% of the most active group meet the guideline of 150 minutes of MVPA a week; 3% of the medium active group do so, but none of the least active group.

Throughout the day, the most active children and youth accumulate more minutes of MVPA, compared with the other two terciles (Figure 3). The largest difference is just after school from 3:00 to 5:00 p.m.

Similarly, the most active adults accumulate more minutes of MVPA in every period of the day than do those who are less active. For the most active

Figure 4

Average daily minutes of moderate-to-vigorous physical activity, by Body Mass Index category and time of day, household population aged 20 to 79, Canada, 2007 to 2009

Minutes

Body mass index category
Normal weight
Overweight
Obese

Time of day
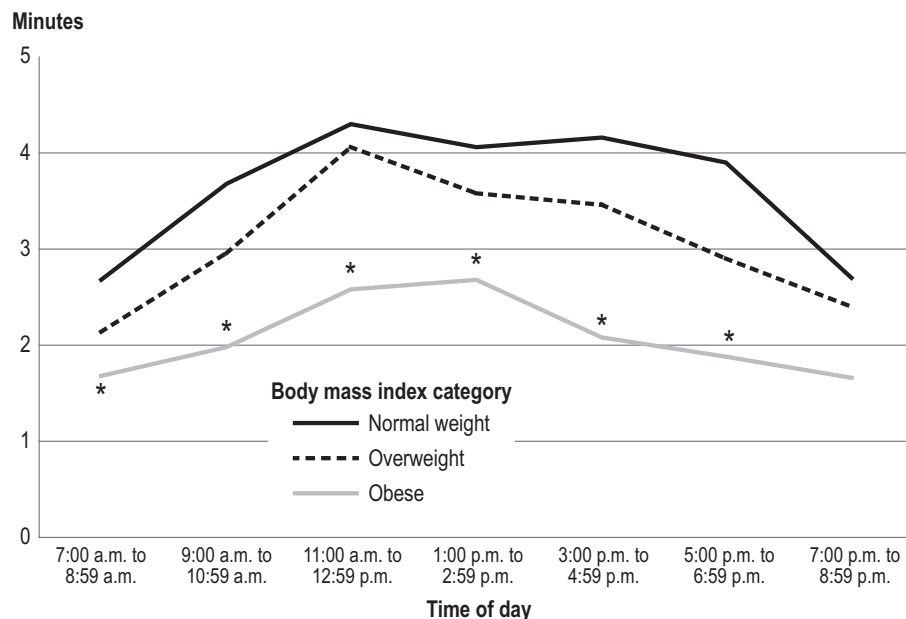
* significantly different from normal weight (p<0.05)
Source: 2007 to 2009 Canadian Health Measures Survey.

adults, minutes of MVPA peak at lunch time between 11:00 a.m. and 1:00 p.m. (Figure 3). This peak in physical activity was not observed for the average active and least active adults.

Influence of obesity

It has been suggested that the level of obesity can influence patterns of physical activity.[24] According to the CHMS, overweight and obese males aged 6 to 79 accumulate fewer minutes of MVPA a day, on average, than do their normal-weight contemporaries.[5,6] This is also true for females at ages 20 to 79,[5] but not at ages 6 to 19.[6] Obesity does not appear to affect the timing of MVPA accumulation among children and youth. However, among adults, the pattern of physical activity during the day (9:00 a.m. to 7:00 p.m.) differs significantly for those in the normal weight range versus those who are overweight/obese (Figure 4). Specifically, the number of minutes of MVPA remains relatively high from lunch time through to dinner time among normal-weight adults, but declines after 3:00 p.m. among those who are obese.

Conclusion

Within-day timing and patterns of MVPA accumulation are useful in understanding variations in physical activity. Results of the 2007 to 2009 CHMS show that the most active individuals accumulate more minutes of MVPA in every period of the day, but especially at lunch time and in the late afternoon. ■

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Measures of abdominal obesity within body mass index categories, 1981 and 2007-2009

by Margot Shields, Mark S. Tremblay, Sarah Connor Gorber and Ian Janssen

Abstract

This article describes measures of abdominal obesity—waist circumference, waist-to-hip ratio, and waist-to-height ratio—within body mass index (BMI) categories, using data from two population-based health surveys. Among normal-weight men, the percentages at increased/high health risk based on these three measures were not statistically different in 2007-2009 than in 1981. By contrast, among normal-weight women, increases were observed in the percentage at increased/high health risk based on each of the three measures. The percentage of overweight men at increased/high risk based on waist circumference rose from 49% in 1981 to 62% in 2007-2009, and among overweight women, the percentage at increased/high risk rose for each of the three measures (64% to 93% for waist circumference, 22% to 51% for waist-to-hip ratio, and 68% to 87% for waist-to-height ratio). Although substantial percentages of men and women in obese class I were at increased/high health risk based on abdominal obesity measures in 1981, by 2007-2009, almost everyone in this BMI category was at increased/high risk.

Key words

Body composition, central obesity, waist circumference, waist-to-height ratio, waist-to-hip ratio

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Body mass index (BMI), a measure of weight in relation to height, is the most widely used indicator of obesity. A BMI-based system[1-3] has long been employed to classify adults in categories based on health risk.

In Canada, the prevalence of overweight and obesity is monitored according to this system (Text Table 1). In recent decades,

Text Table 1
Body mass index (BMI) health risk classification

Category	BMI (kg/m²)	Health risk
Underweight	Less than 18.5	Increased
Normal weight	18.5 to 24.9	Least
Overweight	25.0 to 29.9	Increased
Obese	30.0 or more	
Obese class I	30.0 to 34.9	High
Obese class II	35.0 to 39.9	Very high
Obese class III	40.0 or more	Extremely high

the percentage of Canadian adults classified as having excess weight based on BMI has increased substantially.[4]

However, criticism of this classification is that it provides no information about the distribution of body fat.[1] Evidence suggests that within the normal, overweight and obese class I categories, health risk rises with the level of abdominal obesity.[5,6] Consequently, several organizations, including Health Canada, have recommended

that a combination of BMI and waist circumference be used to classify weight-related health risk.[1,2,7]

Recent research has found that, on average, the waist circumference of Canadian adults with a given BMI value is now larger than in the past,[8] similar to findings for the United States.[9] Therefore, it is important to measure and monitor abdominal obesity within BMI categories.

This article documents changes in obesity indicators between 1981 and 2007-2009 in Canadians aged 20 to 69 years, based on measured data collected in two population-based health surveys (see *The data*). The primary objective was to examine changes in abdominal obesity within BMI categories, based on waist circumference, waist-to-hip ratio, and waist-to-height ratio.

Adiposity measures increase

Among men and women, all four adiposity measures increased significantly between 1981 and 2007-2009 (Table 1). However, the pattern of change differed by BMI category.

Among men in the normal-weight category, the means for the four adiposity measures were not statistically different at the two time points. By contrast, among women in the normal-weight category, mean BMI rose by 0.2 kg/m², and waist circumference, by 4 cm. Significant increases were also observed for waist-to-hip ratio and waist-to-height ratio.

Among those in the overweight category, a significant increase in mean BMI was observed for both sexes. Increases in means for abdominal obesity were particularly notable among overweight women: 7 cm for waist circumference; 0.05 for waist-to-hip ratio; and 0.03 for waist-to-height ratio. Among overweight men, the increases were 2 cm for waist circumference and 0.01 for waist-to-hip ratio; the increase for waist-to-height ratio did not attain statistical significance.

Increases in abdominal obesity measures tended to be greatest for people in the obese categories. For instance, the increase in waist circumference was 11 cm among class II/III men, and 9 cm among class II/III women.

Health risk categories

Health risk ratings for the obesity indicators are presented in Table 2. Ratings for the abdominal obesity indicators are provided within the BMI categories for normal weight, overweight and obese class I. Rating are not presented for obese class II/III, because in both 1981 and 2007-2009, nearly all adults in these categories were at increased/high risk according to the abdominal obesity indicators (data not shown).

Among normal-weight men, the percentages at increased/high health risk based on their waist circumference, waist-to-hip ratio and waist-to-height ratio were not statistically different in 2007-2009 than in 1981. By contrast, among normal-weight women, the percentage at increased/high risk according to each of these measures was approximately three times higher in 2007-2009 than in 1981. Based on their waist circumference, the percentage of normal-weight women at increased/high risk rose from 8% to 23%. The corresponding increases were from 6% to 16% for waist-to-hip ratio, and from 6% to 18% for waist-to-height ratio.

In 2007-2009, 62% of overweight men were at increased/high health risk based on their waist circumference, up from 49% in 1981; the percentage at *high* risk rose from 8% to 20%. However, the percentage of overweight men at increased/high risk based on their waist-to-hip ratio and waist-to-height ratio was not different at the two time points. Based on their waist circumference, 54% of overweight women were at high risk in 2007-2009, up from 17% in 1981.

The data

Current estimates are from the 2007-2009 Canadian Health Measures Survey (CHMS),[10] which collected data at 15 sites across the country from March 2007 through February 2009. The survey covered the household population aged 6 to 79 years. Full-time members of the Canadian Forces and residents of Crown lands, Indian reserves, institutions and certain remote regions were excluded. The sample represented approximately 96% of the population. In addition to a questionnaire, the survey involved physical measures (including height, weight, waist circumference, and hip circumference) at a mobile examination centre. The CHMS estimates in this article are based on 3,074 respondents aged 20 to 69 years. Of the households selected, the response rate was 69.6%. One or two members of each responding household were chosen to participate: 87.6% of selected 20- to 69-year-olds completed the household questionnaire, and 83.6% of these respondents completed the physical examination. The overall combined response rate was 51.0%.

Historical estimates are based on the 1981 Canada Fitness Survey (CFS),[11] which collected data from a nationally representative sample of the population between February and July 1981. The sample consisted of 13,500 households. The overall response rate for the physical measures component of the survey was 49%. The CFS estimates in this article are based on 10,605 respondents aged 20 to 69 years.

Pregnant women were excluded from both data sources.

Each survey measured weight to the nearest 0.1 kg, and height, to the nearest 0.1 cm. Waist circumference was measured at the end of a normal expiration to the nearest 0.1 cm at the mid-point between the last floating rib and the top of the iliac crest.[12,13] Hip circumference was measured at the level of the symphysis pubis and the greatest gluteal protuberance.[12]

Body mass index (BMI) was calculated as weight in kilograms divided by height in metres squared (kg/m²); waist-to-hip ratio as waist circumference in cm divided by hip circumference in cm; and waist-to-height ratio as waist circumference in cm divided by height in cm.

Based on categories recommended by the World Health Organization,[13] Health Canada[1] and Obesity Canada,[2] respondents were divided into the six BMI-based health risk categories (underweight, normal weight, overweight, and obese class I, II and III) and three categories based on waist circumference: low-risk (men, 93.9 cm or less; women, 79.9 cm or less), increased-risk (men, 94.0 to 101.9 cm; women, 80.0 to 87.9 cm), and high-risk (men, 102.0 cm or more; women, 88.0 cm or more). In accordance with recommended cut-points, respondents were also classified as being at increased/high risk based on waist-to-hip ratio (men 0.9 or more; women 0.85 or more)[3] and waist-to-height ratio (0.5 or more for both sexes).[14]

All analyses were weighted to obtain estimates representative of the Canadian population. Estimates based on the CFS were age-standardized to the 2007-2009 population to account for shifts in Canada's age distribution during this period.

Statistical analyses were performed using SAS and SUDAAN software. Standard errors, coefficients of variation, and 95% confidence intervals for CHMS estimates were calculated with the bootstrap technique.[15,16] The number of degrees of freedom was specified as 11 to account for the CHMS sample design.[10] Estimates of sampling error for the CFS estimates were based on formulae for simple random sampling with the incorporation of a design effect of 1.5 to account for the complex design of the survey. Significant differences between means and prevalence estimates across surveys were assessed using t-tests.

Table 1
Means for adiposity measures, by body mass index (BMI) category and sex, household population aged 20 to 69 years, Canada, 1981 and 2007-2009

	Men						Women					
	1981			2007-2009			1981			2007-2009		
	Mean	95% confidence interval		Mean	95% confidence interval		Mean	95% confidence interval		Mean	95% confidence interval	
	Mean	from	to	Mean	from	to	Mean	from	to	Mean	from	to
Total												
Body mass index (kg/m²)	25.5	25.3	25.6	27.6*	27.2	28.0	24.1	23.9	24.4	26.8*	26.0	27.6
Waist circumference (cm)	89.4	88.9	89.9	95.9*	94.6	97.3	76.3	75.8	76.8	86.9*	84.7	89.1
Waist-to-hip ratio	0.90	0.90	0.90	0.93*	0.92	0.94	0.77	0.77	0.78	0.83*	0.82	0.84
Waist-to-height ratio	0.51	0.51	0.52	0.55*	0.54	0.55	0.48	0.47	0.48	0.54*	0.52	0.55
Normal weight (BMI 18.5 to 24.9 kg/m²)												
Body mass index (kg/m²)	22.7	22.6	22.8	22.9	22.6	23.1	21.9	21.8	22.0	22.1*	22.0	22.3
Waist circumference (cm)	82.2	81.8	82.6	82.5	81.6	83.4	71.4	71.1	71.8	75.7*	74.8	76.7
Waist-to-hip ratio	0.87	0.86	0.87	0.87	0.86	0.87	0.75	0.75	0.76	0.79*	0.78	0.80
Waist-to-height ratio	0.47	0.47	0.47	0.47	0.47	0.48	0.44	0.44	0.45	0.46*	0.46	0.47
Overweight (BMI 25.0 to 29.9 kg/m²)												
Body mass index (kg/m²)	27.1	27.0	27.2	27.5*	27.2	27.7	26.9	26.8	27.1	27.4*	27.1	27.6
Waist circumference (cm)	93.8	93.3	94.2	96.1*	95.1	97.1	82.5	81.9	83.2	89.2*	88.1	90.4
Waist-to-hip ratio	0.92	0.92	0.93	0.93*	0.93	0.94	0.80	0.79	0.80	0.85*	0.84	0.86
Waist-to-height ratio	0.54	0.54	0.54	0.55	0.54	0.55	0.52	0.52	0.52	0.55*	0.54	0.56
Obese class I (BMI 30.0 to 34.9 kg/m²)												
Body mass index (kg/m²)	31.5	31.3	31.7	32.0*	31.7	32.3	32.0	31.8	32.3	32.2	31.9	32.5
Waist circumference (cm)	104.2	103.3	105.2	108.0*	106.6	109.4	93.5	92.0	95.0	100.7*	99.2	102.2
Waist-to-hip ratio	0.96	0.95	0.97	0.99*	0.98	1.00	0.84	0.82	0.85	0.89*	0.87	0.90
Waist-to-height ratio	0.60	0.60	0.61	0.62*	0.61	0.63	0.59	0.58	0.60	0.62*	0.61	0.63
Obese class II/III (BMI 35.0 kg/m² or more)												
Body mass index (kg/m²)	37.6	36.2	39.1	39.6*	38.5	40.7	38.5	37.5	39.5	39.5	38.9	40.0
Waist circumference (cm)	115.9	112.3	119.5	126.5*	123.6	129.4	104.1	101.5	106.7	113.5*	112.2	114.8
Waist-to-hip ratio	0.97	0.95	1.00	1.03*	1.01	1.04	0.85	0.80	0.89	0.89	0.88	0.89
Waist-to-height ratio	0.67	0.66	0.69	0.72*	0.70	0.74	0.66	0.64	0.67	0.71*	0.70	0.72

* significantly different from 1981 (p<0.05)
Note: 1981 estimates were age-standardized to 2007-2009 population.
Sources: 1981 Canada Fitness Survey; 2007-2009 Canadian Health Measures Survey.

The percentage of overweight women at increased/high risk based on their waist-to-hip ratio more than doubled from 22% to 51%, and the percentage at increased/high risk based on their waist-to-height ratio rose from 68% to 87%.

In 1981, 62% of men and 82% of women in obese class I were classified at high health risk based on their waist circumference; by 2007-2009, the percentages had risen to 84% and 94%, respectively. Based on their waist-to-hip ratio, the percentage of obese class I men at increased/high risk rose from 90% to 96%; among women, the figure rose from 48% to 75%. At both time points, virtually all men and women in obese class I were classified at increased/high risk based on their waist-to-height ratio.

Shifting distributions

Figure 1 illustrates shifts in the distribution of waist circumference measurements toward the higher risk ranges among people in the normal-weight, overweight and obese class I categories. While the distributions in 1981 and 2007-2009 among normal-weight men were virtually the same, a shift among normal-weight women meant that a higher percentage of them had waist circumferences that put them in the increased and high-risk ranges. Among overweight people of both sexes, there was a shift to larger waist circumferences, on average, particularly among women. For men and women in obese class I, most of the waist circumference distribution fell

beyond the high-risk cut-point in 1981. Nonetheless, there was a pronounced shift to even larger waist circumferences, on average, by 2007-2009.

Trends in the distributions for waist-to-hip ratio and waist-to-height ratio measurements within BMI categories were similar (data not shown). As well, the distribution of BMI values within BMI categories shifted toward higher values. For example, among normal weight women, the percentage whose BMI was at the high end of the category (24 kg/m² or more) rose from 13% in 1981 to 21% in 2007-2009.

Table 2
Percentage distribution of adiposity health risk variables, by sex and body mass index (BMI) category, household population aged 20 to 69 years, Canada, 1981 and 2007-2009

	Total 1981			Total 2007-2009			Normal 1981			Normal 2007-2009			Overweight 1981			Overweight 2007-2009			Obese class 1 1981			Obese class 1 2007-2009		
	%	from	to	%	from	to	%	from	to	%	from	to	%	from	to	%	from	to	%	from	to	%	from	to
Men																								
BMI category																								
Underweight	1.2ᴱ	0.8	1.8	0.8	0.4	1.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Normal	46.3	43.9	48.8	30.5*	25.5	36.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Overweight	42.4	39.9	44.9	44.1	39.0	49.3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Obese class I	8.6	7.2	10.2	17.8*	14.6	21.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Obese class II or III	1.5ᴱ	1.0	2.2	6.9*	5.9	8.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Waist circumference health risk																								
Low	68.2	65.7	70.6	46.3*	41.6	51.1	97.0	95.4	98.1	93.7	89.3	96.4	51.5	47.4	55.5	38.5*	31.4	46.0	F	...	...	F	...	...
Increased	21.8	19.7	24.1	23.0	19.4	27.0	3.0ᴱ	1.9	4.6	6.2ᴱ	3.5	10.7	40.9	37.0	45.0	41.4	35.5	47.4	35.6	27.7	44.4	16.1*ᴱ	8.7	27.9
High	10.0	8.5	11.8	30.7*	25.6	36.3	F	...	...	F	...	...	7.6	5.7	10.2	20.2*	15.3	26.2	62.1	53.4	70.2	83.9*	72.1	91.3
Increased/High	31.8	29.4	34.3	53.7*	48.9	58.4	3.0ᴱ	1.9	4.6	6.3ᴱ	3.6	10.7	48.5	44.5	52.6	61.5*	54.0	68.6	97.7	95.4	98.9	100.0	...	...
Waist-to-hip ratio health risk																								
Low	48.4	45.9	50.9	35.6*	31.7	39.7	71.3	67.7	74.6	71.8	63.1	79.1	30.9	27.6	34.4	28.0	23.5	32.9	10.4ᴱ	6.4	16.6	F	...	...
Increased/High	51.6	49.1	54.1	64.4*	60.3	68.3	28.7	25.4	32.3	28.2	20.9	36.9	69.1	65.6	72.4	72.0	67.1	76.5	89.6	83.4	93.6	96.3*	90.0	98.7
Waist-to-height ratio health risk																								
Low	41.6	39.3	44.0	30.4*	26.0	35.2	76.5	73.0	79.7	79.7	75.2	83.5	11.7	9.9	13.8	12.2	8.9	16.6	F	...	...	F	...	...
Increased/High	58.4	56.0	60.7	69.6*	64.8	74.0	23.5	20.3	27.0	20.3	16.5	24.8	88.3	86.2	90.1	87.8	83.4	91.1	99.7	97.0	100.0	100.0	...	...
Women																								
BMI category																								
Underweight	3.4	2.8	4.2	2.3	1.3	4.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Normal	62.2	59.7	64.7	44.7*	37.7	51.9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Overweight	24.8	22.6	27.2	28.9*	25.7	32.3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Obese class I	7.1	5.8	8.6	12.4*	10.0	15.4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Obese class II or III	2.4ᴱ	1.7	3.5	11.6*	8.4	16.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Waist circumference health risk																								
Low	70.1	67.7	72.5	39.0*	32.6	45.8	92.5	90.5	94.1	77.2*	69.6	83.3	35.6	30.4	41.2	7.5*ᴱ	4.2	13.3	F	...	...	F	...	...
Increased	17.1	15.2	19.2	20.3	16.8	24.4	6.9	5.3	8.8	19.1*	13.6	26.1	47.7	42.2	53.2	38.4*	31.8	45.5	14.0ᴱ	8.9	21.3	F	...	...
High	12.8	11.0	14.7	40.6*	34.5	47.0	F	...	...	3.8*ᴱ	2.6	5.6	16.7	13.0	21.2	54.1*	46.1	61.8	81.6	73.2	87.9	94.3*	85.2	97.9
Increased/High	29.9	27.5	32.3	61.0*	54.2	67.4	7.5	5.9	9.5	22.8*	16.7	30.4	64.4	58.8	69.6	92.5*	86.7	95.8	95.7	88.2	98.5	100.0	...	...
Waist-to-hip ratio health risk																								
Low	86.4	84.4	88.2	60.4*	55.1	65.6	94.5	92.6	95.9	84.2*	77.8	89.0	77.8	72.9	82.1	48.9*	42.5	55.3	52.2	42.0	62.2	24.7*ᴱ	16.6	35.1
Increased/High	13.6	11.8	15.6	39.6*	34.4	44.9	5.5	4.1	7.4	15.8*	11.0	22.2	22.2	17.9	27.1	51.1*	44.7	57.5	47.8	37.8	58.0	75.3*	64.9	83.4
Waist-to-height ratio health risk																								
Low	69.8	67.3	72.3	43.3*	37.6	49.1	93.7	91.7	95.2	82.3*	77.5	86.3	32.1	27.5	37.2	13.0*ᴱ	8.6	19.3	F	...	...	F	...	...
Increased/High	30.2	27.7	32.7	56.7*	50.9	62.4	6.3	4.8	8.3	17.7*	13.7	22.5	67.9	62.8	72.5	87.0*	80.7	91.4	97.8	93.8	99.2	97.5	80.0	99.7

* significantly different from 1981 (p<0.05)
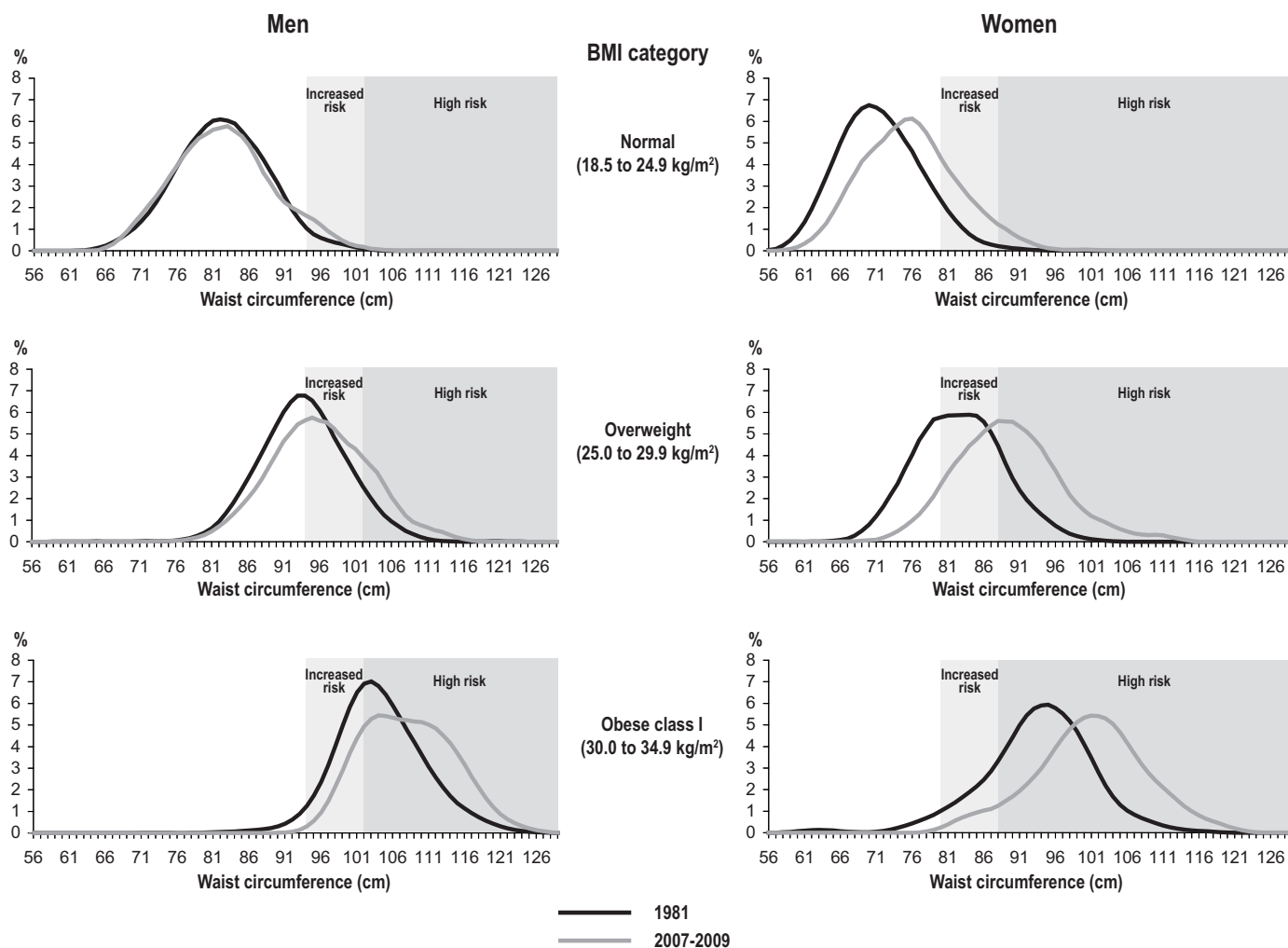ᴱ use with caution
F too unreliable to be published
... not applicable
Note: 1981 estimates were age-standardized to 2007-2009 population.
Sources: 1981 Canada Fitness Survey; 2007-2009 Canadian Health Measures Survey.

Figure 1
Percentage distribution of waist circumference, by body mass index category (BMI), household population aged 20 to 69 years, Canada, 1981 and 2007-2009

Note: 1981 estimates were age-standardized to 2007-2009 population.
Sources: 1981 Canada Fitness Survey; 2007-2009 Canadian Health Measures Survey.

Conclusion

Current surveillance of obesity in Canada relies almost exclusively on BMI. This study reveals that abdominal obesity within BMI categories is increasing. As a result, Canadians with a given BMI are, on average, at higher risk of obesity-related health conditions than they were in 1981. The Canadian body weight classification system and the Canadian clinical practice guidelines recommend that adults' waist circumference also be measured to assess obesity-related health risks.[1,2] The results of this study underscore the importance of measuring and monitoring abdominal obesity within BMI categories. ■

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Prevalence and correlates of folic acid supplement use in Canada • Health matters

39

Prevalence and correlates of folic acid supplement use in Canada

by Cynthia K. Colapinto, Deborah L. O'Connor, Lise Dubois and Mark S. Tremblay

Abstract

Dietary supplements are an important source of folic acid, a nutrient that is vital in reducing the risk of neural tube defects. As part of the 2007 to 2009 Canadian Health Measures Survey, data were collected on supplement use, and biomarkers were directly measured. Use of supplements that contain folic acid was reported by 25% of Canadians aged 6 to 79. Females were more likely than males to report taking folic acid supplements. People who ate fruit and vegetables less than once a day had significantly lower odds of taking folic acid-containing supplements than did those who ate fruit and vegetables at least three times a day. Of those who consumed a folic acid supplement, 91% reported also taking a supplement that contained vitamin B_{12}. Red blood cell folate concentrations below the median (less than 1,248 nmol/L), low-to-marginal serum vitamin B_{12} concentrations (221 pmol/L or less), and high concentrations of plasma homocysteine were negatively correlated with folic acid-containing supplement use.

Keywords

Biological markers, dietary supplements, folate, nutrition, vitamins

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Folate, one of the B-vitamins, is a key nutrient in reducing the risk of neural tube defects.[1] It plays an important role in metabolic pathways that involve vitamin B_{12} and homocysteine.[1] While folate occurs naturally in many foods, such as dark green vegetables and legumes, the most common synthetic form in fortified foods and supplements is folic acid. Members of the general population do not commonly need supplemental folic acid unless it is recommended by a health care professional for certain medical conditions. In fact, high levels of supplemental folic acid may mask and exacerbate vitamin B_{12} deficiency, particularly in the elderly, which could result in neurological damage.[2-4]

According to the Institute of Medicine's Dietary Reference Intakes, the Recommended Dietary Allowance for the population older than age 13 is 0.4 mg of folate a day.[5] For women of childbearing age, an additional 0.4 mg per day from supplements or fortified foods is recommended.[5] Because up to 50% of pregnancies are unplanned, and many women of childbearing age report irregular or no consumption of folic acid before pregnancy, in 1998, Canada approved folic acid fortification of white wheat and other selected grains, in addition to previously implemented supplementation recommendations.[6]

This analysis uses data from the 2007 to 2009 Canadian Health Measures Survey (CHMS) to investigate self-reported intake of folic acid-containing supplements (see *The data*). Associations with socio-demographic, behavioural and clinical factors were studied, including, for the first time in a nationally representative sample, red blood cell folate concentrations.

The data

This study is based on results of cycle 1 of the Canadian Health Measures Survey (CHMS), which collected data from a nationally representative sample of the household population aged 6 to 79. 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.

A Statistics Canada interviewer administered a detailed in-home health questionnaire, which covered medication and natural health product use. One day to six weeks later, respondents visited a mobile examination centre for a series of physical measurements, including blood samples taken by a certified phlebotomist to measure a variety of analytes.[7]

Of the 8,772 households selected for the CHMS, 69.6% agreed to participate; 88.3% of them responded to the in-home survey, and of those, 84.9% visited the mobile examination centre. The overall response rate was 51.7%. A comprehensive consent process was employed; participation was voluntary and respondents could opt out of any part of the survey at any time.[8] The final sample consisted of 5,604 respondents aged 6 to 79 and is representative of approximately 96.3% of the Canadian population. Details about the CHMS are available elsewhere.[7,9]

Drug identification and natural health product numbers were collected from respondents during the in-home interview. This information was verified at the mobile examination centre visit, and changes in drug and supplement use were recorded.[10] Consumption of folic acid supplements—alone or in a multi-vitamin—in the 30 days before the mobile examination centre visit was determined by matching drug identification and natural health product numbers to product information extracted from the Health Canada Drug Product and Licensed Natural Health Product databases.[10,11,12] This approach was also used to quantify vitamin B_{12} supplement use.

Dietary reference intake *age groups* were used for this study. These age groups were collapsed into three categories to achieve adequate sample size in the analyses examining doses of folic acid-containing supplements. Socio-economic status was measured by per person *household income* equivalents (which grouped respondent household income into quartiles after adjusting for household size and composition) and highest level of *household education* (less than postsecondary graduation and postsecondary graduation).[13] *Immigrant status* was defined as born in Canada or not born in Canada.

A brief, non-quantitative questionnaire was used to examine usual frequency of consumption from the *grains* and *fruit and vegetables* food groups. Cereal, white bread, brown bread and pasta were combined to formulate the derived variable for grains. Self-reported *smoking* status and history were used to categorize respondents as daily, former or never smokers. A *physical activity* index of active, moderately active or inactive was derived based on average daily energy expenditure values during self-reported leisure time activities in the three months before the in-home interview.[14]

Measured height and weight were used to calculate *body mass index* ($wt(kg)/ht(m)^2$). The body mass index of adults, excluding pregnant women, was classified using Health Canada's guidelines.[15] Children aged 6 to 17 were classified as being normal weight, overweight or obese based on definitions proposed by the International Obesity Task Force, which account for both the age and sex of the child.[16]

A clinical risk factor variable was created to combine self-reported diabetes mellitus, use of folic acid antagonist medication, and overweight/obesity. Folic acid antagonist medication was determined by matching drug identification numbers—from medications used in the 30 days before the mobile examination centre visit—to information in the Drug Product Database.[11,17] The variable identified three parameters: no risk factors, one risk factor, and more than one risk factor.

Blood was taken from 5,373 CHMS respondents. Red blood cell folate was analyzed using the Immulite 2000 immunoassay (Siemens Canada Ltd., Mississauga).[18] *Red blood cell folate concentration* was calculated from the measured whole-blood folate concentration adjusting for red blood cell volume, without correction for plasma folate concentration. *Serum vitamin B_{12}* was also assessed using the Immulite 2000 immunoassay, a solid phase, competitive chemiluminescent enzyme immunoassay involving an automated alkaline denaturation procedure. The cut-off for marginal Vitamin B_{12} status was 221 pmol/L or less.[2,19] The Vitros 5, 1FS (Ortho Clinical Diagnostics, Markham) was used to assess *plasma homocysteine concentrations*. The quantitative measurement of plasma homocysteine was performed using the VITROS Chemistry Products Homocysteine Reagent, a spectrophotometric method involving three coupled enzymatic reactions (cystathionine synthase, cystathionine lyase and lactate dehydrogenase). Normal plasma homocysteine status was as 8 µmol/L or less for respondents aged 10 or younger, and 15 µmol/L or less for older respondents.[20-22]

Descriptive statistics (frequencies, percentiles) were used to characterize the population. Missing values for predictor variables were removed for individual analyses. T-tests were used to study differences between estimates. With separate logistic regression analyses that controlled for age and household income, each co-variate was examined as a correlate of folic acid-containing supplement use. All estimates were based on data weighted to represent the Canadian population. Variance estimation (95% confidence intervals) and significance testing were based on the bootstrap technique to account for the complex CHMS sampling design.[23] Analyses were conducted in SAS 9.1.3 (SAS Institute Inc., Cary, NC) and SUDAAN v.10.0 (RTI International, Research Triangle Park, NC), using DDF=11 in the SUDAAN procedure statements. Given the 11 degrees of freedom available for variance estimation, Satterthwaite-adjusted statistics were used to test the significance of each regression model's coefficients.[24] Significance was defined as a p-value of <0.05.

The overall response rate to the CHMS was slightly above 50%. Although the survey weights ensured that the sample was representative of the target population, bias might exist if the use of folic acid-containing supplements by non-respondents and respondents differed systematically. The number of independent variables in the regression model was limited by 11 degrees of freedom; future research that combines subsequent CHMS cycles will increase the number of degrees of freedom and permit more complex modelling. The cross-sectional nature of the survey precludes inferences about the temporal ordering of events or causality. As well, the CHMS was not designed to collect information on usual supplement dosage, so precisely how often supplements were consumed could not be determined.

One in four

Results from the CHMS show that one in four Canadians aged 6 to 79 (an estimated 25%) reported taking a supplement containing folic acid in the previous 30 days (Table 1). This figure is consistent with data from the 2004 Canadian Community Health Survey, cycle 2.2 (Nutrition).[25] Females were significantly more likely than males to report taking a supplement that contained folic acid (28% versus 21%).

The use of folic acid-containing supplements was highest in the youngest and oldest age groups, and lowest among teenagers and young adults. The greater likelihood of folic acid supplement use among females than males prevailed

Statistics Canada, Catalogue no. 82-003-XPE • Health Reports, Vol. 23, no. 2, June 2012
Prevalence and correlates of folic acid supplement use in Canada • Health matters

41

Table 1

Prevalence and adjusted odds of folic acid-containing supplement use, by selected characteristics, household population aged 6 to 79, Canada, 2007 to 2009

| | | Supplement use | | | | | |
| | | Prevalence | | | Adjusted odds ratio | | |
Characteristics	Population distribution (%)	%	95% confidence interval from	to	(Controlling for age and household income)	95% confidence interval from	to
Total	100.0	25.0	...	...	...	...	...
Socio-demographic factors							
Sex							
Female	50.2	28.2*	25.9	30.5	1.53*	1.22	1.92
Male[†]	49.8	21.4	17.7	25.6	1.00	...	...
Age group							
6 to 8	3.5	28.5	23.3	34.4	...	...	...
9 to 13	6.8	19.5*[E]	15.1	24.8	...	...	...
14 to 18	7.1	12.5*[‡]	6.9	12.4	...	...	...
19 to 30	18.1	16.5*	12.8	21.0	...	...	...
31 to 50	35.1	28.2	24.8	31.9	...	...	...
51 to 70	24.2	29.6	24.6	35.2	...	...	...
71 to 79	5.3	29.1	22.6	36.5	...	...	...
Household income quartile							
Q1 - lowest	23.2	17.0*	13.4	21.2	...	...	...
Q2	23.2	24.4*	21.1	28.1	...	...	...
Q3	23.4	25.7*	21.4	30.6	...	...	...
Q4 - highest[†]	23.4	32.5	26.1	39.5	...	...	...
Missing	6.7	22.9	17.5	29.3	...	...	...
Highest level of household education							
Less than postsecondary graduation	24.1	21.1	17.6	25.0	0.82	0.61	1.11
Postsecondary graduation[†]	75.9	26.2	23.0	29.7	1.00	...	...
Canadian-born							
Yes[†]	79.1	24.2	21.8	26.7	1.00	...	...
No	20.9	27.1	19.7	36.0	1.22	0.77	1.94
Behavioural factors							
Daily frequency of fruit and vegetable intake							
Less than once	6.4	12.9*	10.1	16.4	0.43*	0.33	0.57
1 to 2 times	45.2	22.6*	18.6	27.0	0.79	0.60	1.03
3 or more times[†]	48.4	28.4	25.9	31.0	1.00	...	...
Daily frequency of grain intake							
Less than once	14.6	22.7	16.2	30.8	0.93	0.44	1.96
1 to 2 times	76.7	25.5	22.9	28.3	1.08	0.65	1.80
3 or more times[†]	8.7	21.9[E]	14.3	21.1	1.00	...	...
Leisure-time physical activity (aged 12 or older)							
Active[†]	26.6	28.4	23.7	33.7	1.00	...	...
Moderately active	25.1	26.3	20.7	32.8	0.88	0.59	1.31
Inactive	48.3	21.8*	19.0	24.8	0.68*	0.51	0.91
Smoking (aged 12 or older)							
Daily	20.3	18.9*	15.0	23.6	0.71*	0.52	0.98
Former	27.0	29.1*	25.0	33.6	1.02	0.78	1.33
Never smoked[†]	52.7	24.5	21.6	27.7	1.00	...	...
Clinical factors							
Body mass index (BMI)							
Underweight/Normal weight[†]	45.0	24.9	21.9	28.2	1.00	...	...
Overweight/Obese	55.0	24.0	21.1	27.1	0.80*	0.66	0.97
Red blood cell folate concentration							
Below median (less than 1,248 nmol/L)	50.1	14.2*	11.9	16.8	0.33*	0.25	0.43
At or above median (1,248 nmol/L or more)[†]	49.9	35.0	30.9	39.3	1.00	...	...
Serum vitamin B$_{12}$ concentration							
Low to marginal (221 pmol/L or less)	22.8	12.2*	9.1	16.1	0.33*	0.24	0.47
Replete (more than 221 pmol/L)[†]	77.2	28.3	25.4	31.3	1.00	...	...
Plasma homocysteine concentration							
Normal[†‡]	98.2	25.3	22.7	28.1	1.00	...	...
High	2.8	11.5*	8.0	16.2	0.33*	0.22	0.52

N = 5,604
[†] reference group
[‡] 8 µmol/L or less at age 10 or younger, and 15 µmol/L or less for older than age 10
* significantly different from reference group (p<0.05)
[E] use with caution
Note: Missing values were removed for individual analyses.
Source: 2007 to 2009 Canadian Health Measures Survey.

in age groups older than 30 (data not shown). Use peaked among women older than age 70 (36%) and was lowest among boys aged 14 to 18 (11%) (data not shown).

A positive gradient by household income emerged, with those in the lower income quartiles being significantly less likely than those in the highest quartile to have taken a supplement containing folic acid.

Even when the potential influence of age and household income was taken into account, females were significantly more likely than males to have consumed a folic acid-containing supplement (OR: 1.53; CI: 1.22, 1.92). Household education and country of birth were not significant correlates of folic acid supplement use.

Diet, exercise and smoking

Together, grains and fruit and vegetables are responsible for 62% to 78% of Canadians' dietary folate intake.[10,26,27] However, people who ate fruit and vegetables relatively infrequently (less than once a day), had significantly low odds (OR: 0.43; CI: 0.33, 0.57) of taking a supplement that contained folic acid, compared with people who ate fruit and vegetables three or more times a day. Grain intake was not significantly related to folic acid supplement use (Table 1).

People who reported inactive leisure time had significantly low odds of taking folic acid supplements, compared with those whose leisure time was active. As well, the odds of folic acid supplement use were significantly low for daily smokers, compared with people who had never smoked. Having a family physician and the frequency of alcohol consumption were not related to the use of folic acid-containing supplements (data not shown).

The odds of taking a supplement that contained folic acid were significantly low for people whose BMI put them in the overweight/obese category.

Biomarkers

Red blood cell folate is the best indicator of tissue folate stores.[28] People whose

Figure 1

Reported dose of folic acid-containing supplement, by sex, household population aged 6 to 79, Canada, 2007 to 2009
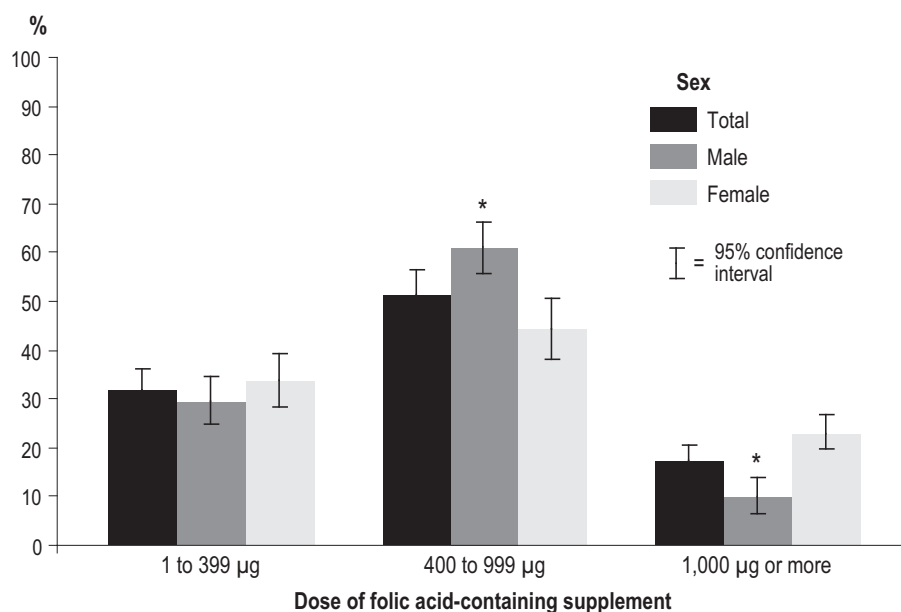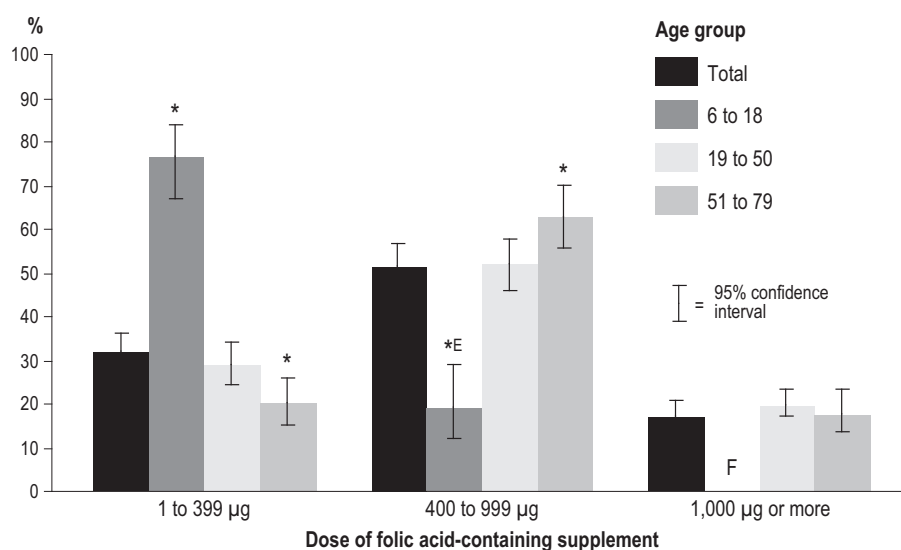

N = 1,357
* significantly different from females (p<0.05)
Note: Based on respondents who reported taking folic acid-containing supplement.
Source: 2007 to 2009 Canadian Health Measures Survey.

Figure 2

Reported dose of folic acid-containing supplement, by age group, household population aged 6 to 79, Canada, 2007 to 2009

N = 1,357
* significantly different from 19-to-50 age group (p<0.05)
E use with caution
F too unreliable to be published
Note: Based on respondents who reported taking folic acid-containing supplement.
Source: 2007 to 2009 Canadian Health Measures Survey.

red blood cell folate concentrations were below the median (less than 1,248 nmol/L) were significantly less likely to report taking a folic-acid containing supplement (OR: 0.33; CI: 0.25, 0.43) than were people whose concentrations were at or above the median.

The Tolerable Upper Limit for folate is 1,000 µg of the synthetic form a day. Higher amounts may mask a vitamin B_{12} deficiency.[5] Overall, 17.4% of folic acid supplement users consumed 1,000 µg or more (Figures 1 and 2). Canadian prenatal nutrition guidelines and federal natural health product regulations[29,30] support the combined use of vitamin B_{12} and folic acid supplements to reduce the risk of masking a vitamin B_{12} deficiency. A large majority (91%) of CHMS respondents who took a folic acid-containing supplement also reported taking a supplement that contained vitamin B_{12}. Further, individuals with low serum vitamin B_{12} concentrations were less likely to have consumed a folic acid-containing supplement (OR: 0.33; CI: 0.24, 0.47) than were people whose vitamin B_{12} concentrations were higher.

High plasma homocysteine concentrations are a biomarker for low concentrations of both folate and vitamin B_{12}.[20] Individuals with high homocysteine concentrations were less likely to consume folic acid-containing supplements (OR: 0.33; CI: 0.22, 0.52) than were those whose plasma homocysteine concentrations were in the normal range.

The clinical risk factor variable was not significantly correlated with folic acid-containing supplement use (data not shown).

Dosage

The amount of folic acid in the supplements used by about half (51%) of supplements takers ranged from 400 to 999 µg, and for another third (32%), the folic acid dose was 1 to 399 µg (Figure 1). The remaining 17% took supplements that contained 1,000 µg or more of folic acid: 22% of females and 10% of males.

The most common dose of folic acid for children and teenagers aged 6 to 18 was 1 to 399 µg (Figure 2). Folic acid-containing supplements designed for Canadian children contain 100 to 400 µg.[7] At older ages, particularly 51 to 79, the dosage most frequently reported was 400 to 999 µg. Around 20% of people older than 19 reported taking supplements containing at least 1000 µg of folic acid. Such high intake was extremely rare at younger ages.

Conclusion

The use of folic acid-containing supplements is associated with a number of factors: socio-demographic (sex, age, household income), behavioural (frequency of consumption of fruit and vegetables, physical activity, smoking, overweight/obesity) and clinical (blood concentrations of RBC folate, serum vitamin B12 and plasma homocysteine). The results in this overview can inform fortification and supplementation policy in Canada. ■

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Physical activity, sedentary behaviour and sleep in Canadian children: Parent-report versus direct measures and relative associations with health risk

by Rachel C. Colley, Suzy L. Wong, Didier Garriguet, Ian Janssen, Sarah Connor Gorber and Mark S. Tremblay

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/m²)		Waist circumference (cm)	
	beta	R²	beta	R²
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

Movement variables	Full model	
	Body mass index (kg/m²)	Waist circumference (cm)
	beta	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 (R²)	**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.

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.

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

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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