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- r revised
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Bone health: Osteoporosis, calcium and vitamin D

by Didier Garriguet

Abstract

Background
Osteoporosis is a bone disease that predisposes to fractures. Sufficient intake of calcium and vitamin D is recommended for prevention and treatment.

Data and methods
Based on 28,406 respondents aged 50 or older to the 2009 Canadian Community Health Survey (CCHS)—Healthy Aging, the population who reported being diagnosed with osteoporosis is profiled. Analysis of calcium and vitamin D intake is based on 10,879 respondents aged 50 or older to the 2004 CCHS—Nutrition. Frequencies, averages and cross-tabulations were produced to estimate the prevalence of diagnosed osteoporosis, dietary intake of calcium and vitamin D, the use of supplements, and total calcium and vitamin D intake. Associations between a diagnosis of osteoporosis and socio-economic, dietary and lifestyle factors were examined with multiple logistic regression.

Results
In 2009, 19.2% of women and 3.4% of men aged 50 or older reported having been diagnosed with osteoporosis; the 2004 rates were similar. Age, sex and household income were associated with the probability of reporting osteoporosis. In 2004, based on dietary and supplement intake, 45% to 69% of the population aged 50 or older had inadequate intake of calcium, and 54% to 66% had inadequate intake of vitamin D.

Interpretation
A large percentage of people aged 50 or older, particularly women, have osteoporosis. The prevalence of inadequate intake of calcium and vitamin D is relatively high.

Keywords
bone density, bone diseases, bone loss, nutrition surveys, 24-hour dietary recall, vitamin and mineral supplements

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The human skeleton is constantly being restored and replaced. In growing children, bone formation exceeds bone loss. The two processes balance out in adulthood, but with advancing age, bone mass starts to decrease.

Osteoporosis is a disease characterized not only by a loss of bone mass, but also by increased bone fragility and risk of fracture.[1] The condition primarily affects older people, particularly women, and is associated with 80% of fractures in people older than age 60. Those fractures can result in reduced quality of life, long hospital stays, institutionalization and higher mortality. The cost is high for the individuals involved and for the health care system.[2]

The prevention and treatment of osteoporosis usually entail special attention to the intake of two nutrients: calcium, which is essential for bone health, and vitamin D, which improves the absorption of calcium.[3-5] Dairy products are the main dietary source of calcium, although it is also found in some fruits, vegetables and grain products. Very few foods provide concentrated Vitamin D. It is added to milk, which is the largest dietary source. The human body also creates vitamin D through sun exposure. Both calcium and vitamin D can be taken in the form of supplements.

This article profiles the population aged 50 or older who reported having been diagnosed with osteoporosis. Variables associated with increased risk of diagnosis and differences between 2004 and 2009 are presented. Intake of calcium and vitamin D from food and from supplements is analyzed by the presence or absence of osteoporosis.

Methods

Data sources

The data are from two Statistics Canada household surveys: the 2004 Canadian Community Health Survey (CCHS)—Nutrition and the 2009 CCHS—Healthy Aging. Both surveys excluded full-time members of the Canadian Forces and residents of the three territories, Indian reserves or Crown lands, selected remote areas, institutions and Canadian Forces bases (military and civilian). Detailed descriptions of the design, sample and interview procedures of the surveys are available in published reports.[6-8]

The 2004 CCHS—Nutrition used a 24-hour dietary recall to estimate food and nutrient intake. A total of 35,107 people completed an initial recall, and a subsample of 10,786 completed a second recall three to ten days later. The response rates were 76.5% and 72.8%, respectively. To help respondents remember what they ate and drank the previous day, the automated multiple-pass method,[9,10] was used. It consists of five steps:

- a quick list (respondents reported all foods and beverages consumed);
- questions about specific food groups and frequently forgotten foods;
- questions about the type of meal and when it was eaten;
- questions asking for more detail about the foods and beverages and the quantities consumed;
- a final review.

The 2009 CCHS—Healthy Aging had a response rate of 74.4% with a sample of 30,865 people aged 45 or older.

This study is based on data for 10,879 people aged 50 or older who completed the initial 24-hour recall in 2004, and for 28,406 people aged 50 or older who completed the 2009 CCHS.

Calcium and vitamin D requirements

In 2010, the Institute of Medicine released new dietary reference intakes for calcium and vitamin D.[3] For calcium, the estimated average requirement (EAR) for men aged 50 to 70 is 800 mg a day. The EAR is higher—1,000 mg a day—for women aged 50 or older and for men aged 71 or older. The prevalence of inadequate intake can be estimated using the EAR as a cut-point. At age 50 or older, the tolerable upper intake level (UL), above which the potential of adverse effects exists, is 2,000 mg a day.

The EAR for vitamin D at age 50 or older is 10 μg a day, and the UL is 100 μg a day.

Methods of analysis

On the basis of weighted data from the 2004 and 2009 CCHS, frequencies, averages and cross-tabulations were produced to estimate the prevalence of diagnosed osteoporosis, dietary intake of calcium and vitamin D, the use of supplements, and total calcium and vitamin D intake. Associations between the risk of a diagnosis of osteoporosis and socio-economic, dietary and lifestyle factors were examined with multiple logistic regression.

The percentage of the population below the EAR or exceeding the UL for calcium and vitamin D was determined using the Software for Intake Distribution Estimation (SIDE),[11,12] based on estimates of usual intake from the 24-hour recalls in the 2004 CCHS. To estimate total intake of calcium and vitamin D from both food and supplements, the dietary intake of respondents who did not take supplements was combined with the dietary and supplement intake of respondents who took supplements. This method was explained in a published report.[13]

Confidence intervals were estimated with the bootstrap technique, which takes the complex survey design into account.[14-16] The significance level was set at 0.05.

Definitions

Both the 2004 and the 2009 CCHS determined the presence of *osteoporosis* by asking respondents if a health professional had diagnosed them as having the condition.

The following socio-demographic variables were defined the same way in both surveys: *immigrant status, highest level of household education* (less than secondary graduation, secondary graduation, some postsecondary, and postsecondary graduation), and *household income*. Household income was total self-reported household income from all sources in the previous 12 months. The ratio of total household income to the low-income cut-off for the relevant household size and community size was calculated for each household. The ratios were adjusted by dividing them by the highest ratio for all respondents combined. The adjusted ratios were divided into quintiles.

Aboriginal status differed slightly in the two surveys. In 2004, "Aboriginal" was among the choices in the question on cultural and racial origins. In 2009, respondents were asked if they were Aboriginal before the question on cultural and racial origins.

The lifestyle variables—*smoking* (smokers are defined as those who smoke every day or occasionally; former smokers as those who no longer smoke but used to do so daily or occasionally) and *alcohol consumption* in the 12 months before the interview (yes or no)—were the same in both surveys.

In 2004, the frequency of *fruit and vegetable consumption* was measured as the sum of the frequencies with which respondents reported consuming foods in six categories: fruit juice, fruit excluding juice, green salad, potatoes (excluding fries, hash browns and chips), carrots, and other vegetables. In 2009, respondents were asked how many servings of fruits and vegetables they consumed per day in general. This question also contributed to the nutritional risk index.

High nutritional risk, which is specific to the 2009 CCHS—Healthy Aging, is defined as a nutritional risk index of less than 38. The index consists of 10 components measuring weight

Table 1
Percentage diagnosed with osteoporosis, by age group and sex, household population aged 50 or older, Canada excluding territories, 2009

	Total			50 to 70			71 or older		
		95% confidence interval			95% confidence interval			95% confidence interval	
	%	from	to	%	from	to	%	from	to
Total	**11.6**	**11.1**	**12.1**	**8.6**	**8.1**	**9.2**	**20.3**	**19.2**	**21.4**
Men	3.4	2.9	3.9	2.5	2.0	3.0	6.4	5.3	7.5
Women	19.2	18.3	20.2	14.7	13.7	15.8	31.1	29.5	32.7

Source: 2009 Canadian Community Health Survey—Healthy Aging.

change in the last six months, appetite, fruit and vegetable consumption, fluid consumption, meals, and meal preparation.

Body mass index (BMI) is weight in kilograms divided by height in metres squared. It is used to classify participants as underweight (BMI less than 18.5 kg/m^2), normal weight (18.5 kg/m^2 to 24.9 kg/m^2), overweight (25 kg/m^2 to 29.9 kg/m^2) or obese (greater than or equal to 30 kg/m^2).[17] In this study, BMI was used only with 2009 data. Weight and height were self-reported.

In 2004, respondents were asked how many days in the previous 30 days they had taken supplements and how many they took on average. In 2009, respondents were specifically asked how often they *took vitamin D or calcium supplements* in the previous month. Respondents were identified as users if they had taken supplements at least once in the past month. More information about these derived variables is available in the survey documentation.[18]

Data about calcium and vitamin D intake from food pertain to 2004; this information was not collected in 2009. The calcium and vitamin D content of food was derived from Health Canada's Canadian Nutrient File (Supplement 2001b).[19] Supplement composition was taken from the September 2003 Drug Product Database (DPD)[20] in the case of drug identification numbers (DINs) listed at the time of data collection, and from the spring 2005 DPD in the case of DINs that were missing or incorrect.

Results

Osteoporosis

In 2009, 19.2% of women and 3.4% of men aged 50 or older reported that they had been diagnosed with osteoporosis by a health professional; at age 71 or older, the percentages were much higher: 31.1% of women and 6.4% of men (Table 1). These figures were unchanged from 2004 (data not shown).

In addition to age and sex, diagnosed osteoporosis was significantly associated with Aboriginal status, low household

Table 2
Adjusted odds ratios relating osteoporosis diagnosis to selected characteristics, household population aged 50 or older, Canada excluding territories, 2009

Characteristic	Adjusted odds ratio	95% confidence interval from	95% confidence interval to
Sex			
Men	0.25*	0.21	0.30
Women†	1.00	...	...
Age group			
50 to 70	0.48*	0.42	0.54
71 or older†	1.00	...	...
Aboriginal			
Yes	1.75*	1.14	2.69
No†	1.00	...	...
Immigrant			
Yes	0.92	0.79	1.07
No†	1.00	...	...
Highest level of household education			
Less than secondary graduation	1.01	0.87	1.18
Secondary graduation	0.92	0.76	1.12
Some postsecondary	0.93	0.72	1.21
Postsecondary graduation†	1.00	...	...
Household income quintile			
First (lowest)	2.34*	1.81	3.04
Second	1.97*	1.51	2.57
Third	1.44*	1.08	1.90
Fourth	1.48*	1.12	1.95
Fifth (highest)†	1.00	...	...
Smoker			
Yes	1.02	0.82	1.26
Former	0.94	0.82	1.07
No†	1.00	...	...
Drank alcohol in last 12 months			
Yes	0.83*	0.73	0.94
No†	1.00	...	...
Daily fruit/vegetable consumption			
3 servings or less	1.00	0.87	1.15
4 to 6 servings†	1.00	...	...
7 servings or more	0.85	0.69	1.05
High nutritional risk			
Yes	1.18*	1.03	1.34
No†	1.00	...	...
Body mass index category			
Underweight	1.61*	1.17	2.24
Normal weight†	1.00	...	...
Overweight	0.75*	0.66	0.87
Obese	0.77*	0.65	0.92
Took calcium supplements in last month			
Yes	2.56*	2.19	2.98
No†	1.00	...	...
Took vitamin D supplements in last month			
Yes	1.58*	1.35	1.83
No†	1.00	...	...
Province of residence			
Newfoundland and Labrador	1.04	0.81	1.32
Prince Edward Island	0.82	0.62	1.09
Nova Scotia	0.91	0.72	1.16
New Brunswick	0.88	0.67	1.16
Quebec	0.99	0.84	1.18
Ontario†	1.00	...	...
Manitoba	0.60*	0.47	0.76
Saskatchewan	0.88	0.69	1.11
Alberta	0.96	0.79	1.18
British Columbia	0.96	0.79	1.18

† reference category
* significantly different from estimate for reference category ($p<0.05$)
... not applicable
Source: 2009 Canadian Community Health Survey—Healthy Aging.

income, alcohol consumption in the previous 12 months, high nutritional risk, low body mass index and the use of calcium or vitamin D supplements (Table 2). However, for some factors, whether they preceded or followed the diagnosis, or indeed, were a consequence of it, could not be determined. For instance, people who took calcium and vitamin D supplements had significantly high odds of having been diagnosed with osteoporosis. But taking such supplements is a component of osteoporosis treatment, so it is possible that the diagnosis triggered their use. By contrast, low body mass index, a known risk factor, probably predated the diagnosis.

The high odds of having been diagnosed with osteoporosis among members of households in the lowest income quintile largely reflected women aged 50 to 70 (Figure 1). At age 71 or older, the percentage of women with osteoporosis did not differ significantly by household income.

Findings for 2004 provide much the same picture; low household income, Aboriginal descent and underweight were significantly related to having been diagnosed with osteoporosis (data not shown).

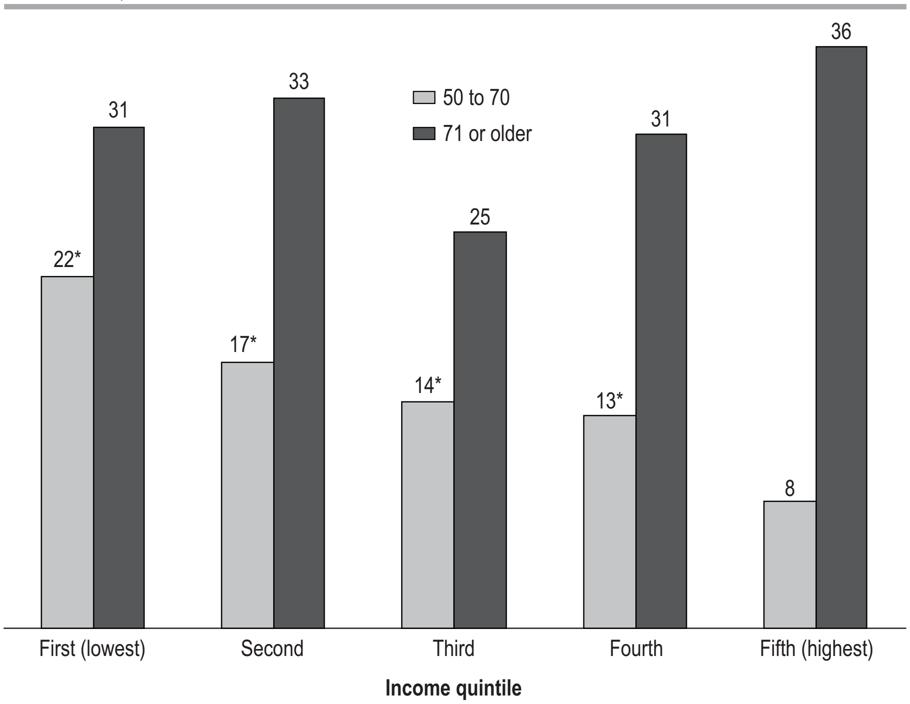
Calcium

In 2004, Canadians older than age 50 obtained an average of 771 mg of calcium a day from what they ate and drank. Milk, cheese, bread, vegetables (except potatoes) and yogurt were the main dietary sources. Based on the dietary reference intakes of the Institute of Medicine, about half of men aged 50 to 70 did not obtain adequate calcium from food alone; for women aged 50 or older and for men aged 71 or older, the percentage with inadequate calcium intake from food was 80% (Table 3).

However, 28% of men and 48% of women aged 50 or older reported taking supplements containing calcium (Table 3). Among those with osteoporosis, the percentages taking calcium supplements were higher—36% of men and 59% of women (data not shown).

Total daily calcium intake from food and supplements combined averaged 969 mg for people aged 50 or older in 2004. Depending on age group and

Figure 1
Percentage diagnosed with osteoporosis, by age group and household income quintile, female household population aged 50 or older, Canada excluding territories, 2009



* significantly different from estimate for fifth quintile (p<0.05)
Source: 2009 Canadian Community Health Survey—Healthy Aging.

What is already known on this subject?

- Osteoporosis is characterized by a loss of bone mass and increased bone fragility and risk of fracture.
- The condition primarily affects older people, notably women.
- The prevention and treatment of osteoporosis usually involve sufficient intake of calcium and vitamin D.

What does this study add?

- This study provides recent data on the prevalence of diagnosed osteoporosis and on the use of calcium and vitamin D supplements
- In 2009, 19.2% of women and 3.4% of men aged 50 or older reported that they had been diagnosed with osteoporosis; at age 71 or older, the corresponding percentages were 31.1% and 6.4%.
- According to nutrition data from 2004, 28% of men and 48% of women aged 50 or older took calcium supplements; for those with osteoporosis, the percentages were 36% and 59%.
- An estimated 27% of men and 48% of women took vitamin D supplements; for people with osteoporosis, the percentages were 38% and 57%.
- Even among those who took supplements, at least 25% had inadequate calcium intake, and more than 10% had inadequate vitamin D intake.

Table 3
Calcium and vitamin D intake, by age group and sex, household population aged 50 or older, Canada excluding territories, 2004

	50 to 70						71 or older					
	Men			Women			Men			Women		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
	Estimate	from	to	Estimate	from	to	Estimate	from	to	Estimate	from	to
Calcium												
Intake from food only												
Average (mg)	824	793	856	751	725	776	774	711	837	689	659	719
% below EAR	53.2	48.5	57.8	81.5	78.5	84.6	79.2	73.2	83.7	86.4	83.2	89.6
% consuming supplements containing calcium	28.3	25.7	31.0	49.0	46.3	51.7	27.2	23.4	31.0	45.9	42.6	49.2
Combined intake from food and supplements												
Total population												
Average (mg)	913	879	947	1,058	1,020	1,096	891	812	970	947	908	986
% below EAR	44.5	40.0	49.0	56.8	53.5	60.1	69.4	63.5	75.3	63.1	59.2	67.0
Supplement users only												
Average (mg)	1,135	1,059	1,211	1,417	1,360	1,475	1,268	1,098	1,438	1,274	1,217	1,331
% below EAR	24.9	17.1	32.7	26.9	23.2	30.6	40.0	27.3	52.7	33.3	27.8	38.8
% above UL	5.7[E]	2.8	8.6	16.2	13.1	19.3	F	...	...	9.9	7.2	12.6
Vitamin D												
Intake from food only												
Average (μg)	6.8	6.0	7.6	4.9	4.5	5.4	6.6	5.7	7.4	5.9	4.6	7.1
% below EAR	80.0	73.9	86.4	91.5	87.3	95.9	86.0	79.6	91.4	87.8	78.9	95.3
% consuming supplements containing vitamin D	27.2	24.5	29.8	45.0	42.2	47.7	28.5	24.6	32.5	43.0	39.8	46.1
Combined intake from food and supplements												
Total population												
Average (μg)	9.5	8.6	10.4	10.2	9.5	10.9	10.1	9.0	11.2	11.0	9.7	12.4
% below EAR	64.9	60.2	69.6	57.6	53.1	62.2	66.3	60.4	72.1	54.3	46.6	61.9
Supplement users only												
Average (μg)	18.2	15.8	20.6	16.7	15.8	17.6	19.4	17.2	21.6	17.3	16.3	18.4
% below EAR	15.0[E]	7.7	22.3	16.7	13.2	20.2	11.8[E]	5.5	18.1	14.4	10.5	18.3

E use with caution
F too unreliable to be published
... not applicable
Notes: EAR: estimated average requirement; UL: Tolerable Upper Intake Level threshold; Calcium: EAR=800 mg for men aged 50 to 70, 1,000 mg for men aged 71 or older and women aged 50 or older; UL=2,000 mg; Vitamin D: EAR=10μg.
Source: 2004 Canadian Community Health Survey—Nutrition.

sex, 45% to 70% had inadequate intake (Table 3). The average total calcium intake of those who took supplements was 1,303 mg, 515 mg of which came from supplements. Even so, 25% to 40% of them had inadequate total intake. On the other hand, a substantial share of supplement users, particularly women, consumed more calcium than the tolerable upper intake level threshold of 2,000 mg (Table 3).

The amount of calcium obtained from food and beverages did not differ significantly between people who had and had not been diagnosed with osteoporosis (Figure 2). However, those with osteoporosis derived more calcium from supplements, which resulted in significantly higher total intake, compared with people who did not have osteoporosis.

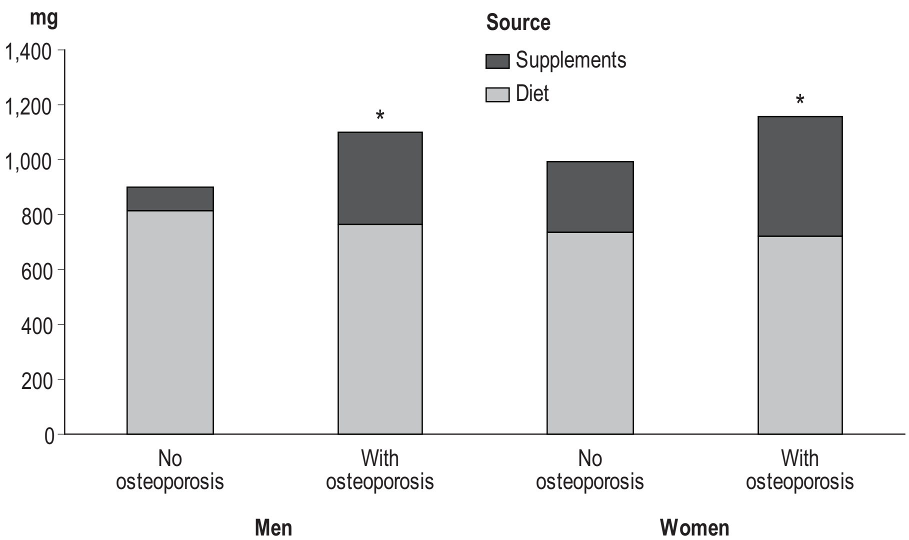
Vitamin D

Milk, fish, margarine, eggs and beef are the main dietary sources of vitamin D. In 2004, the food and beverages that Canadians aged 50 or older consumed gave them an average of 5.9 μg of vitamin D a day, well below the Institute of Medicine's EAR of 10 μg. Based on diet alone, more than 80% of people in this age range were below the EAR.

In 2004, 27% of men and 44% of women took vitamin D supplements (Table 3). For people with osteoporosis, the percentage using vitamin D supplements was 38% among men and 57% among women (data not shown).

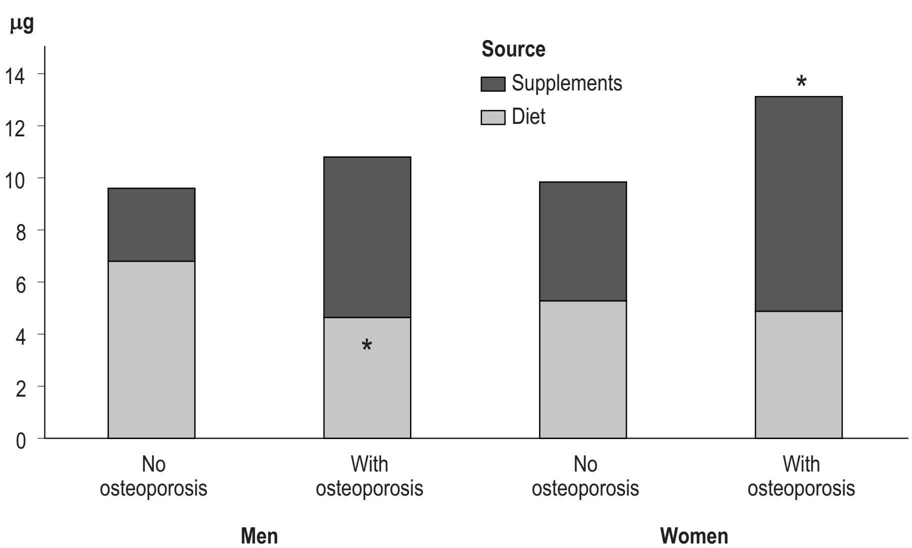
At age 50 or older, total daily vitamin D intake from diet and supplements combined averaged 10 μg. However, 54% to 66% of people in this age range were below the EAR. For supplement users alone, total vitamin D intake averaged 17.5 μg a day, 11.3 μg of which came from supplements; 12% to 17% of this population were below the EAR (Table 3). Fewer than 1% of people aged

Figure 2
Average daily calcium consumption, by source, osteoporosis diagnosis and sex, household population aged 50 or older, Canada excluding territories, 2004



* significantly different from estimate for no osteoporosis (p<0.05)
Source: 2004 Canadian Community Health Survey—Nutrition.

Figure 3
Average daily vitamin D consumption, by source, osteoporosis diagnosis and sex, household population aged 50 or older, Canada excluding territories, 2004



* significantly different from estimate for no osteoporosis (p<0.05)
Source: 2004 Canadian Community Health Survey—Nutrition.

50 or older had vitamin D intake above the tolerable upper intake level of 100 µg (data not shown).

Men diagnosed with osteoporosis obtained less vitamin D from their diets than did men who did not have the condition; when supplements were included, total vitamin D intake did not differ between men who did and did not have osteoporosis (Figure 3). Among women, vitamin D intake from food and beverages was similar whether or not they had osteoporosis. However, when supplements were included, women with osteoporosis had significantly higher total vitamin D intake.

Discussion

The self-reported prevalence of diagnosed osteoporosis and the characteristics associated with it did not change between 2004 and 2009. Many of the characteristics identified in this study have been observed previously or are established risk factors. Low BMI, for example, is a well-documented risk factor for fractures[21] and osteoporosis.[22] The nutritional risk variable used in this analysis is based, in part, on weight loss, which is also associated with fractures and osteoporosis.[23-25] As well, higher fracture risks for Aboriginal Canadians have been reported.[26]

Clinical practice guidelines recommend that those with osteoporosis consume sufficient calcium and vitamin D.[27] Therefore, it is no surprise that in this study, people with the condition were more likely than those without it to have taken supplements and to have derived larger amounts of calcium and vitamin D from supplements. In fact, those with osteoporosis had the same dietary calcium intake as people without the condition. Moreover, men with osteoporosis actually obtained less vitamin D from dietary sources alone. Taking supplements offset the difference in vitamin D intake among men and gave those with osteoporosis an advantage in calcium intake.

The link between osteoporosis and household income has received relatively little attention, and the results of the research that has been conducted are not definitive. A comprehensive review of articles published between 1966 and 2007 on the association between socio-economic status and osteoporosis fracture uncovered only three studies that found a higher risk of fracture in lower-income people.[28] A study of American women older than age 50 reported no correlation between osteoporosis diagnosis and household income.[29] By contrast, an association between low bone density and low income has been reported,[30] and according to a Canadian study,[26] fracture risks were higher among low-income people. However, because these studies were cross-sectional, the osteoporosis diagnosis itself may have affected household income—for example, by restricting the ability to work. Supplementary analyses of the 2004 CCHS data showed a significant correlation between household income and supplement use, but not between household income and total intake of calcium or vitamin D (data not shown).

Measured concentrations of vitamin D in the blood (25-hydroxyvitamin D [25(OH)D]) and reported vitamin D intake differed. According to recent data from the 2007 to 2009 Canadian Health Measures Survey, an estimated 22% of 50- to 79-year-olds had measured blood concentrations below 50 nmol/L, the level targeted by the EAR.[3] However, results from the 2004 CCHS show that the prevalence of inadequate vitamin D intake was around 60%. Sun exposure might account for this difference, because the EAR assumes that it is minimal. Underreporting of intake is another possible explanation.

Limitations

The main limitation of this study is that it is based on cross-sectional data. Characteristics in childhood or even before birth may affect the risks of developing osteoporosis in adulthood.[31] Such longitudinal factors could not be taken into account.

In addition, the osteoporosis diagnosis is self-reported, and therefore, prevalence is likely underestimated because some people who have the condition may not have been diagnosed.

Nutrition surveys are subject to underreporting of energy intake, and by extension, of the intake of nutrients such as calcium and vitamin D. Earlier studies of the collection instrument used by the CCHS estimated average energy underreporting at 10%[32] or 11%.[33]

No nutritional data for calcium and vitamin D were available for 2009. The 2004 data on dietary and supplement intake are the most recent and comprehensive available.

Conclusion

According to the 2009 CCHS—Healthy Aging, 3% of men and 19% of women aged 50 or older reported having been diagnosed with osteoporosis. A diagnosis of osteoporosis was significantly associated with age, sex, Aboriginal origin, high nutritional risk and underweight. The odds were also high for people in lower-income households, notably women aged 50 to 70.

Physicians often recommend increased calcium and vitamin D consumption for people with osteoporosis. And in fact, those with osteoporosis were more likely to take supplements, and so had higher total calcium and vitamin D intake than did people who did not have the condition. Yet household income was not significantly related to the total intake of calcium and vitamin D. While sufficient calcium and vitamin D are required to promote bone health, other nutrients are also involved.[34] As well, smoking and excessive sodium, caffeine and alcohol consumption can increase the risk of osteoporosis,[35] and a balanced diet and physical activity, especially weight-bearing exercises, can reduce it. More detailed studies might provide a clearer understanding of the associations between osteoporosis and demographic, socio-economic, dietary and lifestyle factors. ■

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Adults' use of health services in the year before death by suicide in Alberta

by Kenneth B. Morrison and Lory Laing

Abstract

Background

The suicide rate in Alberta is consistently above the Canadian average. Health care use profiles of those who die by suicide in Alberta are currently unknown.

Data and methods

Death records were selected for people aged 25 to 64 with suicide coded as the underlying cause of death from April 1, 2003 to March 31, 2006. The death records were linked to administrative records pertaining to physician visits, emergency department visits, inpatient hospital separations, and community mental health visits. The control group was the Alberta population aged 25 to 64 who did not die by suicide. Frequency estimates were produced to determine the characteristics of the study population. Odds ratios relating to demographics, exposure to health care services, and case-control status were estimated with logistic regression.

Results

Almost 90% of suicides had a health service in the year before their death. Suicides averaged 16.6 visits per person, compared with 7.7 visits for non-suicides. Much of the health service use among people who died by suicide appears to have been driven by mental disorders.

Interpretation

Information about health service delivery to those who die by suicide can guide prevention and intervention efforts.

Keywords

Emergency medical services, family physicians, health services accessibility, medical record linkage, mental health, self-injurious behaviour

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Mental illness, particularly depressive disorder, is an important predictor of suicide.[1-4] Almost by definition, people who die by suicide are distressed, so contact with both psychiatric and primary health care services is common in the period before their death.[1,5-8]

On average, someone in Alberta dies by suicide each day. During the five years from 2002 through 2006, more than 2,000 Albertans died by suicide—over 400 a year, on average. Among the provinces, Alberta's suicide rate is second highest after Quebec.[9] While suicide prevention efforts often target the young and elderly, most suicides in Alberta occur in those middle-aged.

This study, based on linked administrative data for Albertans aged 25 to 64, examines health service use patterns of people who died by suicide. Most earlier research that has used administrative data to study suicide was limited to a single type of contact with the health care system, and few studies presented information about contact with physicians in various settings.[10] A Danish study[11] that attempted to bring together health-related administrative records found a high prevalence of psychiatric morbidity and a high rate of contacts with general practitioners (GPs) in the period close to suicide. However, it is difficult to draw generalizations from that analysis because a control group was not used, and diagnostic information was not presented.

The current study of adult Albertans who died by suicide provides both a control group (the Alberta population who did not die by suicide) and detailed diagnostic information. The linkable data sources pertain to physician visits, ambulatory care (emergency department) visits, inpatient hospitalizations, and community-based mental health services. The focus is on the use of health care services in the year before suicide—the period during which intervention might have been feasible.

Methods

Study design

Record linkage and a population-based case-control design were employed to investigate the health service use and demographics of adult Albertans who died by suicide and those who did not. Death records[12] were linked to health service records using a unique personal health number identifier obtained through deterministic linkage with

Alberta Health and Wellness (AHW) registry files.[13] Socio-demographic data available included sex, age, residence location, and health insurance premium subsidy category. The study design was approved by the Health Research Ethics Board of the University of Alberta.

Case and control selection

Cases

From a mortality database maintained by Alberta Health and Wellness,[12] records with suicide coded as the underlying cause of death (ICD-10 codes X60-X84) over the three-year period from April 1, 2003 to March 31, 2006 were selected. Records were restricted to Alberta residents aged 25 to 64. A personal health number was available for 99% (933/940) of the suicides. To ensure one year's exposure to possible health services for all cases before their death, selection was limited to individuals who were active on the AHW registry in the year they died and one year prior. This resulted in 854 suicide cases being selected for the study.

Controls

Because the objective was to compare the characteristics of those who died by suicide with the general population, 25- to 64-year-olds registered to receive health services in Alberta during the 2004/2005 fiscal year (the middle year of case selection) were chosen. The records selected represented approximately 99% of the Alberta population in that age group at the time. Suicide cases were removed. Specific subgroups, such as those with a mental disorder diagnosis, were identified for additional analyses. The selection of the controls was also limited to individuals who were active on the AHW registry during the year and one year earlier. A total of 1,752,323 controls were used for the study.

Data resources

Tracking of health service use of those who died by suicide began at April 1, 2002. A minimum of one year of retrospective data was available for all participants. Hospitalizations thought to be related to the suicide itself (same date) were excluded from analysis.

The reference for all recipient identifiers in AHW data is the Alberta Health Care Insurance Plan (AHCIP) Registry. The registry contains basic demographic and geographic information on Albertans eligible to receive health services.[13] During the study period, the registry was also used to collect health care insurance premiums. Based on AHCIP premium subsidy categories, a proxy socio-economic variable[14] was developed: no subsidy, subsidy, First Nations, and social assistance (welfare). The four categories are mutually exclusive.

AHW administrative holdings include a claims system that pays providers for billable services; this system contains recipient, provider, service and diagnostic data. Also available are hospital morbidity files, which include information on diagnosis and procedure interventions for people assigned an inpatient bed. Information about health services provided in an outpatient setting (emergency room) was obtained from the Alberta Ambulatory Care Classification System. Data were also obtained from the Alberta Mental Health Board for services provided through community mental health services.

Diagnoses for physician visits were coded in International Classification of Diseases (ICD) Version 9. Diagnoses for emergency department visits and inpatient separations were coded in ICD-10. Community mental health services diagnoses were coded in Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition and converted to ICD-9.

Analysis

Frequency estimates were produced to describe the characteristics of the study population. Health service visits were treated as a continuous variable and presented as both the percentage of individuals who had a health visit, and as the mean number of visits. The ratio of suicides to non-suicides was calculated. Confidence intervals were used to determine significant differences between groups. Logistic regression was used to estimate odds ratios relating to health service exposure, socio-demographics, and case-control status.

The regression model developed included socio-demographic variables (sex, age group, region of residence, premium subsidy category) and measures of health service use (physician visits, emergency department visits, inpatient separations, community mental health service visits). Service counts were collapsed into groups for ease of interpretation. Visits diagnosed as anxiety/stress, depression or substance disorder were included as dichotomous variables; also included were the variables of psychiatrist visit and emergency department visit with a diagnosis of intentional self-harm. The c statistic, measuring the discriminative power of the logistic equation, was 67.8%. Analyses were completed using SAS® software (version 9.1).

Results

Male, middle-aged, social assistance

The socio-demographic characteristics of people who died by suicide and those who did not differed substantially (Table 1). About three-quarters (73%) of the suicides were male, whereas the male/female ratio among non-suicides was almost 1:1. Close to two-thirds (65%) of suicides were aged 35 to 54, compared with 57% of non-suicides. Suicides were less likely than non-suicides to reside in the Calgary region, but more likely to reside in the Aspen and Peace Country regions (north of Edmonton). Compared with non-suicides, suicides were more likely to be First Nations (Status Indian) or to have received social assistance.

Use of health services

Similar percentages of suicides (86%) and non-suicides (84%) had had at least one physician visit in the previous year. Suicides, however, were much more likely than non-suicides to have had an emergency department visit (58% versus 22%), an inpatient hospital separation

Table 1
Socio-demographic characteristics of suicides and non-suicides, population aged 25 to 64 registered to receive health services, Alberta, 2002/2003 to 2005/2006

	Suicides				Non-suicides†				
			95% confidence interval				95% confidence interval		Suicide/ Non-suicide
	Number	%	from	to	Number	%	from	to	ratio
Total	**854**	**100.0**	**...**	**...**	**1,752,323**	**100.0**	**...**	**...**	**...**
Sex									
Women	228	26.7	23.7	29.7	871,873	49.8	49.7	49.8	0.5
Men	626	73.3	70.3	76.3	880,450	50.2	50.2	50.3	1.5
Age group									
25 to 34	167	19.6	16.9	22.2	453,748	25.9	25.8	26.0	0.8
35 to 44	288	33.7	30.6	36.9	504,398	28.8	28.7	28.9	1.2
45 to 54	265	31.0	27.9	34.1	489,595	27.9	27.9	28.0	1.1
55 to 64	134	15.7	13.3	18.1	304,582	17.4	17.3	17.4	0.9
Health region									
South/East Central	80	9.4	7.4	11.3	184,484	10.5	10.5	10.6	0.9
Calgary	261	30.6	27.5	33.7	663,138	37.8	37.8	37.9	0.8
David Thompson	91	10.7	8.6	12.7	152,006	8.7	8.6	8.7	1.2
Capital	295	34.5	31.4	37.7	553,306	31.6	31.5	31.6	1.1
Aspen/Peace Country	112	13.1	10.9	15.4	160,324	9.1	9.1	9.2	1.4
Northern Lights	12	1.4	0.6	2.2	39,009	2.2	2.2	2.2	0.6
Missing	3	0.4	...	...	56	0.0	...	...	...
Alberta Health Care Insurance Plan premium subsidy category									
No subsidy	591	69.2	66.1	72.3	1,465,092	83.6	83.6	83.7	0.8
Subsidy	72	8.4	6.6	10.3	177,820	10.1	10.1	10.2	0.8
First Nations	71	8.3	6.5	10.2	55,162	3.1	3.1	3.2	2.6
Social assistance	120	14.1	11.7	16.4	54,249	3.1	3.1	3.1	4.5

† 2004/2005 fiscal year
... not applicable
Sources: Alberta Health Care Insurance Plan Population Registry, Alberta Health and Wellness Death Database.

(28% versus 6%), or a community mental health service (8% versus 1%) (data not shown). For both suicides and non-suicides, a higher percentage of women than men had accessed health services (suicides: 96% versus 87%; non-suicides: 92% versus 80%) (data not shown). Of those who died by suicide, 99% of First Nations individuals and 98% of social assistance recipients had received a health service in the year before their death.

Overall, suicides averaged more than twice the number of health service visits per person, compared with non-suicides (16.6 versus 7.7) (Figure 1). While less frequent, the difference in service use between the groups was most evident for services other than physician visits—suicides averaged 5 times more emergency department visits, 6 times more inpatient hospital separations, and 12 times more community mental health services. Women in both groups averaged notably more health visits than did men.

Considerable differences in health service use emerged by premium subsidy category. In each category, suicides averaged approximately twice as many visits as non-suicides (Figure 2). Suicides who had received social assistance averaged 34 visits, almost twice as many as the next closest subsidy category—First Nations—who averaged 18 visits.

Diagnosis

Health care visits with mental disorder diagnoses were particularly high for suicides: an average of 28 times more emergency department visits per person and almost 50 times more inpatient hospitalizations per person than non-suicides (Table 2).

For both suicides and non-suicides, depression and anxiety/stress were the mental disorder diagnoses with the highest average number of visits. Suicides, however, averaged over 60 times more inpatient separations with a depression diagnosis than did non-suicides. Relatively few visits were recorded with a diagnosis of substance-related disorder, but overall, suicides averaged 15 times more such visits than did non-suicides.

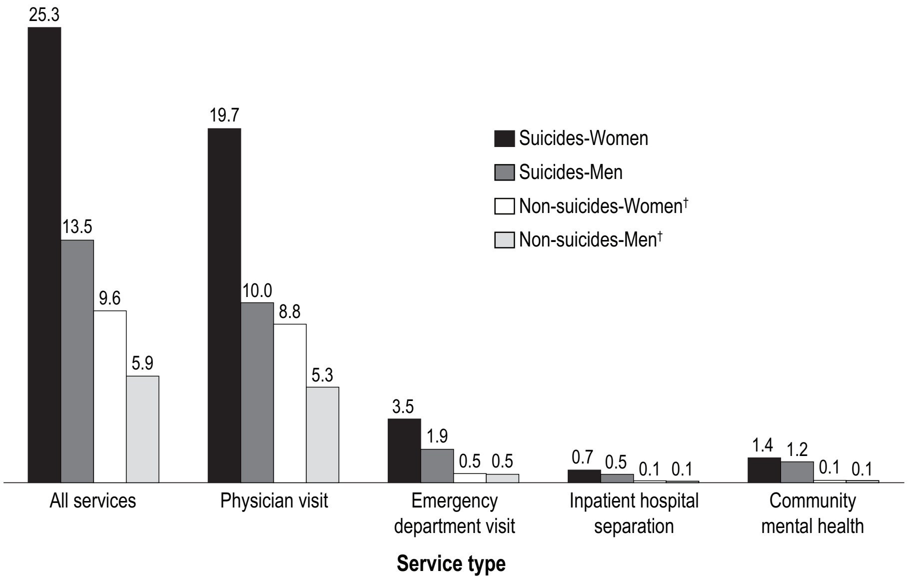
A considerable number of suicides' emergency department visits were attributable to injury and poisoning. The percentage for suicides was notably higher than the percentage for non-suicides in every injury category (for example, assault, poisoning, falls). Intentional self-harm was the emergency department injury diagnosis recorded for the highest percentage of suicides (8.4%), but the lowest percentage of non-suicides (0.1%) (data not shown).

Logistic regression analysis

When the effects of the demographic, geographic, socio-economic and service type variables were considered simultaneously, several strong associations with suicide emerged (Table 3). Men's odds of suicide were more than three times those of women. The odds of suicide among 25- to 34-year-olds were significantly lower than the odds for people aged 35 to 44. Compared with residents of the Capital Health Region (Edmonton area), those who lived in southern and eastern Alberta (Chinook, Palliser, and East-Central Health Regions) and far northeastern Alberta (Northern Lights Health Region) had low odds of suicide. The odds ratio for First Nations individuals was significantly higher than that for people who received no premium subsidy.

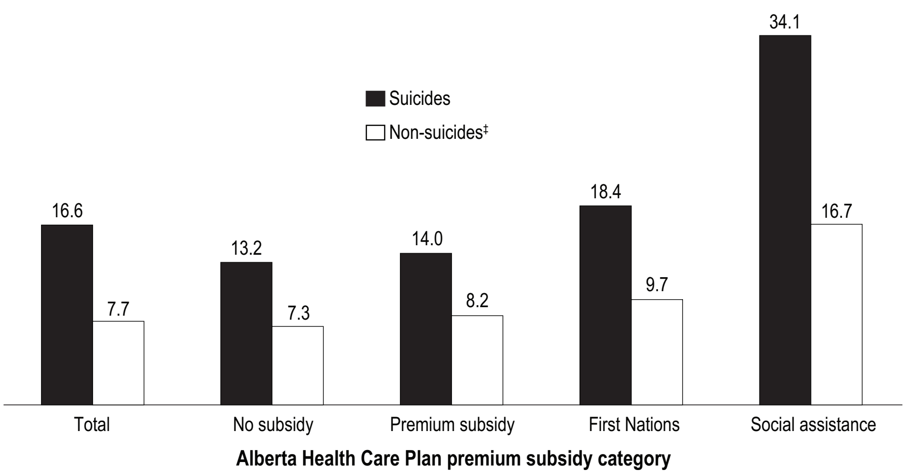
People with no or just one physician visit in the previous year had higher odds of suicide, compared with those who had 2 to 12 visits (the typical range for this age group). Having at least one

Figure 1
Mean number of health care visits in past year of suicides and non-suicides, by sex and service type, population aged 25 to 64 registered to receive health services, Alberta, 2002/2003 to 2005/2006



† 2004/2005 fiscal year
Sources: Alberta Health Care Insurance Plan Population Registry, Alberta Health and Wellness Death Database, Alberta Health and Wellness Physician Claims files, Alberta Ambulatory Care Classification System, Alberta Health and Wellness Inpatient Hospital files, Alberta Mental Health Board

Figure 2
Mean number of health care visits† in past year of suicides and non-suicides, by Alberta Health Care Insurance Plan premium subsidy category, population aged 25 to 64 registered to receive health services, Alberta, 2002/2003 to 2005/2006



† physician visits, emergency department visits, inpatient separations, and community mental health services
‡ 2004/2005 fiscal year
Sources: Alberta Health Care Insurance Plan Population Registry, Alberta Health and Wellness Death Database, Alberta Health and Wellness Physician Claims files, Alberta Ambulatory Care Classification System, Alberta Health and Wellness Inpatient Hospital files, Alberta Mental Health Board.

What is already known on this subject?

- Contact with psychiatric and primary care services is common in the time preceding suicide.
- Mental illness, particularly depressive disorder, is an important predictor of suicide.
- Most studies that have used administrative data to study health care use before suicide were limited to a single type of contact, and few presented information about health care contacts in different settings.

What does this study add?

- This study provides detailed diagnostic information from a variety of administrative databases and uses a control group (the entire Alberta population who did not die by suicide).
- Almost 90% of those who died by suicide received a health service during the year before their death.
- Groups thought to be at risk of not accessing health services had, in fact, higher service use.
- Of those with a diagnosis of depression, suicides were considerably more likely than non-suicides to have a depression diagnosis through an emergency department visit, an inpatient separation, or a community mental health service visit.
- Almost 60% of those who died by suicide had an emergency department visit in the year before their death.

Table 2
Mean number of health care visits in past year of suicides and non-suicides, by service type and ICD diagnostic chapter, population aged 25 to 64 registered to receive health services, Alberta, 2002/2003 to 2005/2006

		Suicides†					Non-suicides‡					
				95% confidence interval					95% confidence interval			
	ICD-9 Diagnostic Chapter	Number	Mean	from	to	Standard error	Number	Mean	from	to	Standard error	Suicide/ Non-suicide ratio
	Physician visits (ICD-9)											
Total		**10,736**	**12.57**	**11.50**	**13.64**	**0.55**	**12,345,668**	**7.05**	**7.03**	**7.06**	**0.01**	**1.8**
5	Mental disorders	4,492	5.26	4.49	6.03	0.39	1,045,061	0.60	0.59	0.60	0.00	8.8
	Anxiety/Neurosis/Stress	1,442	1.69	1.23	2.14	0.23	381,658	0.22	0.22	0.22	0.00	7.8
	Depressive disorders	1,523	1.78	1.47	2.10	0.16	392,380	0.22	0.22	0.23	0.00	8.0
	Substance-related disorders	235	0.28	0.19	0.36	0.04	39,241	0.02	0.02	0.02	0.00	12.3
6	Nervous and sense organs	407	0.48	0.32	0.63	0.08	594,806	0.34	0.34	0.34	0.00	1.4
8	Respiratory	450	0.53	0.45	0.61	0.04	887,828	0.51	0.50	0.51	0.00	1.0
10	Genitourinary	215	0.25	0.19	0.31	0.03	684,953	0.39	0.39	0.39	0.00	0.6
12	Skin and subcutaneous	318	0.37	0.28	0.46	0.05	521,175	0.30	0.30	0.30	0.00	1.3
13	Musculoskeletal	1,195	1.40	1.16	1.64	0.12	2,116,594	1.21	1.20	1.21	0.00	1.2
16	Symptoms and signs	1,211	1.42	1.20	1.64	0.11	1,385,894	0.79	0.79	0.79	0.00	1.8
17	Injury and poisoning	754	0.88	0.72	1.05	0.08	1,399,248	0.80	0.79	0.80	0.00	1.1
VC	Factors influencing health	511	0.60	0.45	0.74	0.07	1,559,665	0.89	0.89	0.89	0.00	0.7
	All other Chapters (and uncoded)	1,183	1.39	1.21	1.57	0.09	2,150,444	1.23	1.22	1.23	0.00	1.1
	Emergency department visits (ICD-10)											
Total		**1,968**	**2.30**	**1.85**	**2.76**	**0.23**	**855,770**	**0.49**	**0.49**	**0.49**	**0.00**	**4.7**
V	Mental and behavioural	485	0.57	0.46	0.67	0.05	36,083	0.02	0.02	0.02	0.00	27.6
	Anxiety/Neurosis/Stress	112	0.13	0.09	0.17	0.02	11,258	0.01	0.01	0.01	0.00	20.4
	Depressive disorders	135	0.16	0.12	0.20	0.02	6,230	0.00	0.00	0.00	0.00	44.5
	Substance-related disorders	104	0.12	0.09	0.16	0.02	11,533	0.01	0.01	0.01	0.00	18.5
VI	Nervous	62	0.07	0.01	0.13	0.03	26,856	0.02	0.01	0.02	0.00	4.7
X	Respiratory	62	0.07	0.05	0.10	0.01	71,936	0.04	0.04	0.04	0.00	1.8
XI	Digestive	85	0.10	0.07	0.13	0.02	55,643	0.03	0.03	0.03	0.00	3.1
XII	Skin and subcutaneous	57	0.07	0.04	0.09	0.01	28,026	0.02	0.02	0.02	0.00	4.2
XIII	Musculoskeletal	102	0.12	0.08	0.16	0.02	56,947	0.03	0.03	0.03	0.00	3.7
XVIII	Symptoms and signs	185	0.22	0.18	0.26	0.02	110,800	0.06	0.06	0.06	0.00	3.4
XIX	Injury and poisoning	423	0.50	0.43	0.56	0.03	179,922	0.10	0.10	0.10	0.00	4.8
XXI	Factors influencing health	394	0.46	0.13	0.79	0.17	158,958	0.09	0.09	0.09	0.00	5.1
	All other Chapters	113	0.13	0.10	0.17	0.02	130,599	0.07	0.07	0.08	0.00	1.8
	Inpatient separations (ICD-10)											
Total		**452**	**0.53**	**0.45**	**0.61**	**0.04**	**147,507**	**0.08**	**0.08**	**0.08**	**0.00**	**6.3**
II	Neoplasms	9	0.01	0.00	0.02	0.00	9,651	0.01	0.01	0.01	0.00	1.9
V	Mental and behavioural	292	0.34	0.28	0.40	0.03	12,347	0.01	0.01	0.01	0.00	48.5
	Anxiety/Neurosis/Stress	42	0.05	0.03	0.06	0.01	1,696	0.00	0.00	0.00	0.00	50.8
	Depressive disorders	83	0.10	0.07	0.13	0.02	2,802	0.00	0.00	0.00	0.00	60.8
	Substance-related disorders	65	0.08	0.05	0.10	0.01	2,750	0.00	0.00	0.00	0.00	48.5
IX	Circulatory	11	0.01	0.00	0.02	0.00	10,427	0.01	0.01	0.01	0.00	2.2
X	Respiratory	17	0.02	0.01	0.03	0.01	6,644	0.00	0.00	0.00	0.00	5.3
XI	Digestive	22	0.03	0.01	0.04	0.01	16,128	0.01	0.01	0.01	0.00	2.8
XIV	Genitourinary system	8	0.01	0.00	0.02	0.00	10,480	0.01	0.01	0.01	0.00	1.6
XV	Pregnancy and childbirth	5	0.01	0.00	0.01	0.00	34,666	0.02	0.02	0.02	0.00	0.3
XIX	Injury and poisoning	41	0.05	0.03	0.07	0.01	12,424	0.01	0.01	0.01	0.00	6.8
XXI	Factors influencing health	12	0.01	0.01	0.02	0.00	8,666	0.00	0.00	0.01	0.00	2.8
	All other Chapters	35	0.04	0.02	0.06	0.01	26,074	0.01	0.01	0.02	0.00	2.8

† suicides N=854; non-suicides N=1,752,323
‡ 2004/2005 fiscal year
Notes: Physician claims on same day in same facility with same diagnosis and provider specialty are consolidated. Excludes emergency department visits and inpatient separations on day of death.
Sources: Alberta Health Care Insurance Plan Population Registry, Alberta Health and Wellness Death Database, Alberta Health and Wellness Physician Claims files, Alberta Ambulatory Care Classification System, Alberta Health and Wellness Inpatient Hospital files.

Table 3
Adjusted odds ratios relating selected characteristics to suicides, population aged 25 to 64 registered to receive health services, Alberta, 2002/2003 to 2005/2006

Effect	Adjusted odds ratio	95% confidence interval from	95% confidence interval to	Effect p-value
Sex				<.0001
Women†	1.00	...	...	
Men	3.33***	2.84	3.91	
Age group				<.0001
25 to 34	0.61***	0.50	0.74	
35 to 44†	1.00	...	...	
45 to 54	1.03	0.87	1.21	
55 to 64	0.93	0.75	1.14	
Health region				0.024
South/East Central	0.72**	0.56	0.92	
Calgary	0.89	0.76	1.06	
David Thompson	0.99	0.78	1.26	
Capital†	1.00	...	...	
Aspen/Peace Country	1.04	0.83	1.31	
Northern Lights	0.52*	0.29	0.93	
Alberta Health Care Insurance Plan premium subsidy category				0.001
No subsidy†	1.00	...	...	
Subsidy	1.00	0.78	1.28	
First Nations	1.67***	1.28	2.18	
Social assistance	1.23	0.98	1.54	
Number of physician visits				<.0001
0 to 1	1.63***	1.34	1.97	
2 to 12†	1.00	...	...	
13 or more	0.95	0.79	1.13	
Number of emergency department visits				<.0001
0†	1.00	...	...	
1	2.25***	1.86	2.72	
2 or more	3.28***	2.69	4.00	
Inpatient hospital separation‡	1.56***	1.28	1.90	<.0001
Community mental health visit‡	1.23	0.93	1.62	0.142
Anxiety/Stress diagnosis visit‡	1.82***	1.52	2.17	<.0001
Depression diagnosis visit‡	3.27***	2.71	3.95	<.0001
Substance disorder visit‡	1.88***	1.50	2.35	<.0001
Psychiatrist visit‡	3.20***	2.59	3.94	<.0001
Self-harm emergency department visit‡	5.25***	3.93	7.00	<.0001

† reference category
‡ reference category is absence of characteristic
* significantly different from reference category (p<0.05)
** significantly different from reference category (p<0.01)
***significantly different from reference category (p<0.001)
... not applicable
Sources: Alberta Health Care Insurance Plan Population Registry, Alberta Health and Wellness Death Database, Alberta Health and Wellness Physician Claims files, Alberta Ambulatory Care Classification System, Alberta Health and Wellness Inpatient Hospital files, Alberta Mental Health Board.

emergency department visit was strongly associated with suicide, as was having at least one inpatient hospital separation. Community mental health service visits were not significantly associated with suicide.

All three mental disorder diagnoses in the model were significantly associated with suicide, particularly depression. Having a psychiatrist visit was also strongly associated with suicide. The odds of suicide among people who had an emergency department visit with a diagnosis of intentional self-harm were five times the odds for people who did not have this experience.

Discussion

The aim of this study was to determine if people who die by suicide in Alberta have particular risk factors or distinctive health care use profiles that could be taken into account in suicide prevention. Findings of previous studies about the frequency of health care contacts and the importance of mental illness as a predictor of suicide were reinforced. As expected, the demographic characteristics of those who died by suicide differed from the characteristics of those who did not. The highest prevalence of suicide was among middle-aged men.[15]

Most large-scale studies of suicide that include an income measure are ecological.[16] This analysis, however, was strengthened by the inclusion of an individual-level proxy variable for socio-economic status, rare in large-scale studies based on administrative data. It was also possible to identify First Nations individuals, and they made up a larger percentage of those who died by suicide than they did of the general population.[14,17,18] One result not fully anticipated was that social assistance recipients (non-First Nations) made up an even greater share of suicides.

Overall, almost 90% of suicides had a health service contact during the year before death; 86% had a physician visit, a figure that exceeds the 76% reported in a review of 40 suicide studies by Luoma et al.[1]

Contrary to other research,[6,19] this analysis found that groups thought to be at risk of not accessing health services were, in fact, among the higher service users. In this study of those who died by suicide, almost all First Nations individuals (99%) and social assistance recipients (98%) had had a health service contact in the year before their death. First Nations suicides averaged 18 visits; social assistance recipients, 34 visits.

Much of the health service use among people who died by suicide appears to have been driven by mental disorders: 60% of suicides, compared with 18% of non-suicides, had a health care visit with a mental disorder diagnosis in the previous year. By contrast, the percentage of suicides diagnosed with substance-related disorders was low, compared with other studies.[20-22] For example, Tanney's review of psychological autopsy studies reported a median of 41% of suicides with a diagnosis of substance abuse.[20] A possible explanation for the discrepancy is that many of the substance treatment programs in Alberta were operated by the Alberta Alcohol and Drug Abuse Commission (AADAC), whose data were not included in this study. As well, because the psychological autopsy model can capture suicide cases who did not receive health services, such studies are bound to be more sensitive to underlying conditions than are administrative data.[11]

With such a high prevalence of treated mental disorders among suicides, a better control group than *all* non-suicides might be non-suicides *with a mental disorder*. However, in analyses limited to suicides and non-suicides with a diagnosis of depression in the year, differences persisted. Most suicides diagnosed with depression were male, whereas most non-suicides diagnosed with depression were female. While service use for both groups varied considerably by sex, differences between men and women were still less than differences between suicides and non-suicides. Almost all non-suicides received their depression diagnosis through physician visits; suicides were considerably more likely to have had the diagnosis in an emergency department visit, an inpatient separation, or a community mental health service.

In this study, close to 60% of suicides had had an emergency department visit in the year before their death, well above the 39% reported by Gairin et al. in the U.K.[23] (some of the difference obviously reflects the different medical systems). Regression analysis undertaken in this study confirmed the strong association between emergency department visits and subsequent suicide.

Limitations

AHW data are collected for administrative purposes, which must be considered when interpreting the results of analysis.

A larger percentage of the population may have had a health visit with a mental health diagnosis than is indicated in this analysis, but because of data quality concerns, information from the Alberta Mental Health Board was restricted to community mental health services. As well, diagnostic coding for physician visits tends not to be as specific as diagnoses for emergency department visits or inpatient hospital separations.

Conclusions

Almost 90% of those who died by suicide in Alberta received a health service in the year before their death, and they had, on average, 17 health visits. While the vast majority of those who died by suicide saw a GP in the year before their death, the greatest ratio differences in health care contacts between suicides and non-suicides were for services other than physician visits. ■

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Sugar consumption among Canadians of all ages

by Kellie Langlois and Didier Garriguet

Abstract
According to the 2004 Canadian Community Health Survey—Nutrition, Canadians consumed an average of 110 grams (26 teaspoons) of sugar a day, approximately 20% of their total energy intake. While over 30% of this sugar came from vegetables and fruit, 35% came from the "other" foods category, which consists of items such as soft drinks, salad dressings and candy. The top ten sources of sugar accounted for approximately 85% of daily sugar intake. Beverages (milk, fruit juice, fruit drinks and regular soft drinks) represented 44% of the sugar consumed by children and adolescents, and 35% of that consumed by adults. Diabetics' average sugar intake was less than that of non-diabetics, but at 17%, exceeded the recommended 10% cut-off of total daily calories.

Keywords
Carbohydrates, caloric intake, diabetes, diet, energy intake, food

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One in every five calories that Canadians consume comes from sugar. This dietary sugar may occur naturally, for instance, in fruit and milk, or it may have been added to foods and beverages to improve palatability, for instance, in soft drinks, salad dressings, syrup and candy.

Although the body handles naturally occurring and added sugar in the same way, foods high in added sugar tend to have lower nutrient densities, and thus, provide little nutritional value. By contrast, foods with naturally occurring sugars tend to be higher in nutrients.[1]

Some debate surrounds the association between high sugar intake and adverse health effects, such as tooth decay, hyperactivity, and obesity.[2-4] No recommendations have been made about the intake of total sugar, nor does consensus exist about the consumption of added sugars. The Institute of Medicine recommends that no more than 25% of total daily energy intake (calories) come from added sugars. The World Health Organization recommends a daily maximum of 10% of calories from free sugars.[5]

This article describes dietary intake of sugar in a nationally representative sample of Canadian children and adults. Nutritional information was collected via a 24-hour dietary recall as part of the 2004 Canadian Community Health Survey (CCHS)—Nutrition. Respondents were asked to report everything they ate and drank during the previous 24 hours. The sugar content of these foods and beverages was determined using Health Canada's Canadian Nutrient File 2001b, Supplement[6] (see *The data*). This study reports daily intake of sugar by food group and by the top ten sources, but the data do not distinguish between naturally occurring and added sugars. As a result, it is not possible to assess where Canadians stand in relation to the Institute of Medicine and World Health Organization thresholds. The term "sugar" in this article represents the sum of naturally occurring and added sugars.

Average daily intake

On average, in 2004, Canadians consumed 110.0 grams of sugar a day, the equivalent of 26 teaspoons.[7] This amounted to 21.4% of their total daily calorie intake.

Absolute daily sugar consumption varied substantially with age (Figure 1). It was lowest among women aged 71 or older (83 grams or 20 teaspoons), and highest among teenage boys aged 14 to

18 (172 grams or 41 teaspoons). In every age group, males consumed significantly more sugar than did females.

The picture differs when the average percentage of daily calories coming from sugar is considered (Figure 2). From age 19 on, women derived a significantly higher percentage of their total calories from sugar than did men. The average ranged from a low of 19% among men aged 31 to 70 to 27% among children aged 1 to 3.

Food groups

To some extent, the sugar derived from the various food groups may be used as a proxy to distinguish between added versus naturally occurring sugars (Table 1). Sugar from vegetables and fruit and from milk products is more likely to be naturally occurring than is sugar that comes from the "other" foods category, which includes items such as soft drinks and candy that are high in added sugars.[1]

Overall, more than a third (35%) of the sugar that Canadians consumed came from the "other" foods category. The percentage peaked at 46% among teenage boys (Table 1). Regardless of

The data

The data are from the 2004 Canadian Community Health Survey (CCHS)—Nutrition, which collected information about the food and nutrient intake of the household population aged 0 or older. The 2004 CCHS excluded members of the regular Canadian Forces and residents of the three territories, Indian reserves, institutions and some remote areas, as well as all residents (military and civilian) of Canadian Forces bases. Detailed descriptions of the survey design, sample and interview procedures are available in a published report.[8]

This article is based on data from the "24-hour dietary recall" component of the 2004 CCHS. Respondents were asked to list all foods and beverages that they consumed during the 24 hours before the day of their interview (midnight to midnight). Interviewers used the "Automated Multiple Pass Method,"[9,10] with a five-step approach to help respondents remember what they had to eat and drink:

- quick list (respondents reported all foods and beverages consumed in whatever order they wished);
- questions about specific food categories and frequently forgotten foods;
- questions about the time of consumption and type of meal (for example, lunch, dinner);
- questions seeking more detailed, precise descriptions of foods and beverages and quantities consumed; and
- a final review.

A total of 35,107 people completed the initial 24-hour dietary recall, and a subsample of 10,786 completed a second recall three to ten days later, which aimed to assess day-to-day variations in intake. The response rates were 76.5% and 72.8%, respectively. This study uses data from the first recall only. Children younger than age 1 (n=289), respondents with "null" or invalid dietary recalls (n=62), pregnant (n=175) or breastfeeding (n=92) women, and children who were being breastfed (n=104) were excluded. Consequently, this analysis is based on 34,386 respondents aged 1 or older.

Information about children younger than age 6 was collected from their parents, and interviews for children aged 6 to 11 were conducted with parental help. Sugar intake was based on all foods and beverages reported (ingredients not recipes), the composition of which was calculated using Health Canada's Canadian Nutrient File (Supplement 2001b).[6] Approximately 4% of the food and recipe items were missing sugar information; missing values were set to zero when analyzed. More information on this derived variable can be found in the survey documentation.[11]

Respondents were asked about specific "long-term" health conditions that had lasted or were expected to last at least 6 months and had been diagnosed by a health professional. Those who replied "yes" to the question, "Do you have diabetes," were classified as diabetic.

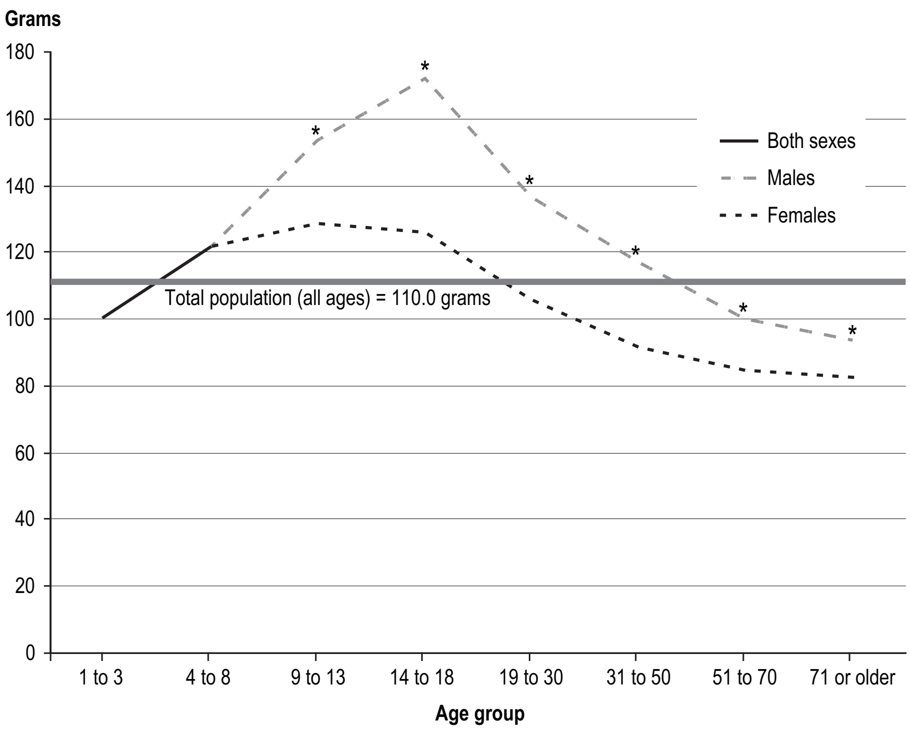
Food groups were categorized according to *Canada's Food Guide*: grain products, vegetables and fruit, meat and alternatives, milk products, and other.[12]

The top ten sources of sugar were examined. Milk included all forms of milk reported: whole, 2%, 1%, skim, evaporated, condensed, and other types of milk (soya, goat, whey, buttermilk). Fruit included citrus fruits (oranges, grapefruits, etc.), apples, bananas, cherries, grapes and raisins, melons (canteloup, honeydew, watermelon), peaches, nectarines, pears, pineapple, plums and prunes, strawberries, and other fruits (blueberries, dates, kiwis, fruit salads, dry fruit, etc.). Confectionary included candy, gum, popsicles, sherbert, jello, dessert toppings, pudding mixes, and chocolate bars. Cereals, grains and pasta included pasta, rice, cereal grains and flours, whole grain, oats, and high-fibre bread, and breakfast cereals (other). Vegetables included beans, broccoli, cabbage and kale, cauliflower, carrots, celery, corn, lettuce and leafy greens (spinach, mustard greens, etc.), mushrooms, onions, green onions, leeks, garlic, peas and snow peas, red and green peppers, squashes, tomatoes, tomato and vegetable juices, potatoes, and other vegetables (cucumber, immature beans, brussel sprouts, beets, turnips).

To account for the complex survey design, bootstrap weights were used to estimate standard errors, coefficients of variation, and confidence intervals.[13,14] T-tests were used to test differences between estimates. The significance level was set at $p < 0.05$.

This article has a number of limitations. The 2004 CCHS did not distinguish between added sugars and naturally occurring sugars. As well, sugar intake was self-reported, and so may be prone to recall bias or selective under-reporting. An earlier analysis[15] showed an almost 10% difference in total sugar intake among plausible respondents, compared with respondents who under-reported the calories they consumed. The data are seven years old (2004), but they are the most recent that are available on Canadians' sugar consumption. Data from the United States show a 10% decrease in sugar consumption from 2003/2004 to 2007/2008 among Americans.

Figure 1
Average daily sugar intake, by age group and sex, household population aged 1 or older, Canada excluding territories, 2004



* significantly different from estimate for females in same age group (p<0.05)
Source: 2004 Canadian Community Health Survey—Nutrition.

among children and adolescents (25% versus 38%) and among adults (27% versus 40%) (data not shown).

Top ten sources

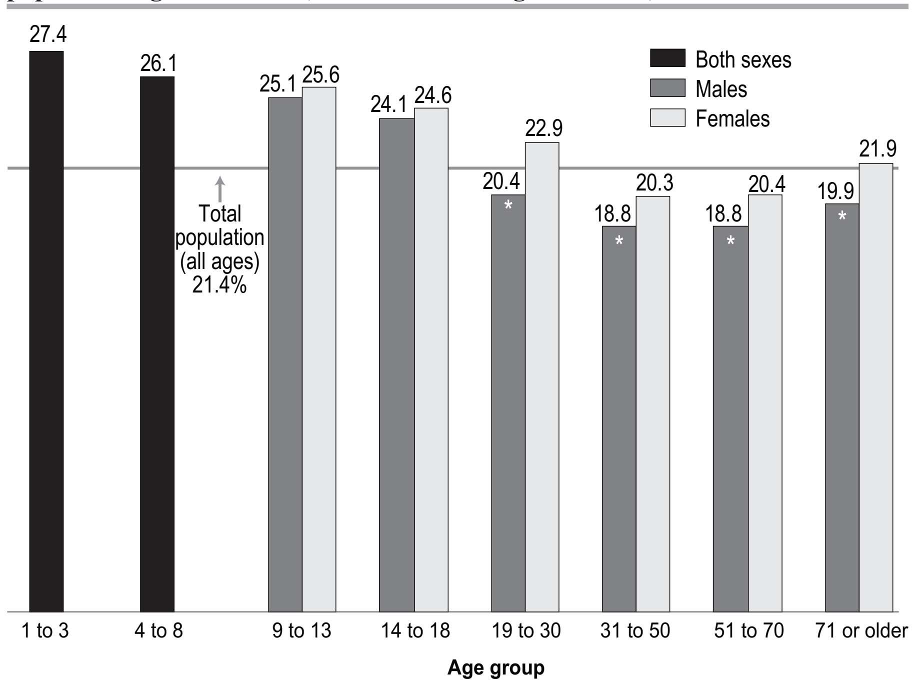
Ten sources accounted for approximately 85% of total sugar intake (Table 2). Almost half (44%) the average daily sugar intake of children and adolescents came from beverages, specifically milk (20% at ages 1 to 8; 14% at ages 9 to 18), fruit juice (15% and 9%), regular soft drinks (4% and 14%), and fruit drinks (6% and 7%). Milk was the primary source of sugar among children aged 1 to 8, but by ages 9 to 18, regular soft drinks ranked first. Beverages accounted for 35% of adults' daily sugar intake. Fruit also ranked high as a source of sugar: 15% for children and 17% for adults; apples and bananas were the most popular (data not shown). The percentage of sugar derived from confectionary items (for instance, chocolate bars, candies) was about twice as high for children (9%) and adolescents (10%) as for adults (5%).

age, males consumed more sugar from "other" foods than did females.

The percentage of total sugar intake that came from "other" foods rose from 17% at ages 1 to 3 to more than 40% at ages 14 to 18. However, among seniors aged 71 or older the percentage was 25%. The relatively low sugar intake of older adults (94 grams a day for men; 83 grams for women) was attributable to the decline in sugar from "other" foods associated with advancing age.

In fact, individuals who consumed the most sugar (above the 75th percentile in the distribution of consumption) derived more of it from the "other" foods category (and therefore, from added sugars) than from food groups that contain more naturally occurring sugars. Conversely, people who consumed the least sugar (in the 25th percentile of the distribution) got significantly less sugar from the "other" foods category than did individuals above the 75th percentile. This was true

Figure 2
Percentage of daily calories from sugar, by age group and sex, household population aged 1 or older, Canada excluding territories, 2004



* significantly different from estimate for females in same age group (p<0.05)
Source: 2004 Canadian Community Health Survey—Nutrition.

Table 1
Percentage distribution of sources of sugar intake, by food group, age group and sex, household population aged 1 or older, Canada excluding territories, 2004

	Grain products			Vegetables and fruit			Meat and alternatives			Milk products			Other foods		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
Age group and sex	%	from	to	%	from	to	%	from	to	%	from	to	%	from	to
Total	**14.2**	**13.8**	**14.6**	**31.1**	**30.5**	**31.6**	**1.3**	**1.2**	**1.3**	**17.7**	**17.3**	**18.1**	**34.7**	**34.0**	**35.4**
1 to 3	11.4	10.4	12.3	38.0	36.5	39.6	0.9	0.8	1.0	31.0	29.6	32.4	16.5	14.7	18.4
4 to 8	15.8	15.0	16.6	29.9	28.6	31.2	1.0	0.9	1.2	24.5	23.5	25.6	27.0	25.6	28.4
9 to 13															
Boys	15.9	14.7	17.0	22.8*	21.1	24.5	1.0	0.9	1.2	21.5	20.0	23.0	37.5*	35.2	39.9
Girls	14.9	13.8	16.0	27.9	26.1	29.6	0.8	0.7	1.0	20.8	19.5	22.0	34.4	32.5	36.4
14 to 18															
Boys	13.8	12.7	15.0	20.0*	18.4	21.6	1.0	0.8	1.1	18.7	17.3	20.1	45.8*	43.5	48.0
Girls	12.8	11.4	14.1	24.6	22.9	26.3	0.9	0.7	1.0	18.7	17.2	20.3	41.8	39.7	43.9
19 to 30															
Men	12.8	11.5	14.1	25.7*	23.5	27.8	1.5 *	1.3	1.8	15.5	13.9	17.1	43.2*	40.8	45.5
Women	12.5	11.1	13.9	30.4	28.0	32.9	1.2	0.9	1.4	16.8	15.4	18.2	37.8	35.1	40.5
31 to 50															
Men	14.4	13.1	15.6	29.5*	27.5	31.5	1.4	1.1	1.6	14.2*	12.9	15.4	39.8*	37.5	42.1
Women	13.4	12.0	14.7	33.2	31.2	35.2	1.3	1.1	1.5	17.8	16.5	19.1	33.6	31.1	36.0
51 to 70															
Men	15.0	13.8	16.3	37.3	35.0	39.7	1.6	1.4	1.8	14.8*	13.6	16.1	30.5*	28.6	32.4
Women	15.0	13.9	16.1	39.1	37.5	40.7	1.5	1.4	1.7	17.1	16.0	18.2	26.5	24.8	28.3
71 or older															
Men	17.6	15.6	19.6	37.6*	35.7	39.4	1.6*	1.3	1.9	17.7	15.4	20.0	24.8*	22.7	26.8
Women	16.1	14.9	17.2	42.4	40.7	44.2	1.1	0.9	1.3	18.2	17.0	19.3	21.4	20.0	22.9

* significantly different from estimate for females in same age group ($p<0.05$)
Source: 2004 Canadian Community Health Survey—Nutrition.

Table 2
Top ten sources of sugar intake, by age group, household population aged 1 or older, Canada excluding territories, 2004

Ages 1 to 8		Ages 9 to 18		Age 19 or older	
	% of total sugar intake		% of total sugar intake		% of total sugar intake
Milk	19.9	Soft drinks - regular	14.3	Fruit	17.4
Fruit	14.9	Milk	14.0	Soft drinks - regular	13.0
Fruit juice	14.6	Fruit	10.6	Sugars (white and brown)	11.4
Confectionary	8.7	Confectionary	10.3	Milk	10.7
Fruit drinks	6.2	Fruit juice	9.1	Fruit juice	7.6
Sugars (white and brown)	5.4	Fruit drinks	7.4	Vegetables	6.8
Other sugars (syrups, molasses, honey, etc)	5.3	Sugars (white and brown)	6.3	Confectionary	5.3
Cereals, grains and pasta	4.3	Other sugars (syrups, molasses, honey, etc)	5.4	Other sugars (syrups, molasses, honey, etc)	4.5
Soft drinks - regular	3.6	Cereals, grains and pasta	4.5	Fruit drinks	3.7
Vegetables	2.9	Vegetables	3.3	Cereals, grains and pasta	3.3

Source: 2004 Canadian Community Health Survey—Nutrition.

Diabetes

As part of their treatment, diabetics are advised to eat a well-balanced diet and limit their sugar intake to less than 10% of daily calories.[16] Results of the 2004 CCHS indicate that diabetics consume significantly less sugar than do non-diabetics: 73.4 versus 111.5 grams a day (Table 3). However, as a percentage of daily calories, sugar consumption among diabetics answering the survey averaged 17%, a level which exceeds the current recommendation. Even so, this was still significantly lower than non-diabetics' daily average of 21.5% of calories. As well, compared with people who did not have diagnosed diabetes, diabetics derived a larger percentage of the sugar they consumed from vegetables and fruit

Table 3
Average daily sugar intake and percentage distribution of sources of sugar, by diabetes status, household population aged 1 or older, Canada excluding territories, 2004

	Diabetes			Without diabetes		
		95% confidence interval			95% confidence interval	
	Estimate	from	to	Estimate	from	to
Average total sugar intake (grams)	**73.4***	**69.4**	**77.4**	**111.5**	**109.9**	**113.1**
% of calories	**17.0***	**16.2**	**17.8**	**21.5**	**21.3**	**21.8**
Distribution by food group	%			%		
Grain products	16.0*	14.4	17.5	14.2	13.8	14.6
Vegetables and fruit	40.2*	37.6	42.8	30.8	30.5	31.4
Meat and alternatives	1.9*	1.6	2.3	1.3	1.2	1.3
Milk products	20.0*	18.3	21.7	17.7	17.4	18.1
Other foods	21.1*	18.5	23.7	35.1	33.9	35.8

* significantly different from estimate for those without diabetes ($p<0.05$)
Source: 2004 Canadian Community Health Survey—Nutrition.

(40% versus 31%), milk (20% versus 18%) and grains (16% versus 14%), and a much lower percentage from the "other" foods category (21% versus 35%).

Conclusion

The sugar that Canadians consume accounts for 21% of their daily calories. While 31% of this sugar comes from vegetables and fruit, a higher percentage—35%—comes from "other" foods. Beverages are among the top sources of sugar. Diabetics consume significantly less sugar than do non-diabetics, but their average consumption exceeds the recommended level. ■

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Self-reported pH1N1 influenza vaccination coverage for Ontario

by Julie Foisy, Laura C. Rosella, Ruth Sanderson, Jemila Seid Hamid, Badal Dhar and Natasha S. Crowcroft

Abstract

Background

In the fall of 2009, Canada undertook a mass vaccination campaign against pH1N1. This report provides an overview of self-reported pH1N1 vaccination coverage of the Ontario population, building on an existing random digit-dialling telephone survey, in which 9,010 Ontario adults participated. Based on the results, 34.5% of Ontario residents were vaccinated: 33.3% of adults aged 18 or older and 38.6% of children and adolescents younger than age 18. Respondents reporting high-risk chronic conditions were significantly more likely to report being vaccinated than were people who did not report such conditions. Determining vaccination uptake for the Ontario population is important in the evaluation of the province's pH1N1 prevention program.

Keywords

immunization, influenza A virus H1N1 subtype, preventive health services, population-based health planning

Authors

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The mass vaccination campaign against pH1N1 that Canada undertook in the fall of 2009 was the largest ever conducted in the country. The vaccine became available to Ontario residents October 26, and by December 6, the province had distributed enough doses to cover 81% of the population.[1] Because the vaccine was delivered through public health units, several methods were used to document coverage, making an overall Ontario estimate challenging to compute. This report, based on an existing random digit-dialling telephone survey, provides an overview of self-reported pH1N1 vaccination uptake for Ontario (see *The data*).

One in three

Based on the results of the Rapid Risk Factor Surveillance System (RRFSS) survey, pH1N1 vaccination coverage for Ontario from the end of October 2009 to the end of April 2010 was 34.5% overall: 33.3% for adults aged 18 or older, and 38.6% for children and adolescents younger than age 18 (Table 1). Sensitivity analyses that excluded respondents missing age information yielded almost the same percentages: 34.4% overall, 33.0% for adults, and 38.5% for children and adolescents.

These results are broadly in line with estimates in two earlier reports. The Chief Medical Officer of Health's report, released in June 2010, used data from a weekly Ipsos Reid poll conducted from October 2009 to mid-January 2010 to determine pH1N1 vaccination coverage. According to this poll, approximately 39% of Ontarians had been vaccinated,[2] somewhat above the estimate in the current analysis.

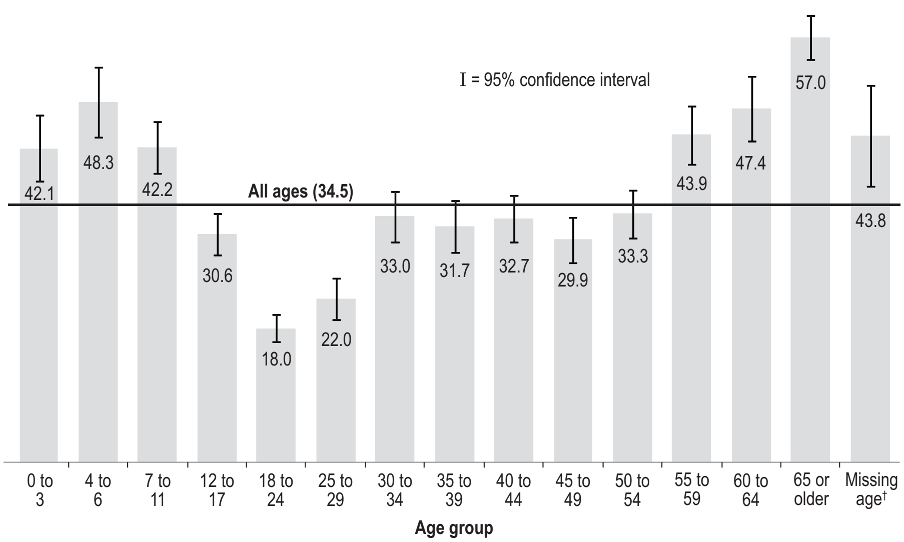
Based on data from the RRFSS survey, 33% of Ontario residents aged 12 or older received the pH1N1 vaccine. For the same age group and the same

Table 1
Percentage vaccinated against pH1N1, by selected characteristics, household population, Ontario, October 2009 through April 2010

Characteristic	Sample size	Weighted %	95% confidence interval from	to
Total	**11,720**	**34.5**	**33.7**	**35.4**
Age group				
0 to 17	2,791	38.6	36.8	40.4
18 or older	8,929	33.3	32.3	34.3
Sex				
Male	3,675	30.9	29.5	32.3
Female	5,254	35.7	34.3	37.1
High-risk chronic condition				
Yes	2,286	45.4	43.1	47.7
No	6,643	30.2	29.2	31.3
Adults with children in household				
Yes	2,853	35.2	34.0	36.4
No	6,063	33.8	32.5	35.0

Source: Ontario Rapid Risk Surveillance System, January through May 2010.

Figure 1
Percentage vaccinated against pH1N1, by age group, household population, Ontario, October 2009 through April 2010



† 19 children, 208 adults
Source: Ontario Rapid Risk Surveillance System, January through May 2010.

interview period (January through April 2010), the Canadian Community Health Survey reported 32.2%.[3]

The vaccination status of adults living in households with at least one child (35.2%) did not differ significantly from that of adults in households with no children (33.8%).

Youngest and oldest

The percentage of individuals vaccinated varied by age, with the highest levels at the extreme ends of the age range (Figure 1). Fully 57% of seniors aged 65 or older were vaccinated, as were more than 40% of adults aged 55 to 64 and children aged 0 to 11. By contrast, around 20% of adults aged 18 to 29 reported having been vaccinated.

Higher percentage of women

Overall, a significantly higher percentage of women than men aged 18 or older were vaccinated (35.7% versus 30.9%; $p<0.0001$), a pattern that prevailed in most age groups (Table 2). At ages 40 to 44, the difference (39.0% versus 26.0%) was statistically significant.

Chronic conditions

One in five (20.3%) adults aged 18 or older reported a chronic condition that, according to the National Advisory Committee on Immunizations,[4] put them at high risk of complications from pH1N1 infection. These people were significantly more likely than those without a high-risk chronic condition to have been vaccinated: 45.4% versus 30.2%. While women were generally more likely than men to have been vaccinated, for those with high-risk chronic conditions, the percentages were almost the same (Table 2).

November peak

The pH1N1 vaccine was available to Ontario residents from October 26, with nearly 23% of people who were vaccinated receiving their shot in the first week of the campaign. Almost 44% of vaccinated Ontarians received their vaccination in November (Figure 2).

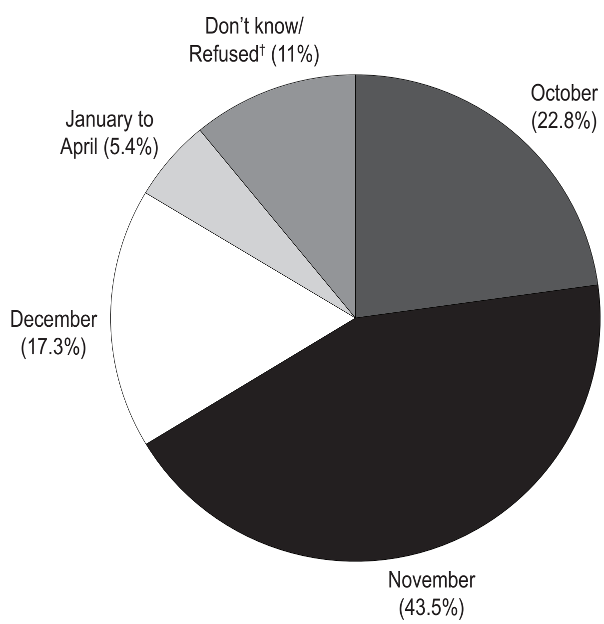
In December, a further 17.3% of vaccinated people received the pH1N1 vaccine. A number of factors may have contributed to the decline observed in December. For example, by the time priority was extended to include the general population (in December), many may have felt that obtaining the vaccination was not necessary. Results from a study in Australia showed that a high percentage of people were not vaccinated for this reason.[5] In the January to April 2010 period, 5.4% of

Table 2
Percentage vaccinated against pH1N1, by sex, age group and chronic condition, household population aged 18 or older, Ontario, October 2009 through April 2010

	Men			Women		
		95% confidence interval			95% confidence interval	
	%	from	to	%	from	to
Age group						
18 to 24	16.8	14.3	19.2	19.3	16.6	21.9
25 to 29	18.2	14.6	21.8	25.9	21.7	30.2
30 to 34	28.9	24.3	33.5	37.3	32.4	42.2
35 to 39	27.0	22.2	31.9	35.9	31.0	40.8
40 to 44	26.0	21.7	30.2	39.0	34.4	43.6
45 to 49	29.4	25.0	33.8	30.4	26.2	34.6
50 to 54	33.4	28.8	37.9	33.2	28.6	37.8
55 to 59	39.5	34.2	44.8	48.5	42.9	54.2
60 to 64	45.7	39.8	51.6	49.5	42.9	56.1
65 or older	59.2	55.0	63.5	54.9	50.8	59.1
Missing†	35.1	24.3	46.0	49.3	40.8	57.7
High-risk chronic condition						
Yes	45.5	42.1	48.8	45.3	42.2	48.5
No	27.4	25.9	28.8	33.1	31.6	34.7

† n=208
Source: Ontario Rapid Risk Surveillance System, January through May 2010.

Figure 2
Percentage vaccinated against pH1N1, by month, household population, Ontario, October 2009 through April 2010



† n=426
Source: Ontario Rapid Risk Surveillance System, January through May 2010.

those who received the pH1N1 vaccine had their shot.

Conclusion

Estimates of vaccination coverage are important in the evaluation of Ontario's pH1N1 prevention program. Identifying the extent of coverage offers important information on the potential burden of future waves of pH1N1. Individuals at highest risk of complications from pH1N1[6]—young children, the elderly and those with chronic conditions—had high rates of vaccination. This suggests that a large number of Ontario residents who were at highest risk were protected as a result of having been vaccinated. ■

Acknowledgements

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The data

Data were collected using Ontario's Rapid Risk Factor Surveillance System (RRFSS) infrastructure. RRFSS is an ongoing, random digit-dialing telephone survey of the adult population in private households in 18 of the province's 36 health regions. RRFSS gathers surveillance data, monitors public opinion on key public health issues, and collects information on emerging issues of importance to public health in Ontario. More information about RRFSS can be found at www.rrfss.ca.

The 18 health units that regularly participate in RRFSS each obtain information from approximately 400 households for every four-month data collection cycle; surveys are conducted by the Institute for Social Research at York University. For this study of pH1N1 vaccination uptake, Public Health Ontario funded an augmentation of the sample to include households in the 18 health units not usually involved in RRFSS.

A two-stage stratified cluster sampling design was used, with households as the first stage and household members as the second. In the first stage, telephone numbers of private households were chosen from telephone books and commercially available compiled lists.[7] The sample included numbers on either side of those that were selected, thereby ensuring that numbers that were not "listed" would be included. This made it possible to access cellphones as well as land lines. Residents of long-term care facilities, penitentiaries and other institutions were not included. In the second stage, an adult in the selected household was chosen. In households with more than one adult, the person whose birthday came next was selected. If children younger than 18 lived in the household, the adult respondent answered questions about the child with the next birthday. Interviews were conducted from January 14 through May 4, 2010.

Respondents were asked, "Since October 2009, have you received the H1N1 flu shot?" Those who reported having had a flu shot were asked, "In what month was that?" For children and adolescents younger than 18, the same questions were asked of the adults responding on their behalf. Respondents were asked if a doctor or other health care professional had ever told them they had any of the following disorders: high blood pressure, asthma, diabetes, or any other chronic disease including but not limited to heart disease, cancer or thyroid disorder. Those who reported having been diagnosed with asthma, diabetes, cancer, heart, lung or kidney disease or an immune or blood disorder were classified as having a *high-risk chronic disease.*[4]

A total of 9,010 adults participated in the survey (participation rate= 57.7%). Those whose vaccination month was incompatible with the month in which they were interviewed were dropped (n=36; 0.4%), as were those with a refused/don't know response (n=45; 0.5%) to the vaccination question. In total, 8,929 adults were retained for analysis.

As well, 2,867 adults who were interviewed lived in a household with at least one child. Of these, 11 (0.4%) reported a vaccination date for the child incompatible with their interview month, and 65 (2.3%) were not aware of or refused to provide information about the child's vaccination status. Consequently, 2,791 children and adolescents younger than age 18 were retained for analysis.

Results for people aged 18 or older were weighted to account for the number of adults in the household and the population in each health unit area, and were then post-stratified by the age and sex distribution of the 2009 Ontario population. Adult weights were normalized to maintain the effective sample size and incorporated into all analyses. Weights could not be calculated for respondents missing age information (n=208); they were assigned a weight of 1 and included in the final analysis. A sensitivity analysis removing individuals with missing age was also conducted. Results for children and adolescents younger than 18 were weighted to account for the number of children in the household. Those missing the number of children in the household (n=7) were assigned a weight of 1 and included in the final analysis. Sensitivity analyses were also conducted. Analyses were carried out using SAS Statistical Software (Version 9.2, Cary, NC) and PASW Statistics 18, Release 18.0.0 (SPSS Inc., Chicago, IL). All analyses were weighted, and two-sided 95% confidence intervals were calculated using normal approximation.

The relatively high participation rate and the small percentage excluded because of incomplete responses on the outcome variable tend to increase confidence in the results. Nonetheless, vaccine uptake may have been underestimated. Respondents might have been in the process of obtaining a pH1N1 vaccination while the interviews were being conducted. However, the majority of Ontario's mass vaccination clinics were closed in December.[8] While the possibility of recall bias exists, the novel nature of the immunization campaign and the media attention it received suggest that the risk of recall bias is minimal. Age was reported in years, so for children younger than 1 year of age, it is not clear if the child was more than 6 months old and unvaccinated, or under 6 months and not eligible. The small number (n=126) to whom this possibility applied minimizes this limitation. Because the survey was self-reported, the possibility of misclassification of vaccine status cannot be ruled out. Finally, by definition, a telephone survey excludes people without telephones, such as those who are homeless or live in remote areas. Statistics Canada estimates that 0.9% of Canadian households do not have telephone service.[9]

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Bias in self-reported estimates of obesity in Canadian health surveys: An update on correction equations for adults

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

Abstract

Background
This study compares the bias in self-reported height, weight and body mass index (BMI) in the 2008 and 2005 Canadian Community Health Surveys and the 2007 to 2009 Canadian Health Measures Survey. The feasibility of using correction equations to adjust self-reported 2008 Canadian Community Health Survey values to more closely approximate measured values is assessed.

Data and methods
Data are from the 2008 and 2005 Canadian Community Health Surveys and the 2007 to 2009 Canadian Health Measures Survey. In these surveys, respondents reported their height and weight, and were subsequently measured. Regression equations based on the 2007 to 2009 Canadian Health Measures Survey and the 2005 Canadian Community Health Survey were applied to self-reported 2008 Canadian Community Health Survey data. These equations predicted measured BMI based on self-reported BMI.

Results
The bias in reporting height was similar across all three surveys, but the bias in reporting weight was larger in the two Canadian Community Health Surveys, and as a result, discrepancies in estimates of obesity between self-reported and measured values were greater. Application of correction equations based on 2005 Canadian Community Health Survey data to self-reported values in the 2008 Canadian Community Health Survey produced more accurate estimates of obesity than did equations based on Canadian Health Measures Survey data.

Interpretation
Survey context may influence the magnitude of the bias in self-reported weight. Respondents who are aware that they will be weighed may report their weight more accurately. Additional data points are required to determine whether the bias in self-reported measures in the Canadian Community Health Survey is changing.

Keywords
Body mass index, direct measure, measurement error, misclassification, prevalence, sensitivity, specificity

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The health consequences of excess body weight have made obesity a public health challenge throughout the world.[1] Accurate monitoring of the prevalence of obesity is critical in the assessment of intervention programs.

Obesity prevalence estimates are commonly based on body mass index (BMI), a measure of weight in relation to height. Each year, Statistics Canada's Canadian Community Health Survey collects self-reported height and weight data from respondents in order to monitor obesity trends at the national, provincial and health region levels. However, self-reports overestimate height and underestimate weight.[2,3] Consequently, the prevalence of obesity based on self-reported data is underestimated. Moreover, the magnitude of the bias has increased over time.[4]

Another problem with using self-reported data is that the relationship between obesity and obesity-related diseases is distorted. The misclassification that occurs when BMI categories are based on self-reported height and weight results in elevated associations between obesity and diseases such as hypertension and diabetes,[5-7] and in underestimates of the health care burden of these conditions.[7]

In 2005, the Canadian Community Health Survey collected both self-reported and measured height and weight for a subsample of respondents. Data for this subsample were used to develop correction equations to apply to the self-reported data to produce obesity prevalence estimates that approximated those derived from measured data.[8]

Statistics Canada planned to periodically collect both measured and self-reported height and weight from a subsample of Canadian Community Health Survey respondents to monitor the magnitude of the bias and adjust the correction equations. Such data were, in fact, collected in 2008. But around the same time, in partnership with Health Canada and the Public Health Agency of Canada, Statistics Canada launched the Canadian Health Measures Survey,[9] which collected both self-reported and measured height and weight. Because this survey will be conducted every two years, a decision was made to drop the direct measurement component from the Canadian Community Health Survey and use the Community Health Measures Survey to correct for biases in the self-reported Canadian Community Health Survey data. However, the context and methods of the two surveys differ: before respondents to the Canadian Health Measures Survey report their height and weight, they are informed that they will later be measured; Canadian Community Health Survey respondents do not know this. Thus, the bias in height, weight, BMI, and consequently, the prevalence of obesity may differ between the two data sources and possibly preclude the use of Canadian Health Measures Survey data to establish correction equations for the Canadian Community Health Survey.

The purpose of this study was to address the following questions:

1. Does the bias in height, weight and BMI differ depending on the context of the survey?
2. Does the bias vary over time (2005 versus 2008 Canadian Community Health Survey)?
3. Can correction equations be successfully applied to the self-reported 2008 Canadian Community Health Survey data:
   - established with 2007 to 2009 Canadian Health Measures Survey data?
   - established with 2005 Canadian Community Health Survey data?

Methods

Data sources

Data for this study were from the 2008 and 2005 Canadian Community Health Surveys and the 2007 to 2009 Canadian Health Measures Survey.

The Canadian Community Health Survey is an ongoing survey designed to provide cross-sectional estimates of health determinants, health status and health system use at a subprovincial level.[10] The survey covers the non-institutional household population aged 12 or older in all provinces and territories, except members of the regular Canadian Forces and residents of Indian reserves, Canadian Forces bases (military and civilian), and some remote areas. It is representative of 98% of the population.

In both 2008 and 2005, a subsample of respondents was selected in the ten provinces (the territories were excluded) for direct measurement. The subsamples were randomly selected from the Canadian Community Health Survey area frame for which all interviews were conducted in person in the respondent's home. These respondents were asked their height and weight, and later in the interview, their height and weight were measured. Before they self-reported their height and weight, they had not been told that their measurements would be taken. In 2008, the response rate to the subsample was 85.0% at the household level and 59.7% for the direct measurement component, for an overall response rate of 50.7%. In 2005, the response rate to the subsample was 87.0% at the household level and 64.2% for the direct measurement component, for an overall response rate of 55.9%.

Data for the Canadian Health Measures Survey were collected at 15 sites across Canada from March 2007 through February 2009. The survey covered the household population aged 6 to 79. Residents of Indian Reserves or Crown lands, institutions and certain remote regions, and full-time members of the Canadian Forces were excluded; 96.3% of Canadians were represented. Technical details of the sample design can be found in a published report.[11] In addition to a detailed questionnaire administered in the respondent's home, the survey involved physical measures (including height and weight) at a mobile examination centre one day to six weeks after the home interview. In the introduction to the home interview (before the questions on height and weight were asked), respondents were told that measurements would be taken ("... the second part of the survey involves a visit to a clinic to collect direct physical measures such as blood pressure, height and weight, and fitness levels").[12] The household response rate was 69.6%—that is, in 69.6% of selected households, the sex and date of birth of all household members were provided by a household resident. In each responding household, one or two members were chosen to participate in the survey; 88.3% of selected respondents completed the household questionnaire, and 84.9% of those who completed the questionnaire participated in the subsequent examination centre component. The overall response rate was 51.7%. Because two people were selected in some households, the overall response rate is not the result of multiplying the household and person response rates.[13]

Measures and definitions

This study is based on adults aged 18 to 79 for whom both measured and self-reported values of height and weight were collected. Pregnant women were excluded. Sample sizes for the Canadian Community Health Survey are 3,876 for 2008 and 3,895 for 2005. The sample size for the Canadian Health Measure Survey is 3,625.

In each survey, self-reported height and weight were collected in the respondent's home with the questions:

- "How tall are you without shoes on?" Categories for height in feet and inches were listed on the questionnaire, with corresponding metric values in brackets.
- "How much do you weigh?" After reporting weight, respondents were asked if they had reported in pounds or kilograms; more than 90% reported in pounds.

The Canadian Community Health Survey interview lasted about 50 minutes. Self-reported height and weight were collected close to the beginning, and the measurements were taken near the end. Interviewers were trained to measure height and weight. Height (without shoes) was measured to the nearest 0.5 cm with a measuring tape attached to a wall. Weight was measured to the nearest 0.1 kg with a calibrated digital scale (ProFit UC-321 made by Lifesource).

In the Canadian Health Measures Survey, the measures were taken at a mobile examination centre by specialists with a degree in kinesiology and certification from the Canadian Society for Exercise Physiology as either a Certified Exercise Physiologist or Certified Personal Trainer. Height was measured to the nearest 0.1 cm using a ProScale M150 digital stadiometer (Accurate Technology Inc., Fletcher, USA), and weight, to the nearest 0.1 kg with a Mettler Toledo VLC with Panther Plus terminal scale (Mettler Toledo Canada, Mississauga, Canada). Equipment was calibrated regularly.

Body mass index (BMI) is a measure of weight adjusted for height. BMI is calculated by dividing weight in kilograms by the square of height in metres. "Measured BMI" refers to BMI calculated from measured height and weight, and "self-reported BMI," to BMI calculated from self-reported height and weight. Corrected BMI values were derived from correction equations applied to self-reported values. Based on Canadian guidelines,[14] which are in line with those of the World Health Organization,[15] respondents were categorized as *underweight* (BMI less than 18.5 kg/m^2), *normal weight* (BMI 18.5 to 24.9 kg/m^2), *overweight* (BMI 25.0 to 29.9 kg/m^2), or *obese* (BMI 30.0 kg/m^2 or more).

Analytical techniques

The bias associated with using self-reported data for weight, height and BMI was estimated by calculating the difference between self-reported and measured values (self-reported minus measured). A negative difference indicates under-reporting, and a positive difference, over-reporting.

The degree of misclassification that resulted from using self-reports to assign respondents to BMI categories was assessed by calculating sensitivity and specificity. Sensitivity is the percentage of true positives (the percentage of obese, overweight, normal weight or underweight individuals, based on measured values, who were appropriately classified as such based on self-reported values). Specificity is the percentage of true negatives (the percentage of non-obese, non-overweight, non-normal weight, or non-underweight individuals correctly classified as such based on self-reported values).

Previously established correction equations derived from the 2005 Canadian Community Health Survey data[8] were applied to 2008 Canadian Community Health Survey self-reported values. The original study tested four models:

- Model 1 (*Height and Weight Full*): Measured height and weight were predicted based on self-reported values along with factors significantly associated with the bias in height and weight. BMI was calculated using these corrected values of height and weight.
- Model 2 (*BMI Full*): Measured BMI was predicted based on self-reported BMI as well as factors significantly associated with the bias in BMI.
- Model 3 (*Height and Weight Reduced*): Measured height and weight were predicted based solely on the self-reported values, and BMI was calculated using these corrected values of height and weight.
- Model 4 (*BMI Reduced*): Measured BMI was predicted based solely on self-reported BMI.

The variables considered in relation to the bias in height, weight and BMI in the full models were determined from a review of the literature and availability in the survey: age group, education, employment status, immigrant status, race/ethnicity, household income, self-perceived general health, self-perceived mental health, chronic conditions (arthritis, hypertension, diabetes, heart disease, cancer and mood disorders), perceived stress, satisfaction with life, smoking status, perception of weight, leisure-time physical activity level, and end-digit preference.

All analyses were run separately for men and women. Interactions and quadratic terms (including a quadratic term for BMI) were tested. The four models were assessed by comparing corrected means for BMI, prevalence rates by BMI category, and sensitivity and specificity values. As no model was consistently superior, the model based solely on self-reported BMI (*BMI reduced*) was recommended because it was the most parsimonious.[8]

For the current study, the methods used to generate the correction equations in the earlier study were replicated using 2007 to 2009 Canadian Health Measures Survey data. The equations were then applied to self-reported values from the 2008 Canadian Community Health Survey. As in the earlier study, the results for the four models were similar, and therefore, only the results of the *BMI reduced* models are presented here. Thus, the current study evaluates the feasibility of correcting self-reported BMI values in the 2008 Canadian Community Health Survey using two *BMI reduced* models: one applying equations based on the *BMI reduced* model from the 2005 Canadian Community Health Survey data, and the other applying equations based on the *BMI reduced* model from the 2007 to 2009 Canadian Health Measures Survey data (Appendix Table A).

Corrected prevalence estimates of BMI categories for the 2008 Canadian Community Health Survey were produced based on the two models to see how closely they approximated estimates based on measured values. Sensitivity and specificity estimates based on corrected values were generated for each model.

Correction equations were also developed based on half the 2008 Canadian Community Health Survey sample and then applied to the other half (similar to the approach in the earlier study). The results were similar to what was observed when the 2005 correction equations were applied to the 2008 Canadian Community Health Survey data (data not shown).

Data for all surveys were weighted, and all measures of variance were estimated with the bootstrap technique[16,17] to account for the complex survey designs. For the Canadian Health Measures Survey, the number of degrees of freedom was specified as 11. SAS (version 9.1) and SUDAAN (version 10) were used for all analyses.

Results

For both sexes in each survey, height was over-reported, and weight, under-reported (Table 1). As a result, mean BMI and the prevalence of obesity were higher when based on measured than on self-reported data.

The magnitude of the bias in height was similar in each survey. This was not true for weight. In the 2008 Canadian Community Health Survey, weight was under-reported by an average of 2.2 kg among men, and by 2.7 kg among women. Results had been similar in 2005, with men under-reporting by an average of 1.9 kg, and women, 2.8 kg. In the 2007 to 2009 Canadian Health Measures Survey, weight was under-reported to a lesser degree—0.6 kg among men and 1.6 kg among women. Consequently, the bias in the prevalence of obesity was approximately twice as high in the two Canadian Community Health Surveys as in the Canadian Health Measures Survey (Table 1).

Sensitivity and specificity values were similar for the two Canadian Community Health Surveys (Table 2). In the Canadian Health Measures Survey, sensitivity values were higher for overweight and obese men and obese women than in the 2008 Canadian Community Health Survey. Specificity for normal-weight men and women was higher in the Canadian Health Measures Survey than in the 2005 and 2008 Canadian Community Health Surveys.

Corrections were made to the self-reported BMI values in the 2008 Canadian Community Health Survey based on two sets of regression equations (one generated from the 2005 Canadian Community Health Survey, and the other from the Canadian Health Measures Survey) (see *Methods* and Appendix Table A).

In the 2008 Canadian Community Health Survey, based on self-reported height and weight, BMI was underestimated by 1.2 kg/m^2 for men

Table 1
Mean height, weight, body mass index (BMI) and prevalence of obesity, by collection method and sex, household population aged 18 to 79, Canada, 2008, 2007 to 2009, and 2005

	Self-reported			Measured			Bias		
		95% confidence interval			95% confidence interval		Self-reported minus measured	95% confidence interval	
	Estimate	from	to	Estimate	from	to		from	to
2008 Canadian Community Health Survey									
Men									
Mean height (cm)	175.8*	175.3	176.3	174.6	174.1	175.1	1.2	0.9	1.5
Mean weight (kg)	81.6*	80.7	82.5	83.8	82.8	84.7	-2.2	-2.4	-1.9
Mean BMI (kg/m^2)	26.4*	26.1	26.6	27.5	27.2	27.9	-1.2	-1.4	-1.0
% obese (BMI 30.0 kg/m^2 or more)	18.5*	16.0	21.2	26.1	23.4	28.9	-7.6	-9.5	-5.7
Women									
Mean height (cm)	162.1*	161.7	162.5	161.2	160.7	161.6	0.9	0.6	1.2
Mean weight (kg)	66.8*	66.0	67.7	69.5	68.6	70.4	-2.7	-2.9	-2.4
Mean BMI (kg/m^2)	25.4*	25.1	25.7	26.9	26.5	27.3	-1.5	-1.7	-1.2
% obese (BMI 30.0 kg/m^2 or more)	16.1*	14.2	18.2	23.3	20.8	25.9	-7.2	-9.2	-5.2
2007 to 2009 Canadian Health Measures Survey									
Men									
Mean height (cm)	176.4*	175.5	177.2	175.1	174.4	175.9	1.2	1.0	1.4
Mean weight (kg)	83.9*	82.2	85.7	84.6	82.8	86.4	-0.6†	-0.9	-0.3
Mean BMI (kg/m^2)	26.9*	26.6	27.3	27.5	27.1	27.9	-0.6†	-0.7	-0.5
% obese (BMI 30.0 kg/m^2 or more)	21.2*	17.5	25.4	24.2	20.6	28.2	-3.0†	-5.7	-0.3
Women									
Mean height (cm)	163.1*	162.7	163.6	162.3	161.9	162.8	0.8	0.6	1.0
Mean weight (kg)	68.4*	66.4	70.5	70.1	68.1	72.1	-1.6†	-1.9	-1.4
Mean BMI (kg/m^2)	25.8*	25.0	26.5	26.6	25.9	27.4	-0.9†	-1.0	-0.7
% obese (BMI 30.0 kg/m^2 or more)	18.8*	15.4	22.8	23.2	19.3	27.6	-4.4†	-6.5	-2.2
2005 Canadian Community Health Survey									
Men									
Mean height (cm)	176.4*	176.0	176.9	175.3	174.7	175.8	1.1	0.8	1.5
Mean weight (kg)	82.0*	81.0	83.0	83.9	82.8	84.9	-1.9	-2.2	-1.6
Mean BMI (kg/m^2)	26.3*	26.0	26.6	27.3	27.0	27.7	-1.0	-1.2	-0.8
% obese (BMI 30.0 kg/m^2 or more)	16.7*	14.0	19.9	26.2	23.1	29.4	-9.4	-11.9	-7.0
Women									
Mean height (cm)	162.6*	162.1	163.1	162.1	161.5	162.6	0.6	0.3	0.8
Mean weight (kg)	66.6*	65.5	67.6	69.4	68.2	70.5	-2.8	-3.1	-2.4
Mean BMI (kg/m^2)	25.2*	24.8	25.6	26.5	26.0	26.9	-1.3	-1.5	-1.1
% obese (BMI 30.0 kg/m^2 or more)	16.0*	13.7	18.6	23.0	20.3	25.9	-7.0	-8.7	-5.3

* significantly different from estimate for measured ($p < 0.05$)
† significantly different from corresponding estimate for 2008 Canadian Community Health Survey ($p < 0.05$)
Sources: 2008 Canadian Community Health Survey (subsample); 2007 to 2009 Canadian Health Measures Survey; 2005 Canadian Community Health Survey (subsample 2).

and by 1.5 kg/m^2 for women (Table 3). Application of the corrections based on the Canadian Health Measures Survey model reduced the bias to 0.6 kg/m^2 for men and to 0.7 kg/m^2 for women. Use of the 2005 Canadian Community Health Survey correction equations further decreased the bias—to 0.2 kg/m^2 for men and to 0.3 kg/m^2 for women (Table 3). Although both models reduced the BMI bias, means based on corrected values remained significantly lower than means based on measured values.

For both sexes, percentage distributions by BMI category differed significantly when based on self-reported versus measured values (Table 4). The correction equations yielded distributions closer to those based on measured values. However, for the distributions based on the Canadian Health Measures

Table 2
Sensitivity and specificity values for self-reported data, by sex, household population aged 18 to 79, Canada, 2008, 2007 to 2009, and 2005

	2008 Canadian Community Health Survey			2007 to 2009 Canadian Health Measures Survey			2005 Canadian Community Health Survey		
		95% confidence interval			95% confidence interval			95% confidence interval	
	%	from	to	%	from	to	%	from	to
Sensitivity (% true positives)									
Men									
Underweight	58.7	29.0	83.1	75.3	39.2	93.5	38.8	14.7	70.1
Normal weight	90.6	85.5	94.0	90.1	85.6	93.3	94.0	91.3	96.0
Overweight	69.7	65.2	73.8	78.8*	72.8	83.8	71.3	66.0	76.1
Obese	67.4	61.1	73.1	78.9*	69.6	85.9	58.9	51.7	65.8
Women									
Underweight	73.0	58.0	84.2	69.1	38.3	88.9	77.0	58.6	88.8
Normal weight	93.6	90.8	95.6	94.7	92.4	96.3	91.7	88.1	94.2
Overweight	68.4	63.4	73.1	74.3	68.9	79.0	63.7	57.5	69.4
Obese	65.2	58.4	71.5	77.9*	68.4	85.2	67.4	60.7	73.5
Specificity (% true negatives)									
Men									
Underweight	99.7	99.2	99.9	99.8	99.3	100.0	99.6	99.3	99.8
Normal weight	81.6	78.6	84.3	89.1*	84.2	92.6	83.5	80.1	86.4
Overweight	81.5	77.6	84.8	85.8	80.2	90.0	79.7	76.0	83.0
Obese	98.8	97.5	99.4	97.2	95.5	98.3	98.2	96.0	99.2
Women									
Underweight	97.8	96.6	98.6	98.6	97.6	99.2	97.8	96.8	98.4
Normal weight	81.6	78.7	84.3	86.3*	83.5	88.7	79.0	75.0	82.5
Overweight	88.4	85.4	90.9	91.4	87.9	93.9	88.5	85.8	90.8
Obese	98.8	98.0	99.3	99.0	97.2	99.6	99.4	98.9	99.6

* significantly different from estimate for 2008 Canadian Community Health Survey ($p < 0.05$)
Sources: 2008 Canadian Community Health Survey (subsample); 2007 to 2009 Canadian Health Measures Survey; 2005 Canadian Community Health Survey (subsample 2).

Survey correction equations, significant differences remained.

Among men, the prevalence of obesity in the 2008 Canadian Community Health Survey was 26.1% based on measured values, and 18.5% based on self-reported values. When the self-reported values were corrected using the Canadian Health Measures Survey correction equation, the prevalence of obesity was 22.0% (Table 4), significantly below the measured value. By contrast, the prevalence of obesity based on the 2005 Canadian Community Health Survey correction equation—24.9%—was not statistically different from the measured estimate.

Results were similar for women. In the 2008 Canadian Community Health Survey, the prevalence of obesity among women was 23.3% based on measured values and 16.1% based on self-reported values; using the 2005 correction equation, the corrected self-reported estimate was 22.8%, which was not statistically different from the measured estimate. Although the Canadian Health Measures Survey correction equation improved the estimate based on self-reported values, it remained significantly below the measured estimate.

Table 3
Mean body mass index (BMI) for self-reported, measured and corrected data, by sex, household population aged 18 to 79, Canada, 2008

	Self-reported				Measured	Corrected: Based on 2007 to 2009 Canadian Health Measures Survey				Corrected: Based on 2005 Canadian Community Health Survey			
			95% confidence interval					95% confidence interval				95% confidence interval	
	Mean	Bias	from	to	Mean	Mean	Bias	from	to	Mean	Bias	from	to
Men	26.4*	-1.2	-1.4	-1.0	27.5	26.9*	-0.6	-0.8	-0.4	27.3*	-0.2	-0.4	0.0
Women	25.4*	-1.5	-1.7	-1.2	26.9	26.2*	-0.7	-0.9	-0.5	26.6*	-0.3	-0.5	-0.1

* significantly different from measured estimate ($p < 0.05$)
Note: The bias is the mean of the difference between the self-reported/corrected value and the measured value.
Source: 2008 Canadian Community Health Survey (subsample).

Table 4
Percentage distribution of population, by body mass index (BMI) category and sex, based on self-reported, measured and corrected data, household population aged 18 to 79, Canada, 2008

	Self-reported			Measured			Corrected: Based on 2007 to 2009 Canadian Health Measures Survey			Corrected: Based on 2005 Canadian Community Health Survey		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
BMI category	%	from	to	%	from	to	%	from	to	%	from	to
Men												
Underweight	1.2[E]	0.7	2.0	1.4[E]	0.8	2.6	1.1[E]	0.6	1.9	1.1[E]	0.6	1.9
Normal weight	40.2*	37.2	43.4	30.3	27.4	33.4	33.1*	30.1	36.3	32.1	29.1	35.2
Overweight	40.1	36.9	43.4	42.2	39.2	45.3	43.8	40.5	47.2	42.0	38.8	45.1
Obese	18.5*	16.0	21.2	26.1	23.4	28.9	22.0*	19.4	24.8	24.9	22.3	27.7
p-value Chi-squared test†	*p=0.00*						*p=0.00*			*p=0.20*		
Women												
Underweight	4.0*	3.0	5.5	2.6[E]	1.8	3.7	2.9[E]	2.0	4.3	1.9[E]	1.2	3.1
Normal weight	50.3*	47.3	53.3	42.4	39.3	45.6	44.4*	41.3	47.6	41.8	38.7	45.0
Overweight	29.6	26.7	32.7	31.7	28.8	34.8	33.3	30.2	36.4	33.5	30.5	36.7
Obese	16.1*	14.2	18.2	23.3	20.8	25.9	19.4*	17.2	21.8	22.8	20.4	25.3
p-value Chi-squared test†	*p=0.00*						*p=0.00*			*p=0.27*		

* significantly different from measured estimate ($p < 0.05$)
† result of Chi-squared test comparing self-reported/corrected BMI distribution with measured distribution
E use with caution
Source: 2008 Canadian Community Health Survey (subsample).

Based on self-reported 2008 Canadian Community Health Survey data, *sensitivity* for the obese category was 67% for men and 65% for women, meaning that self-reports correctly classified about two-thirds of obese men and women (Table 5). Corrections using the Canadian Health Measures Survey equations improved sensitivity to 77% for men and to 75% for women. However, the 2005 correction equations yielded even higher sensitivity values: 84% for men and 82% for women.

The use of correction equations also improved sensitivity estimates for the overweight category. However, for the normal-weight category, sensitivity estimates based on corrected values were lower than those based on self-reported values: in some cases, respondents correctly classified as normal weight based on self-reports were erroneously classified as overweight based on the correction equations.

Correction equations, notably those based on the 2005 Canadian Community Health Survey, improved *specificity* estimates for the normal-weight category. For the obese category, the correction equations slightly reduced specificity.

The ultimate goal of establishing correction equations for the Canadian Community Health Survey is to be able to apply them to the full sample in order to estimate obesity at provincial and health region levels. To this end, the two sets of correction equations were applied to the full 2007 to 2008 Canadian Community Health Survey sample of 107,141 respondents aged 18 to 79, 38% of whom were interviewed in person, and the remaining 62%, by telephone. For both sexes, full-sample obesity estimates corrected with the 2005 equations were similar to measured obesity estimates based on the 2008 subsample (Table 6). In fact, corrected estimates for all BMI categories based on the 2005 correction equations were similar to measured estimates except for normal-weight women for whom the corrected estimate was somewhat higher. Again, the Canadian Health Measures Survey correction equations resulted in some improvements, but they were less effective than the 2005 correction equations.

Discussion

Consistent with past research,[2] this study found biases when height and weight are based on self-reported values. Because survey respondents tended to over-report height and under-report weight, the self-reported data underestimated the prevalence of obesity.

The magnitude of the bias in height was similar across the three surveys, but the bias in weight was lower in the Canadian Health Measures Survey than in the two Canadian Community Health Surveys. As a result, the bias in the prevalence of obesity was approximately twice as high in the two Canadian Community Health Surveys as in the Canadian Health Measures Survey. Sensitivity for the obese category was substantially higher in the Canadian Health Measures Survey, meaning that obese respondents to that survey were far more likely to be accurately identified as obese based on self-reported values. Survey context likely played a role in these discrepancies. Before they reported their height and weight, respondents to the Canadian Health Measures Survey

Table 5
Sensitivity and specificity values for self-reported and corrected data, by sex, household population aged 18 to 79, Canada, 2008

	Self-reported			Corrected: Based on 2007 to 2009 Canadian Health Measures Survey			Corrected: Based on 2005 Canadian Community Health Survey		
		95% confidence interval			95% confidence interval			95% confidence interval	
	%	from	to	%	from	to	%	from	to
Sensitivity (% true positives)									
Men									
Underweight	58.7	29.0	83.1	58.7	29.0	83.1	58.7	29.0	83.1
Normal weight	90.6	85.5	94.0	84.9*	79.7	89.0	83.5*	77.9	87.8
Overweight	69.7	65.2	73.8	80.0*	75.8	83.7	78.4*	73.8	82.4
Obese	67.4	61.1	73.1	77.4*	71.8	82.1	83.7*	78.8	87.6
Women									
Underweight	73.0	58.0	84.2	55.2*	38.3	71.1	26.4*	14.6	43.0
Normal weight	93.6	90.8	95.6	89.8*	86.2	92.5	85.4*	81.4	88.7
Overweight	68.4	63.4	73.1	79.0*	74.5	83.0	77.6*	73.1	81.6
Obese	65.2	58.4	71.5	75.4*	69.1	80.8	81.5*	74.9	86.6
Specificity (% true negatives)									
Men									
Underweight	99.7	99.2	99.9	99.8	99.3	99.9	99.8	99.3	99.9
Normal weight	81.6	78.6	84.3	89.4*	86.8	91.5	90.2*	87.6	92.3
Overweight	81.5	77.6	84.8	82.6	79.0	85.7	84.7*	81.2	87.6
Obese	98.8	97.5	99.4	97.5*	96.0	98.5	95.8*	93.9	97.2
Women									
Underweight	97.8	96.6	98.6	98.5*	97.2	99.2	98.8*	97.5	99.4
Normal weight	81.6	78.7	84.3	89.0*	86.5	91.1	90.3*	87.9	92.3
Overweight	88.4	85.4	90.9	88.0	85.0	90.5	87.0	83.9	89.5
Obese	98.8	98.0	99.3	97.6*	96.0	98.5	95.0*	93.3	96.3

* significantly different from self-reported estimate ($p < 0.05$)
Source: 2008 Canadian Community Health Survey (subsample).

were informed that their height and weight would later be measured. By contrast, the subsample of respondents selected for the direct measurement component of the Canadian Community Health Survey had no prior indication that their measurements would be taken. As suggested in other research,[18] self-reports may be more accurate if respondents know that they will be weighed and measured.

The methodology and context of the Canadian Health Measures Survey are similar to the National Health and Nutrition Examination Survey (NHANES) conducted in the United States.[19] The bias in *height* in the Canadian Health Measures Survey and the Canadian Community Health Surveys is similar to that in the 2003/2004 NHANES (1.2 cm for men and 0.5 cm for women aged 18 to 74).[4] For women aged 18 to 74, the bias in *weight* in the NHANES (-1.3 kg) was similar to that in the Canadian Health Measures Survey (-1.6 kg), and substantially less than the bias in the 2008 Canadian Community Health Survey (-2.7 kg). In the Canadian Health Measures Survey, men also under-reported weight but not as much as in the Canadian Community Health Survey; in the NHANES, men did not under-report weight.

The current study found no change in the bias between the 2005 and 2008 Canadian Community Health Surveys, although three years is a short period over which to assess change. Nonetheless, a Swiss study found that the bias remained relatively constant in that population

What is already known on this subject?

- Body mass index values based on self-reported height and weight underestimate the true prevalence of obesity.
- For fiscal and logistical reasons, the practice of collecting self-reported height and weight will continue in Statistics Canada's Canadian Community Health Survey.
- Correction equations based on half of the 2005 Canadian Community Health Survey subsample, for whom both measured and self-reported values were collected, were successfully applied to the other half of the sample to produce more accurate estimates of obesity.

What does this study add?

- The bias in obesity estimates appears to depend on survey context.
- The bias in weight in the 2007 to 2009 Canadian Health Measures Survey (respondents were aware that direct measures would be taken) was substantially lower than the bias in the Canadian Community Health Survey (respondents were not informed before self-reporting that direct measures would be taken).
- Correction equations based on 2005 Canadian Community Health Survey data were successfully applied to self-reported 2008 Canadian Community Health Survey values to produce more accurate estimates of obesity.
- Differences between corrected estimates of obesity from the Canadian Community Health Survey and measured estimates from the Canadian Health Measures Survey should be monitored over time to determine if the bias in self-reported values is changing and if new correction equations need to be developed.

Table 6
Percentage distribution of population, by body mass index (BMI) category and sex, based on self-reported, measured and corrected data for full 2007 to 2008 Canadian Community Health Survey, household population aged 18 to 79, Canada

	Self-reported			Measured			Corrected: Based on 2007 to 2009 Canadian Health Measures Survey			Corrected: Based on 2005 Canadian Community Health Survey		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
BMI category	%	from	to	%	from	to	%	from	to	%	from	to
Men												
Underweight	1.1	1.0	1.3	1.4^E	0.8	2.6	0.9	0.8	1.1	0.9	0.8	1.1
Normal weight	40.0*	39.3	40.7	30.3	27.4	33.4	33.6*	32.9	34.3	32.7	32.0	33.3
Overweight	40.5	39.8	41.3	42.2	39.2	45.3	43.9	43.2	44.6	41.9	41.2	42.6
Obese	18.3*	17.8	18.8	26.1	23.4	28.9	21.6*	21.1	22.2	24.5	23.9	25.0
p-value Chi-squared test†	*p=0.00*						*p=0.00*			*p=0.23*		
Women												
Underweight	4.1*	3.8	4.4	2.6^E	1.8	3.7	2.5	2.2	2.7	2.0	1.8	2.2
Normal weight	52.7*	52.0	53.3	42.4	39.3	45.6	48.4*	47.8	49.1	45.8*	45.2	46.4
Overweight	27.1*	26.5	27.7	31.7	28.8	34.8	30.3	29.7	30.9	30.1	29.5	30.7
Obese	16.1*	15.7	16.6	23.3	20.8	25.9	18.8*	18.3	19.3	22.1	21.6	22.7
p-value Chi-squared test†	*p=0.00*						*p=0.00*			*p=0.17*		

* significantly different from measured estimate ($p < 0.05$)
† result of Chi-squared test comparing self-reported/corrected BMI distribution with measured distribution
E use with caution
Note: Measured estimates are based on the 2008 Canadian Community Health Survey subsample. Self-reported and corrected estimates are based on the full 2007 to 2008 Canadian Community Health Survey sample.
Sources: 2007 to 2008 Canadian Community Health Survey (full sample); 2008 Canadian Community Health Survey (subsample).

over three decades.[20] A study that compared changes in the bias in BMI across multiple NHANES cycles (1976 to 1980, 1988 to 1994, 2003/2004) with changes in the bias between the Canadian Heart Health Surveys (from 1986 to 1992) and the 2005 Canadian Community Health Survey concluded that the bias remained relatively stable in the United States but rose in Canada.[4] However, the context of the Canadian Heart Health Surveys was similar to the NHANES and the Canadian Health Measures Survey in that respondents knew that they would be required to visit a clinic for physical measurements. In the Canadian Heart Health Surveys, weight was underestimated by 1.8 kg among men and by 2.3 kg among women (based on the population aged 18 to 74 age-standardized to the 2001 Canadian census). While this bias is less than in the 2005 and 2008 Canadian Community Health Surveys, it is substantially more than in the Canadian Health Measures Survey (weight was underestimated by 0.6 kg among men and by 1.6 kg among women aged 18 to 74). In the Canadian Heart Health Surveys, height was overestimated by 0.6 cm among men and by 0.2 cm among women. This bias in height is less than in the Canadian Health Measures Survey (1.2 cm for men and 0.7 cm for women aged 18 to 74) or either Canadian Community Health Survey. In Canada, a lack of data points from surveys conducted in a similar fashion prevents tracking trends in the bias over time.

With some success, other studies have employed correction equations to adjust self-reported BMI values.[8,21-25] However, the external applicability of these correction equations depends on factors such as survey context, changes in the bias over time, and the population group studied. Because the bias in the Canadian Health Measures Survey was significantly different from those in the Canadian Community Health Surveys, the use of regression equations based on Canadian Health Measures Survey data had limited success in correcting self-reported 2008 Canadian Community Health Survey estimates. This was particularly true for the prevalence of obesity, with a 3- to 4-percentage-point difference remaining between the corrected and measured estimates. Results were similar in an American study that applied regression equations based on data from the NHANES to data from the Behavioural Risk Factor Surveillance System, which collects only self-reported values for height and weight.[18] A previous study based on data from a Dutch population survey also found that correction equations may not be applicable to other datasets.[26]

In the current study, when the regression equations based on the 2005 Canadian Community Health Survey were applied to the self-reported 2008 data, the corrected obesity prevalence estimates approximated those based on measured data. Although sensitivity for the normal-weight group was somewhat reduced, substantial improvements in sensitivity were realized for both sexes in the obese group. Use of the 2005 correction equations would be particularly effective for studies based on the 2008 Canadian Community Health Survey that dichotomize BMI as obese or not obese.

When the 2005 correction equations were applied to the full 2007 to 2008 Canadian Community Health Survey sample, obesity estimates were statistically similar to those derived from measured values for the 2008 subsample. These improvements were realized even though 62% of the interviews in the full sample were by telephone. While further studies are needed to assess the applicability of the equations at provincial and subprovincial levels, the use of correction equations is recommended for all analyses using Canadian Community Health Survey data.

Limitations

The response rates were 51.7% for the Canadian Health Measures Survey, 50.7% for the 2008 Canadian Community Health Survey, and 55.9% for the 2005 Canadian Community Health Survey. Sampling weights were adjusted to compensate for the various levels of non-response, but estimates could be biased if respondents' characteristics differed significantly from those of non-respondents.

Differential non-response may have resulted in the higher bias in the self-reported data from Canadian Community Health Survey than from the Canadian Health Measures Survey. However, prevalence estimates by BMI categories based on measured height and weight did not differ between the 2008 Canadian Community Health Survey and the 2007 to 2009 Canadian Health Measures Survey, which suggests that the differences in the bias in the self-reported data from the two surveys were due to survey context rather than differential non-response.

An American study[27] and a study based on Canadian Community Health Survey data[28] found that telephone interviews resulted in a larger bias in self-reported obesity estimates than did in-person interviews. However, in the current study, the self-reported 2008 Canadian Community Health Survey obesity estimates were similar for the subsample, for which only on in-person interviews were conducted, and for the full 2007 to 2008 sample, for which 62% of interviews were conducted by telephone. When the 2005 regression equations were applied to the full 2007 to 2008 Canadian Community Health Survey sample, the corrected obesity estimates approximated those based on measured data. The differential bias in telephone versus in-person interviews may be changing over time.

Conclusion

Although directly measured height and weight provide the most accurate estimates of the prevalence of obesity, cost and logistical considerations oblige the Canadian Community Health Survey to continue to collect self-reported data. The use of Canadian Health Measures Survey data to develop equations to correct for the bias in these self-reports is less effective than equations from a subsample of Canadian Community Health Survey respondents whose height and weight were measured. Nonetheless, it is important to monitor differences in measured estimates of obesity from the Canadian Health Measures Survey and corrected estimates from the Canadian Community Health Survey over time. Differences would indicate that the bias in self-reported values is changing, resulting in the need to develop new equations to minimize bias and approximate measured values. ■

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Appendix

Table A
Regression equations for correcting self-reported values of body mass index (BMI), by sex, BMI reduced models, based on 2005 Canadian Community Health Survey data and 2007 to 2009 Canadian Health Measures Survey data, household population aged 18 to 79, Canada

		Coefficient	Standard error	p-value	Standardized coefficient	Standard error	p-value
Based on 2005 Canadian Community Health Survey† (population aged 18 or older)							
Men	Intercept	-1.07575	0.555	...	...	...	...
R^2=0.85	BMI self-reported	1.07592	0.020	0.000	0.92416	0.018	0.000
Women	Intercept	-0.12374	0.728	...	...	...	...
R^2=0.91	BMI self-reported	1.05129	0.030	0.000	0.95554	0.027	0.000
Based on 2007 to 2009 Canadian Health Measures Survey							
Men	Intercept	-0.29227	0.289	...	...	...	...
R^2=0.93	BMI self-reported	1.03239	0.011	0.000	0.96473	0.011	0.000
Women	Intercept	0.10927	0.250	...	...	...	...
R^2=0.95	BMI self-reported	1.02584	0.010	0.000	0.97605	0.009	0.000

† equations developed in Reference 8
... not applicable
Sources: 2007 to 2009 Canadian Health Measures Survey; 2005 Canadian Community Health Survey (subsample 2).

Obesity estimates for children based on parent-reported versus direct measures

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

Abstract

Background
Studies based on adolescents and adults have found that the use of self-reported height and weight to calculate body mass index (BMI) yields a lower prevalence of obesity than do estimates based on measured data. Relatively few studies have examined the bias resulting from the use of parent-reported height and weight for children, and the findings have been inconsistent.

Data and methods
Data are from the 2007 to 2009 Canadian Health Measures Survey. Parent-reported height and weight of children aged 6 to 11 (n=854) were obtained. Subsequently, the children's height and weight were directly measured.

Results
On average, parents underestimated the height (3.3 cm) and weight (1.1 kg) of their children. Estimates of the prevalence of obesity were significantly higher when based on parent-reported versus measured values for children aged 6 to 8; the two collection methods yielded similar estimates of obesity for children aged 9 to 11. For children in both age groups, misclassification errors for BMI categories were substantial when based on parent-reported values. This weakened associations between obesity and health indicators such as aerobic fitness and systolic blood pressure. The variance explained by factors associated with the bias in parent-reported height and weight was small, particularly for height. The use of correction equations based on variables associated with the bias resulted in a very modest reduction in misclassification errors.

Interpretation
Bias associated with parental reports of children's height and weight results in misclassification errors for obesity that affect relationships with other variables. Efforts to establish correction equations to adjust for this bias were unsuccessful. Direct measures are required to accurately calculate obesity estimates and their relationships with health indicators in children.

Keywords
bias, body mass index, direct measure, measurement error, misclassification, sensitivity, specificity, validity

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Over the past 25 years, the prevalence of obesity among Canadian children, adolescents and adults has increased substantially,[1-4] mirroring a worldwide phenomenon.[5,6] Monitoring trends in obesity is essential to assess interventions aimed at preventing or reducing obesity in children.

The prevalence of obesity is commonly estimated based on body mass index (BMI), a measure of weight in relation to height. Because of the logistical complexity and expense of obtaining measured height and weight, health surveys frequently assess BMI by asking respondents how tall they are and how much they weigh.

Adults tend to underestimate their weight and overestimate their height[7]; among adolescents, weight is also underestimated, but the bias in height is small.[8] These biases result in systematic underestimation of the prevalence of obesity among adults and adolescents when based on self-reports.[7,8] For children, many surveys rely on a parent to report the height and weight of the child. Studies of the validity of these parental reports are relatively uncommon, and the results are inconsistent.[9-16]

Among adults, the misclassification of BMI categories that occurs when self-reported data are used exaggerates associations between obesity and obesity-related conditions such as diabetes, hypertension and heart disease.[17] An unanswered question is whether the use of parent-reported values influences associations observed between BMI and health risk factors among children.

The 2007 to 2009 Canadian Health Measures Survey (CHMS) collected both parent-reported and measured height and weight for a nationally representative sample of children aged 6 to 11. Using these data, this study investigates the bias that exists when height, weight and BMI are based on parent-reported values. Mean aerobic fitness scores, systolic blood pressure and health scores are examined to see if the use of parent-reported data alters associations between BMI and these indicators. Factors associated with reporting error are used to establish the feasibility of developing correction equations to adjust parent-reported estimates.

Methods

Data source

Data are from cycle 1 of the CHMS, which collected information at 15 sites across Canada from March 2007 through February 2009. The CHMS covered the population aged 6 to 79 living in private households. Residents of Indian Reserves or Crown lands, institutions and certain remote regions, and full-time members of the regular Canadian Forces were excluded. Approximately 96.3% of Canadians were represented.[18] Ethics approval to conduct the survey was obtained from Health Canada's Research Ethics Board.[19] Informed written consent was obtained from respondents aged 14 or older. For younger children, a parent or legal guardian provided written consent, in addition to written assent from the child. Participation was voluntary; respondents could opt out of any part of the survey at any time.

The response rate for households selected for inclusion in the CHMS was 69.6%—that is, in 69.6% of selected households, the sex and date of birth of all household members were provided by a household resident. In each responding household, one or two members were chosen; 88.3% of selected respondents completed the household questionnaire, and 84.9% of those who completed the questionnaire participated in the subsequent examination centre component. The overall response rate was 51.7%. This rate is not the result of multiplying the household and person response rates, since two people were selected in some households.[20]

This article is based on 854 respondents aged 6 to 11 for whom measured and parent-reported values for height and weight were collected. The sample size was 434 for boys and 420 for girls; 349 for children aged 6 to 8 and 505 for those aged 9 to 11. A total of 218 respondents aged 6 to 11 were excluded because of missing values for parent-reported height and/or weight—in 18% of cases, the parent did not know the height of the child, and in 8% of cases, the parent did not know the weight.

Measures and definitions

At the respondent's home, an interviewer administered a questionnaire to the parent covering the child's socio-demographic characteristics, medical history, current health status, and lifestyle behaviours. As part of this interview, the parent was asked:

- "How tall is ... without shoes on?" Categories for height in feet and inches were listed on the questionnaire, with corresponding metric values in brackets.
- "How much does ... weigh?" After reporting weight, parents were asked if they had reported in pounds or kilograms; most (94%) reported in pounds.

In the introduction to the household interview (before the questions on height and weight were asked), parents had been informed that these measurements would later be taken (*... the second part of the survey involves a visit to a clinic to collect direct physical measures such as blood pressure, height and weight, and fitness levels.*)[21]

One day to six weeks later, the child visited a mobile examination centre for a battery of physical measurements, including anthropometry, blood pressure and physical fitness. The anthropometric measures and fitness tests were conducted by health measures specialists with a degree in kinesiology and certification from the Canadian Society for Exercise Physiology as either Certified Exercise Physiologists or Certified Personal Trainers. Height was measured to the nearest 0.1 cm using a ProScale M150 digital stadiometer (Accurate Technology Inc., Fletcher, USA), and weight, to the nearest 0.1 kg with a Mettler Toledo VLC with Panther Plus terminal scale (Mettler Toledo Canada, Mississauga, Canada).

Body mass index (weight in kilograms divided by height in metres squared) was calculated from both measured and parent-reported values. Children were classified as normal weight, overweight, or obese according to two sets of age- and sex-specific BMI cut-points: one set recommended by the International Obesity Task Force (IOTF),[22] and the other, by the World Health Organization.[23] Because the sample was too small to produce a reliable estimate for the underweight category, the normal-weight group included all children whose BMI was below the overweight cut-point.

The influence of *end-digit preference* on the bias in weight and height was examined.[24-26] Parents who reported a weight for their child that ended in 0 or 5 (for example, 80 or 85 pounds) were identified as having end-digit preference for weight; those who reported a value of zero for inches (for example, 4 feet and 0 inches) were identified as having end-digit preference for height. More than half of children (57%) had a parent-reported weight that ended in 0 or 5, although by chance this would be the case for only about 20% of children (10% for each value). A value of zero was reported for inches for 19% of children, although this would be expected by chance for 8% (only one in 12).

Aerobic fitness was measured using the modified Canadian Aerobic Fitness Test (mCAFT).[4,27] Predicted maximal aerobic power (VO_2 max) was calculated based on the results of this test.

Blood pressure was measured with the BpTRU™ BP-300 (BpTRU Medical Devices Ltd., Coquitlam, British Columbia). The BpTRU™, an electronic monitor, automatically inflates and deflates the upper-arm cuff and uses an oscillometric technique to calculate systolic and diastolic blood pressure.[28] Mean systolic blood pressure in this study reflects the average of the last five of six blood pressure measures taken one minute apart.

Health scores were derived from answers to the following question asked of the child's parent: "In general would you say that ...'s health is excellent, very good, good, fair or poor?" A score of 1 (excellent) to 5 (poor) was assigned, with lower scores indicating better health.

Physical activity level was measured by asking, "About how many hours a week does … take part in physical activity (that makes him/her out of breath or warmer than usual):

- in free time at school?"
- in class time at school?"
- outside of school while participating in lessons or league or team sports?"
- outside of school while participating in unorganized activities?"

Responses to the four questions were summed,[29] and children were categorized into three groups: 7 or fewer hours, 8 to 14 hours, or 15 or more hours per week.

Analytical techniques

The bias associated with parent-reported data for weight, height and BMI was estimated by calculating the difference from measured values (parent-reported minus measured). A negative difference indicates under-reporting, and a positive difference, over-reporting.

The degree of misclassification that resulted from using parent-reports was assessed by calculating sensitivity, specificity, and positive and negative predictive values for BMI categories. Sensitivity is the percent of true positives in parent-reported data (percentage of obese, overweight or normal-weight children based on measured values, who were classified as such based on parent-reported values). Specificity is the percent of true negatives in parent-reported data (percentage of non-obese, non-overweight or non-normal-weight children who were classified as such based on parent-reported values). Positive predictive value is the percent of children classified as obese/overweight/normal weight based on parent-reported values who were actually in these categories based on measured values. Negative predictive value is the percent of non-obese/non-overweight/non-normal-weight children based on parent-reported values who were correctly classified in these categories based on measured values.

Mean aerobic fitness scores, systolic blood pressure and health scores were compared between BMI categories to see if using parent-reported height and weight to calculate BMI alters associations between excess weight and these health indicators. These indicators were chosen based on evidence in the literature that they are significantly associated with obesity in children.[1,30,31]

Multiple linear regression was used (with bias as the dependent variable) to identify factors associated with the bias in using parent-reported height and weight. Socio-demographic and other variables, selected based on a review of the literature and availability in the CHMS, were entered as independent variables: sex, age, highest level of education in the household, hours of physical activity per week, and end-digit preference in parent-reported height and weight.

Based on an approach used for adults,[24] the feasibility of establishing equations to correct for the bias in parent-reported height and weight for children was assessed. The CHMS sample of children was randomly divided into subsample A and subsample B, each containing approximately 50% of respondents. Two multiple linear regression models were fit based on subsample A, one with measured height, and the other with measured weight, as the dependent variable. Parent-reported values were entered as independent variables along with variables significantly associated with the bias. Outliers were excluded from these analyses (records for which the difference between parent-reported and measured values was more than 3 standard deviations from the mean). The equations were applied to subsample B, and BMI was recalculated based on corrected values of height and weight. In a second step, four additional sets of correction equations for height and weight were generated using subsample A (one set for each sex-age group to determine if age- and sex-specific corrections yield more accurate results) and applied to subsample B to produce corrected BMI estimates. Sensitivity and specificity estimates and positive and negative predictive values were calculated based on the corrected BMI categories and compared with those based on parent-reported estimates to determine if the corrected estimates reduced BMI misclassification errors.

Estimates of proportions, means and regression coefficients were calculated based on weighted data. Standard errors, coefficients of variation, and 95% confidence intervals were estimated using the bootstrap technique[32,33]; the number of degrees of freedom was specified as 11 to account for the complex design of the CHMS. Differences between estimates were tested for statistical significance, which was established at the 0.05 level. Analyses were conducted with SUDAAN version 10.

Results

Bias in height, weight and BMI

On average, parents underestimated their child's height by 3.3 cm (1.3 inches) and weight by 1.1 kg (2.4 pounds) (Table 1). Just under half of parents (48%) reported height within 2.54 cm (1 inch) of measured height; 64% were within 5.08 cm (2 inches); 77% were within 7.62 cm (3 inches); and the remaining 23% were off by more than 7.62 cm. More than two-thirds (71%) of parents reported weight within 2.3 kg (5 pounds) of measured weight; 86% were within 4.5 kg (10 pounds); 92% were within 6.8 kg (15 pounds); and the remaining 8% were off by more than 6.8 kg.

The bias in *height* did not differ significantly by the child's sex or age group. The bias in *weight* was significantly higher for girls than boys, and for children aged 9 to 11 compared with those aged 6 to 8.

Overall, BMI was 0.7 kg/m^2 higher when based on parent-reported versus measured height and weight. However, for girls and older children, the bias in height and weight offset each other so that mean BMIs calculated using parent-reported and measured values were similar. Among children aged 6 to 8, the substantial bias in height was not offset by the bias in weight, and as a result, BMI based on parent-reported values was significantly higher than BMI based on measured values (1.4 kg/m^2).

Table 1
Mean height, weight and body mass index (BMI), by collection method, sex and age group, household population aged 6 to 11, Canada, 2007 to 2009

	Measured			Parent-reported			Bias		
		95% confidence interval			95% confidence interval			95% confidence interval	
	Estimate	from	to	Estimate	from	to	Parent-reported minus measured	from	to
Mean height (cm)									
Total	**136.6**	**135.3**	**138.0**	**133.4***	**131.6**	**135.2**	**-3.3**	**-4.6**	**-2.0**
Sex									
Boys	136.4	134.6	138.3	133.0*	130.4	135.7	-3.4	-5.2	-1.6
Girls	136.9	135.1	138.7	133.8*	131.6	135.9	-3.1	-4.1	-2.1
Age group (years)									
6 to 8	126.7	125.9	127.5	122.5*	119.9	125.2	-4.2	-6.7	-1.7
9 to 11	144.1	142.8	145.4	141.5*	140.0	142.9	-2.6	-3.5	-1.7
Mean weight (kg)									
Total	**34.0**	**33.0**	**35.0**	**32.9***	**32.2**	**33.7**	**-1.1**	**-1.7**	**-0.6**
Sex									
Boys	34.0	32.7	35.3	33.4	32.1	34.7	-0.6	-1.3	0.1
Girls	34.0	32.5	35.6	32.4*	31.2	33.5	-1.7†	-2.5	-0.9
Age group (years)									
6 to 8	27.1	26.3	27.8	26.5*	25.7	27.3	-0.6	-1.0	-0.1
9 to 11	39.2	37.7	40.7	37.7*	36.6	38.7	-1.5‡	-2.2	-0.9
Mean BMI (kg/m²)									
Total	**17.8**	**17.6**	**18.0**	**18.5***	**18.0**	**19.0**	**0.7**	**0.1**	**1.2**
Sex									
Boys	17.9	17.7	18.2	19.0*	18.1	19.9	1.1	0.2	1.9
Girls	17.7	17.3	18.1	18.0	17.5	18.5	0.3	-0.3	0.8
Age group (years)									
6 to 8	16.7	16.3	17.0	18.1*	17.1	19.1	1.4	0.3	2.5
9 to 11	18.7	18.2	19.1	18.8	18.5	19.1	0.1‡	-0.2	0.5

* significantly different from estimate for measured ($p < 0.05$)
† significantly different from estimate for boys ($p < 0.05$)
‡ significantly different from estimate for age group 6 to 8 years ($p < 0.05$)
Source: 2007 to 2009 Canadian Health Measures Survey.

Prevalence estimates by BMI category

Prevalence estimates by BMI category differed when calculated using parent-reported versus measured height and weight (Table 2). In relation to the cut-points recommended by the IOTF, 11.7% of children aged 6 to 11 were classified as obese based on parent-reported values, which was approximately double the estimate for obesity (5.6%) based on measured values. Similarly, in relation to the World Health Organization cut-points, far more children were assessed as obese based on parent-reported (19.2%) rather than measured (13.2%) height and weight.

As a result of the smaller bias in BMI among older children (ages 9 to 11), prevalence estimates by BMI category for this age group did not differ significantly regardless of whether they were based on measured or parent-reported values. Prevalence estimates for girls were also fairly similar for the two collection methods, although the prevalence of obesity based on the IOTF cut-points was significantly higher when calculated with parent-reported rather than measured values.

Misclassification by BMI category

The degree of misclassification that results when BMI categories are based on parent-reported height and weight was assessed by calculating sensitivity and specificity (Table 3) and positive and negative predictive values (Table 4).

In relation to the IOTF cut-points, sensitivity for normal-weight children was 83%, meaning that 83% of children whose measured height and weight placed them in the normal-weight category were in this category based on parent-reported height and weight; 10% were inappropriately classified as overweight, and 7%, as obese. In relation to the WHO cut-points, sensitivity was 78% for the normal-weight group.

In relation to the IOTF cut-points, sensitivity was 57% for overweight children and 51% for obese children. In relation to the WHO cut-points, sensitivity was particularly low—38%—for the overweight group and somewhat higher—66%—for the obese group.

Positive predictive values were particularly low for the obese and overweight categories (Table 4). For example, with the IOTF cut-points for BMI, the positive predictive value for obesity was 24%, meaning that only 24% of children classified as obese based on parent-reported values were actually obese; 29% of them were overweight, and close to half (47%) were normal weight. It was extensive under-reporting of height that resulted in the very low estimates of positive predictive values for the obese category. Among children erroneously classified as obese based on parent-reported values and the IOTF cut-points, height was under-reported by an average of 21.1 cm (8.3 inches).

Although prevalence estimates of BMI categories were fairly similar for girls and older children, regardless of whether BMI was calculated using parent-reported or measured height and weight, sensitivity and positive predictive value estimates reveal that misclassification was common. For example, in terms of the IOTF cut-points, 8% of children aged 9 to 11 were obese based on parent-reported values, and 6% were obese based on measured values. However, sensitivity was a low 53%, meaning that the use of parent-reported height and weight to calculate BMI resulted in close to half (47%) of obese children in this age group being classified in a lower BMI category. As well, the

Table 2
Percentage distribution of population, by body mass index (BMI) category, collection method, sex and age group, household population aged 6 to 11, Canada, 2007 to 2009

	International Obesity Task Force BMI cut-points						World Health Organization BMI cut-points					
	Measured			Parent-reported			Measured			Parent-reported		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
	Estimate	from	to	Estimate	from	to	Estimate	from	to	Estimate	from	to
Total												
Normal weight†	76.6	73.0	79.8	69.3*	63.4	74.7	65.8	61.7	69.7	60.8*	54.8	66.5
Overweight	17.9	14.5	21.8	19.0	14.0	25.2	21.0	15.7	27.3	20.1	16.7	23.9
Obese	5.6	3.9	7.8	11.7*	8.2	16.4	13.2	11.0	15.8	19.2*	15.2	23.9
Sex												
Boys												
Normal weight†	75.3	70.7	79.5	63.8*	54.7	72.1	62.4	56.5	68.0	53.3*	43.2	63.2
Overweight	18.5	14.2	23.7	22.7	17.0	29.7	20.6	15.0	27.5	21.7	17.0	27.2
Obese	6.2	4.3	8.8	13.4*E	8.4	20.8	17.0	14.2	20.3	25.0*	17.8	34.0
Girls												
Normal weight†	77.9	72.0	82.9	75.2	69.0	80.5	69.4	63.8	74.5	68.8	63.7	73.5
Overweight	17.3	12.1	24.1	15.0E	9.9	22.1	21.4	15.6	28.6	18.4	15.3	21.9
Obese	4.8E	2.1	10.7	9.8*	7.1	13.5	9.2E	5.1	15.9	12.8	10.0	16.4
Age group (years)												
6 to 8												
Normal weight†	79.4	73.1	84.5	67.5*	60.0	74.2	70.3	64.2	75.8	59.9*	50.2	68.9
Overweight	16.2	12.3	21.1	16.1E	10.2	24.5	15.6E	10.2	23.3	16.3	11.4	22.7
Obese	4.4E	2.4	7.8	16.4*E	10.6	24.7	14.0E	9.3	20.6	23.8*	17.7	31.2
9 to 11												
Normal weight†	74.5	67.8	80.2	70.7	63.6	76.8	62.4	55.5	68.9	61.4	54.8	67.7
Overweight	19.1	14.1	25.4	21.2	15.5	28.3	24.9	17.6	34.1	22.9	17.7	29.1
Obese	6.4E	3.5	11.6	8.1	6.2	10.6	12.6E	8.3	18.7	15.7	12.2	19.9

* significantly different from measured estimate ($p < 0.05$)
† includes underweight
E use with caution
Source: 2007 to 2009 Canadian Health Measures Survey.

positive predictive value was only 52%, meaning that close to half (48%) of the children classified as obese were, in fact, not obese.

Association with other health indicators

Based on measured values for height and weight and the IOTF cut-points for BMI, the mean aerobic fitness score of normal-weight children was 6.4 ml/kg/min higher than the score for obese children (Table 5). When parent-reported height and weight were used to calculate BMI, the difference was reduced to 2.4 ml/kg/min. Based on measured values to calculate BMI, mean systolic blood pressure was 5 mmHg higher among obese children than among normal-weight children; based on parent-reported values, this difference was reduced to 1.2 mm Hg and was not statistically significant. Based on measured values, the average health score for obese children was 0.4 higher than the average for normal-weight children (higher scores indicate worse health); the difference was reduced to 0.1 based on height and weight reported by parents and was not statistically significant.

A weakening of the association between excess weight and these health indicators was also observed when the WHO cut-points were used to classify BMI.

Factors associated with the reporting bias

Regression analyses were used to identify factors associated with the bias in parental reporting (Table 6). The only factor significantly associated with the bias in height was end-digit preference (reporting a value of 0 for inches). Parents with end-digit preference were significantly more likely to underestimate the height of their child. Only a small percentage of the bias in height was explained by the factors examined in the regression analysis (R^2=0.06).

The variables in the regression analysis for the bias in parental reporting of weight were more successful in explaining the variance (R^2=0.25). Under-reporting was higher for girls and for children who participated in physical activity 7 or fewer hours a week. The positive association with measured height and the negative association with measured weight result from the tendency of parents of an overweight or obese child to underestimate that child's weight. For example, in relation to the IOTF cut-points, parents underestimated

Table 3
Sensitivity and specificity values for parent-reported body mass index categories, by sex and age group, household population aged 6 to 11, Canada, 2007 to 2009

	International Obesity Task Force BMI cut-points						World Health Organization BMI cut-points					
	Sensitivity			Specificity			Sensitivity			Specificity		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
	%	from	to	%	from	to	%	from	to	%	from	to
Total												
Normal weight†	83.0	77.7	87.3	75.6	67.0	82.5	78.4	72.5	83.4	73.2	66.7	78.8
Overweight	56.5	42.0	70.0	89.2	84.7	92.5	38.3	26.9	51.2	84.8	80.5	88.2
Obese	50.6	40.4	60.7	90.6	85.2	94.1	66.2	55.0	75.8	88.0	82.0	92.2
Sex												
Boys												
Normal weight†	79.1	70.1	85.9	82.7	70.1	90.7	74.1	63.5	82.5	81.3	70.1	89.0
Overweight	60.8	45.2	74.4	85.9	79.4	90.5	40.4	26.5	56.1	83.2	77.2	87.8
Obese	62.6	38.5	81.7	89.8	81.4	94.7	76.3	56.7	88.8	85.5	76.7	91.3
Girls												
Normal weight†	87.1	84.2	89.6	67.0	50.1	80.4	82.6	79.1	85.6	62.5	51.0	72.8
Overweight	51.6	34.5	68.3	92.6	88.7	95.3	36.2	21.9	53.4	86.5	83.1	89.3
Obese	34.1	16.8	56.9	91.4	87.8	94.0	46.0	21.9	72.1	90.5	86.6	93.4
Age group (years)												
6 to 8												
Normal weight†	79.4	72.8	84.7	78.2	63.3	88.2	75.7	65.9	83.4	77.6	70.9	83.1
Overweight	47.3	23.8	72.0	90.0	85.1	93.4	36.0	23.5	50.7	87.4	82.1	91.3
Obese	45.4	23.9	68.9	84.9	76.3	90.8	68.8	50.4	82.7	83.5	75.7	89.2
9 to 11												
Normal weight†	85.9	80.5	90.1	73.9	64.6	81.5	80.7	74.4	85.8	70.6	61.6	78.3
Overweight	62.3	48.1	74.7	88.5	82.7	92.6	39.4	23.8	57.6	82.6	76.3	87.5
Obese	53.2	39.4	66.6	94.9	91.5	97.0	64.0	49.0	76.7	91.3	86.0	94.8

† includes underweight
Source: 2007 to 2009 Canadian Health Measures Survey.

the weight of normal-weight children by 0.4 kg, overweight children by 2.3 kg, and obese children by 6.6 kg. In fact, for obese children, the bias in reporting weight was so great that it was not offset by the bias in reporting height, and resulted in a negative bias in BMI (-2.6 kg/m^2). This is contrary to the finding for the majority of children, for whom the bias in BMI was positive (0.8 kg/m^2 for normal-weight children and 0.9 kg/m^2 for overweight children).

An attempt was made to predict measured height and weight using regression models based on parent-reported values and other factors significantly associated with the bias. For height, the independent variables were parent-reported height and end-digit preference for height. For weight, the independent variables were parent-reported weight, sex, number of hours of physical activity per week, and parent-reported height. The prediction equations were generated using half of the CHMS sample selected at random (subsample A, Appendix Table A). Because of the strong correlations between self-reported and measured values (0.81 for height and 0.93 for weight), the R^2 values for the equations to predict measured height and weight were very high (0.74 for height and 0.92 for weight).

These equations were applied to the other half of the sample (subsample B) to produce corrected estimates of height, weight, BMI, and BMI prevalence categories. The corrected estimates improved sensitivity somewhat for the normal-weight category (Table 7). With the IOTF cut-points, sensitivity in subsample B for the normal-weight category rose from 83% based on parent-reported values to 87%; with the WHO cut-points, sensitivity increased from 79% to 86%. Significant improvements in sensitivity were not realized for the overweight or obese categories based on either set of cut-points.

Regardless of the cut-points, specificity estimates for the obese category were higher when based on corrected rather than parent-reported values. For the normal and overweight categories, specificity estimates did not improve significantly when based on corrected values.

Estimates based on corrected values resulted in some improvements in positive and negative predictive values. However, for the obese group, positive predictive values remained very low, particularly for the IOTF cut-points—only about a third of children classified as

Table 4
Positive and negative predictive values (PPV and NPV) for parent-reported body mass index categories, by sex and age group, household population aged 6 to 11, Canada, 2007 to 2009

	International Obesity Task Force BMI cut-points						World Health Organization BMI cut-points					
	PPV			NPV			PPV			NPV		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
	%	from	to	%	from	to	%	from	to	%	from	to
Total												
Normal weight†	91.7	88.8	94.0	57.7	51.0	64.1	84.9	80.3	88.6	63.8	59.8	67.7
Overweight	53.1	43.4	62.7	90.4	87.0	93.0	40.0	29.8	51.2	83.8	76.3	89.3
Obese	24.0	13.8	38.4	96.9	95.1	98.1	45.8	32.1	60.1	94.5	91.9	96.3
Sex												
Boys												
Normal weight†	93.3	88.7	96.1	56.4	48.4	64.1	86.8	79.8	91.6	65.4	58.7	71.5
Overweight	49.3	37.9	60.8	90.6	85.4	94.1	38.4	26.7	51.6	84.4	76.1	90.1
Obese	29.0	13.7	51.2	97.3	94.2	98.8	51.9	38.5	65.0	94.6	90.4	97.1
Girls												
Normal weight†	90.3	85.3	93.7	59.7	47.7	70.6	83.3	77.3	88.0	61.3	52.6	69.3
Overweight	59.4	40.5	75.9	90.2	86.5	92.9	42.2	29.1	56.4	83.3	74.5	89.4
Obese	16.8	5.8	39.7	96.5	91.9	98.5	32.9	12.4	62.8	94.3	89.9	96.9
Age group (years)												
6 to 8												
Normal weight†	93.4	88.6	96.2	49.6	38.2	61.1	88.9	85.3	91.7	57.4	49.6	64.9
Overweight	47.8	29.5	66.7	89.8	85.6	92.9	34.6	22.7	48.8	88.0	81.2	92.6
Obese	12.1	5.1	26.2	97.1	94.2	98.6	40.5	22.4	61.7	94.2	91.9	96.0
9 to 11												
Normal weight†	90.6	85.5	94.0	64.3	55.9	72.0	82.0	73.9	88.0	68.8	62.4	74.6
Overweight	56.2	44.9	66.9	90.9	85.4	94.4	42.9	27.2	60.2	80.4	70.2	87.8
Obese	41.9	21.4	65.6	96.7	92.8	98.6	51.7	35.2	67.7	94.6	88.4	97.6

† includes underweight
Source: 2007 to 2009 Canadian Health Measures Survey.

Table 5
Mean aerobic fitness score, systolic blood pressure and health score, by collection method and body mass index (BMI) category, household population aged 6 to 11, Canada, 2007 to 2009

	Mean aerobic fitness†: predicted maximal aerobic power (ml/kg/min)						Systolic blood pressure (mm Hg)						Health score					
	Measured			Parent-reported			Measured			Parent-reported			Measured			Parent-reported		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
	Mean	from	to	Mean	from	to	Mean	from	to	Mean	from	to	Mean	from	to	Mean	from	to
International Obesity Task Force BMI cut-points																		
Normal weight†	54.1	53.7	54.6	53.8‡	53.3	54.2	92.2	91.4	93.0	92.5‡	91.8	93.3	1.6	1.5	1.6	1.6	1.5	1.7
Overweight	51.3*	50.4	52.2	52.1*	51.1	53.2	96.4*	94.3	98.4	95.6*	94.2	97.0	1.6	1.4	1.8	1.6	1.4	1.7
Obese	47.7*	45.7	49.6	51.4*‡	49.5	53.3	97.2*	93.1	101.3	93.7‡	90.8	96.5	2.0*	1.8	2.2	1.7‡	1.5	1.9
World Health Organization BMI cut-points																		
Normal weight†	54.3	53.9	54.7	53.7‡	53.2	54.2	91.9	91.0	92.7	92.3	91.4	93.2	1.6	1.5	1.6	1.6	1.5	1.7
Overweight	52.4*	51.4	53.4	53.0	51.7	54.3	95.1*	93.9	96.4	94.6*	93.2	96.1	1.5	1.4	1.7	1.6	1.5	1.8
Obese	49.7*	48.2	51.2	51.9*‡	50.6	53.2	96.9*	94.4	99.3	94.7*‡	93.0	96.4	1.8*	1.6	2.0	1.6‡	1.5	1.8

† based on children aged 8 to 11 (see *Methods*)
‡ significantly different from measured estimate ($p < 0.05$)
* significantly different from estimate for normal weight ($p < 0.05$)
Source: 2007 to 2009 Canadian Health Measures Survey.

Table 6
Regression coefficients relating selected characteristics to difference‡ between measured and self-reported height (cm) and weight (kg), household population aged 6 to 11, Canada, 2007 to 2009

	Height				Weight			
	Regression coefficient (B)	95% confidence interval from	95% confidence interval to	Standardized regression coefficient (beta)	Regression coefficient (B)	95% confidence interval from	95% confidence interval to	Standardized regression coefficient (beta)
Sex								
Boys†	...	...	...	...	...	...	...	...
Girls	-0.10	-1.39	1.18	-0.01	-1.12*	-2.11	-0.14	-0.15
Age	0.63	-0.52	1.78	0.12	-0.01	-0.38	0.37	0.00
Highest level of household education is postsecondary graduation								
Yes	1.43	-1.46	4.33	0.06	0.09	-0.93	1.11	0.01
No†	...	...	...	...	...	...	...	...
Hours of physical activity per week								
7 or fewer	-1.62	-4.65	1.42	-0.06	-0.96*	-1.78	-0.13	-0.08
8 to 14	-1.19	-3.31	0.93	-0.07	-0.54	-1.29	0.21	-0.07
15 or more†	...	...	...	...	...	...	...	...
End-digit preference								
Yes	-5.23*	-7.80	-2.65	-0.23	-0.29	-0.81	0.23	-0.04
No†	...	...	...	...	...	...	...	...
Measured height (cm)	-0.11	-0.29	0.08	-0.14	0.12*	0.02	0.21	0.36
Measured weight (kg)	0.08	-0.04	0.20	0.10	-0.26*	-0.34	-0.17	-0.71
Intercept	3.97				-7.35			
Model information								
R^2	0.06				0.25			

† reference category
‡ self-reported minus measured
* significantly different from estimate for reference category/from 0 (continuous variable) ($p < 0.05$)
... not applicable
Source: 2007 to 2009 Canadian Health Measures Survey.

obese according to the corrected values actually belonged to that category.

Although the R^2 values for the equations predicting measured height and weight were very high (Appendix Table A), those associated with the bias in the self-reported values were low (0.06 for height and 0.25 for weight). Thus, the prediction equations failed to substantially reduce misclassification error.

Corrections to height and weight were also made based on sex-/age group-specific regression equations. Reductions in misclassification error using this approach were similar to those using the simpler approach (data not shown).

Discussion

This study of a nationally representative sample of Canadian children aged 6 to 11 found that parents tend to underestimate the child's height and weight. For children aged 9 to 11, the net effect was that parent-reported BMI was similar to measured BMI, and both types of data yielded similar obesity estimates. For children aged 6 to 8, the bias in weight did not fully compensate for the bias in height, and consequently, the prevalence of obesity was substantially overestimated when based on parent-reported BMI. More important, the use of parent-reported values resulted in significant misclassification errors for children of all ages. A substantial percentage of children who were obese according to their measured height and weight were classified in a lower BMI category. For the most part, these errors resulted from the under-reporting of weight On the other hand, many children who were classified as obese based on parent-reported height and weight were actually overweight or even normal weight. These errors generally resulted from the under-reporting of height.

CHMS results are consistent with a recent American report that compared estimates from the National Health and Nutrition Examination Survey (NHANES), which collected measured height and weight from a nationally representative sample of children, with estimates from the National Health Interview Survey (NHIS), which collected parent-reported values.[34] Among children aged 6 to 11, mean height and weight based on NHANES data were higher than the means based on NHIS data, which suggests that parents underestimated both height and weight.

Other studies[10-16] that analyzed discrepancies between measured and parent-reported values for individual children have yielded inconsistent results. Some studies[10,12] found that parents underestimated height. However, a study of 4-year-olds in the province of Quebec in Canada[11] and a Belgian study of 3- to 7-year-olds[13] found that parents accurately reported height. And a study of 4-year-olds in the Netherlands found that parents overestimated height.[15] The results for weight have been more consistent, with most studies finding that parents underestimate it,[10,12-14,16] although in one, weight was accurately reported,[15] and in another, overestimated for boys.[11]

The bias in the CHMS data tended to be greater than those in other studies, which may reflect differences in protocols used to collect data from parents. In some studies,[13,15] parents measured their children before reporting values for height and weight, a practice that led to less bias.

The tendency for parents of overweight or obese children (based on measured values) to underestimate

Table 7
Sensitivity, specificity, and positive and negative predictive values for parent-reported and corrected body mass index categories, subsample B, household population aged 6 to 11, Canada, 2007 to 2009

	International Obesity Task Force BMI cut-points						World Health Organization BMI cut-points					
	Parent-reported			Corrected			Parent-reported			Corrected		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
	%	from	to	%	from	to	%	from	to	%	from	to
Sensitivity (% true positives)												
Normal weight	83.0	76.0	88.3	87.1*	79.9	91.9	79.4	70.7	86.0	86.1*	76.8	92.1
Overweight	59.4	46.4	71.2	60.0	48.4	70.5	38.7	26.9	52.0	37.6	22.0	56.4
Obese	57.2	32.5	78.8	52.7	27.2	76.9	62.6	42.3	79.3	69.5	52.9	82.3
Specificity (% true negatives)												
Normal weight	77.7	61.7	88.3	75.7	61.0	86.1	72.0	59.0	82.1	68.8	55.0	79.9
Overweight	90.1	84.4	93.9	89.1	83.2	93.1	85.6	79.7	90.0	87.4	79.8	92.3
Obese	90.0	82.7	94.5	94.5*	88.7	97.4	87.4	80.7	92.0	92.9*	87.3	96.2
Positive predictive value												
Normal weight	92.0	84.3	96.1	91.7	84.5	95.7	82.6	75.0	88.3	82.2	73.5	88.6
Overweight	58.9	47.8	69.2	56.7	42.4	70.0	44.5	30.9	59.0	47.1	28.3	66.8
Obese	24.0	13.4	39.2	34.6	13.2	64.7	45.3	30.1	61.5	62.2*	44.3	77.4
Negative predictive value												
Normal weight	59.7	50.9	67.9	65.4	52.2	76.6	67.6	59.9	74.4	74.7*	63.4	83.5
Overweight	90.3	83.7	94.4	90.3	84.1	94.3	82.4	74.8	88.0	82.4	73.4	88.8
Obese	97.5	93.5	99.0	97.3	93.4	98.9	93.3	88.1	96.3	94.8	90.9	97.1

* significantly different from self-reported estimate ($p < 0.05$)
Source: 2007 to 2009 Canadian Health Measures Survey.

the child's weight was fairly consistent across studies.[9,10,13,15,16] This was also the case in the CHMS data and is consistent with findings for Canadian adults.[26]

Among adults, the misclassification that results from the use of self-reported height and weight *elevates* associations between overweight/obesity and obesity-related diseases such as diabetes and heart disease.[17,35,36] It was not possible to replicate those analyses for children because of the low prevalence of these chronic conditions at young ages. However, it was possible to examine children's mean aerobic fitness scores, systolic blood pressure and health scores by BMI category. For children, the use of parent-reported height and weight *weakened* associations with these indicators. This is contrary to the findings for adults and is the result of the substantial degree of misclassification error that occurs across all BMI categories. For example, based on the IOTF cut-points, 24% of the children classified as obese based on parent-reported height and weight were actually obese; 29% of them were overweight; and 47% were normal weight. The high percentage of normal-weight children erroneously classified as obese was the result of parents underestimating height. And at the same time, because many parents with an obese child (based on measured height and weight) under-reported weight, those children were erroneously classified as overweight or normal weight. Thus, with parent-reported data, all BMI categories are diluted, and the end result is the weakened association with other variables.

A study based on Canadian adults found that correction equations could be generated to adjust self-reported data and reduce the misclassification errors that occur with the use of self-reported values.[24] Among children, the variance explained by factors potentially associated with the bias in parent-reported height and weight was small, particularly for height. Furthermore, because parents of obese children substantially underestimated weight (resulting in a negative bias in BMI), while most parents underestimated height (resulting in a positive bias in BMI), predictions based on parent-reported values are difficult. The use of correction equations yielded very modest reductions in misclassification errors. The findings clearly indicate that parental reports of the child's height and weight are not reliable. A report based on American data also concluded that parent-reported values for children are so poor that no correction is possible.[34]

Limitations

The overall non-response rate to the CHMS was 48%. Although adjustments were made to the sampling weights to compensate, the possibility of systematic differences between respondents and non-respondents remains.

Physical measurements were taken as many as six weeks after parents reported their child's height and weight. Some of the bias in parent-reported values may

What is already known on this subject?

- Studies based on adults have found that self-reported values underestimate weight and overestimate height, resulting in lower estimates of obesity than those obtained from measured data.
- Results of the few studies of measures of height and weight among children are inconsistent, and the implications are poorly investigated.

What does this study add?

- In the 2007 to 2009 Canadian Health Measures Survey, parents underestimated the height and weight of children aged 6 to 11, which resulted in an overestimate of body mass index (BMI) among children aged 6 to 8.
- Use of parent-reported height and weight resulted in substantial misclassification errors in prevalence estimates by BMI category.
- The misclassification that occurred with parent-reported values weakened associations between obesity and other variables such as aerobic fitness and systolic blood pressure.
- Efforts to establish correction equations to adjust for the bias in parent-reported data were ineffective.

be due to real changes that occurred in that time (children may have become taller and heavier). If this was the case, a positive association between the number of days and the bias would be expected. However, when the number of days between the household interview and the examination component of the survey was entered into the regressions for the bias in height and weight, it was not significant in either model (data not shown).

The extent to which the results of this study apply to other surveys is unknown. For example, it is not known if the bias in parent-reported data in the National Longitudinal Survey of Children and Youth (NLSCY)[37] is similar to the bias in the CHMS because the context of the two surveys differs. In the introduction to the CHMS, parents were told that they would be asked to visit a mobile examination centre where the child would be measured and weighed. This is not the case for the NLSCY, which does not include a physical measures component. Nonetheless, estimates of the prevalence of overweight and obesity from the NLSCY are similar to estimates based on parent-reported data from the CHMS.[38] Therefore, the potential for biased estimates in the NLSCY warrants investigation.

Finally, the degree to which the biases change over time in Canadian children is unknown, although analyses of Canadian adults show an increase.[39]

Conclusion

This study demonstrates the importance of collecting measured height and weight to accurately classify children with excess body weight in the Canadian population. The use of parent-reported values misrepresents associations between BMI categories and other variables related to obesity, such as aerobic fitness, systolic blood pressure and a subjective assessment of overall health. Correction equations provide only small reductions in reporting bias. Inconsistencies in the magnitude of the bias across studies illustrate the importance of collecting measured values when making temporal or international comparisons. ■

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Appendix

Table A
Regression equations for correcting parent-reported values of height (cm) and weight (kg), generated from split-sample A, household population aged 6 to 11, Canada, 2007 to 2009

	Regression coefficient (B)	95% confidence interval		Standardized regression coefficient (beta)
		from	to	
Height				
End-digit preference				
Yes	1.27	-1.62	4.15	0.04
No†	…	…	…	…
Parent-reported height (cm)	0.71*	0.61	0.81	0.87
Intercept	41.24			
Model information				
R^2=0.74				
Weight				
Sex				
Boys†	…	…	…	…
Girls	0.41	-0.26	1.08	0.02
Hours of physical activity per week				
7 or fewer	2.08*	0.89	3.26	0.06
8 to 14	0.74	-0.01	1.50	0.04
15 or more†	…	…	…	…
Parent-reported height (cm)	0.07*	0.01	0.13	0.11
Parent-reported weight (kg)	0.94*	0.85	1.02	0.89
Intercept	-7.19			
Model information				
R^2=0.92				

† reference category
* significantly different from estimate for reference category/from 0 (continuous variable) ($p < 0.05$)
... not applicable
Note: Dependent variable is measured height/weight.
Source: 2007 to 2009 Canadian Health Measures Survey.