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

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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

Authors
Margot Shields (1-613-951-4177; margot.shields@statcan.gc.ca) is with the Health Analysis Division at Statistics Canada, Ottawa, Ontario, K1A 0T6. Sarah Connor Gorber is with the Public Health Agency of Canada, Ottawa, Ontario. Ian Janssen is with Queens University, Kingston, Ontario. Mark S. Tremblay is with the Children's Hospital of Eastern Ontario Research Institute and the University of Ottawa, Ottawa, Ontario.

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		Parent-reported minus measured	95% confidence interval	
	Estimate	from	to	Estimate	from	to		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		Standardized regression coefficient (beta)	Regression coefficient (B)	95% confidence interval		Standardized regression coefficient (beta)
		from	to			from	to	
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.