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Correcting Self-Reported Estimates of Obesity: Can We More Closely Approximate Measured Values?[1]

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Abstract

This study examined the feasibility of developing correction factors to adjust self-reported measures of Body Mass Index to more closely approximate measured values. Data are from the 2005 Canadian Community Health Survey where respondents were asked to report their height and weight and were subsequently measured. Regression analyses were used to determine which socio-demographic and health characteristics were associated with the discrepancies between reported and measured values. The sample was then split into two groups. In the first, the self-reported BMI and the predictors of the discrepancies were regressed on the measured BMI. Correction equations were generated using all predictor variables that were significant at the $p<0.05$ level. These correction equations were then tested in the second group to derive estimates of sensitivity, specificity and of obesity prevalence. Logistic regression was used to examine the relationship between measured, reported and corrected BMI and obesity-related health conditions. Corrected estimates provided more accurate measures of obesity prevalence, mean BMI and sensitivity levels. Self-reported data exaggerated the relationship between BMI and health conditions, while in most cases the corrected estimates provided odds ratios that were more similar to those generated with the measured BMI.

Key Words: Obesity, Body mass index, Self-report, Direct measure, Measurement error, Bias.

1. Introduction

Past research has demonstrated that the prevalence of obesity is underestimated when estimates are based on self-reported data. Directly measured data provide more accurate estimates, but the costs associated with collecting objective measures at the population level are often prohibitive. As a result, self-reported survey data will likely remain the main source of estimates of obesity at the population level. This study examined the feasibility of developing correction factors to adjust self-reported measures of Body Mass Index (a proxy for obesity) in order to more closely approximate measured values.

2. Methods

Data for this study come from the 2005 Canadian Community Health Survey. As part of the 2005 CCHS a sub-sample of 7,376 respondents aged 12 years and older were asked to self-report their height and weight and then, later in the household interview, they were directly measured by Statistics Canada interviewers. The present study excluded children less than 18 years of age, pregnant and breastfeeding women. Respondents for whom the difference between the reported and measured estimates of height, weight or BMI was more than 3 standard deviations from the mean were considered outliers and were also excluded from the analysis. This left 4080

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[1] This is a summary of the following more detailed manuscript: Connor Gorber S, Shields M, Tremblay MS, McDowell I. The feasibility of establishing correction factors to adjust self-reported estimates of obesity in the Canadian Community Health Survey. *Health Reports* 2008;19: 71-82.

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respondents with measured and reported values for height and weight. CCHS interviewers were trained to measure height and weight. Height was measured to the nearest 0.5 cm and weight to the nearest 0.1 kg.

The full sub-sample (n=4080) of respondents was used to determine which factors were associated with the bias between the reported and measured estimates of BMI. The bias was calculated by subtracting the measured value from the reported value; negative values indicated underestimation and positive values indicated overestimation. Multiple linear regression was used with the bias as the dependent variable in the model and socio-demographic and health variables, selected based on a review of the literature, entered as independent variables. Separate models were estimated with the bias in weight, height and BMI as outcome variables. All models were estimated separately for males and females because the bias has been shown differ between these two groups (Niedhammer et al., 2000; Ziebland et al., 1996; Bostrom and Diderichsen, 1997). Significant variables ($p<0.05$) were used to develop the correction equations.

The sample was then randomly divided into two parts, split sample A and split sample B. Split sample A was used to generate the correction equations using the variables that were significantly associated with the bias in height, weight and BMI that were identified in the first step of the analysis. Split sample B was used to test them. In order to generate the correction equations the measured value was used as the outcome variable and the self-reported value and any variables that were significantly associated with the bias from the first part of the study were used as independent variables. Only significant independent variables (or categorical variables for which at least one category was significant) were retained for the final correction equations.

Four models were tested, two Full Models and two Reduced Models. In model 1 (the first Full Model) estimates of height and weight were first adjusted based on the predictors that were significantly related to the reported-measured bias in height and weight (respectively) in step 1. BMI was then calculated using the adjusted values of height and weight. In model 2 (the second Full Model) BMI was adjusted by regressing the predictors of the bias in BMI from step 1 directly onto measured BMI. The reduced models were similar, except that only the reported estimates of height, weight and BMI were used as independent predictors of the measured values.

Once the correction equations were generated from split sample A, they were applied to the data in split sample B. Descriptive statistics (means, prevalence of selected categories) were used to compare the reported, measured and corrected estimates of obesity. Sensitivity (the proportion of obese respondents, based on the measured values, who were classified as such based on the reported or corrected estimates) and specificity (the proportion of the non-obese who were correctly classified based on the reported or corrected estimates) were used to indicate whether the corrected estimates improved BMI classification compared to the reported estimates. Respondents were categorized according to the World Health Organization (World Health Organization, 1995) and Canadian classification guidelines (Health Canada, 2003) which characterize individuals into underweight (BMI <18.5 kg/m^2), normal weight (BMI 18.5-24.9 kg/m^2), overweight (BMI 25.0-29.9 kg/m^2) and obese (BMI 30.0 kg/m^{2}or over) categories.

Logistic regression was then used in order to determine if the corrected estimates more accurately modeled the relationship between obesity and obesity-related health conditions than self-reported values. All models controlled for age and sex and examined the relationship between BMI (measured, reported and corrected) and one of the following six obesity-related conditions: diabetes, heart disease, hypertension, arthritis, activity limitations and fair or poor self-rated health. This analysis was restricted to those aged 40 years or older because these conditions are more prevalent in these age ranges.

Data were appropriately weighted and all measures of variance were estimated with the bootstrap technique to account for the CCHS's complex survey design (Rao et al., 1991; Rust and Rao, 1996). SAS (version 9.1) was used for all analyses.

3. Results

Consistent with past research, mean values of self-reported height were over-estimated while weight and BMI were under-estimated. Males overestimated height by 1.08 cm and underestimated weight by 1.84 kg and BMI by 0.94

kg/m^2. For women height was overestimated by 0.56 cm and weight and BMI were underestimated by 2.47 kg and 1.19 kg/m^2.
The final correction equations generated from split sample A were as follows:

Males
Full Model 1

$$\begin{aligned}\text{Weight}_{(\text{measured})} = {} & -0.30+1.01(\text{weight}_{\text{reported}})+0.54(\text{age25-34})+0.39(\text{age35-44}) \\ & +0.50(\text{age45-54})+1.69(\text{age55-64})+0.83(\text{age65-74})+0.39(\text{75andolder}) \\ & +1.16(\text{overweight})-1.52(\text{underweight})\end{aligned}$$

$$\begin{aligned}\text{Height}_{(\text{measured})} = {} & 12.17+0.93(\text{height}_{\text{reported}})-1.48(\text{age25-34})-0.43(\text{age35-44})-1.23(\text{age45-54}) \\ & -2.44(\text{age55-64})-2.87(\text{age65-74})-2.84(\text{75and older})+2.22(\text{life dissatisfaction})\end{aligned}$$

Full Model 2

$$\begin{aligned}\text{BMI}_{(\text{measured})} = {} & -0.67+1.04(\text{BMI}_{\text{reported}})+0.64(\text{age25-34})+0.31(\text{age35-44}) \\ & +0.39(\text{age45-54})+1.28(\text{age55-64})+1.16(\text{age65-74})+0.86(\text{75and older}) \\ & -0.97(\text{life dissatisfaction})-0.73(\text{underweight})\end{aligned}$$

Reduced Model 3

$$\text{Weight}_{(\text{measured})} = -2.19+1.05(\text{weight}_{\text{reported}})$$
$$\text{Height}_{(\text{measured})} = 7.70+0.95(\text{height}_{\text{reported}})$$

Reduced Model 4

$$\text{BMI}_{(\text{measured})} = -1.08+1.08(\text{BMI}_{\text{reported}})$$

Females
Full Model 1

$$\text{Weight}_{(\text{measured})} = -1.25+1.04(\text{weight}_{\text{reported}})+1.25(\text{overweight})+0.52(\text{end digit preference})$$

$$\begin{aligned}\text{Height}_{(\text{measured})} = {} & 14.85+0.91(\text{height}_{\text{reported}})-1.20(\text{age25-34})-0.87(\text{age35-44})-0.59(\text{age45-54}) \\ & -1.34(\text{age55-64})-1.42(\text{age65-74})-3.79(\text{75andolder}) \\ & -0.32(\text{ethnicity E/SE Asian})-0.73(\text{ethnicity other})-0.66(\text{activity limitation})\end{aligned}$$

Full Model 2

$$\begin{aligned}\text{BMI}_{(\text{measured})} = {} & 1.01+1.01(\text{BMI}_{\text{reported}})-0.91(\text{high school educ.})-0.32(\text{some post secondary educ.})-0.53(\text{post} \\ & \text{secondary educ.})+0.70(\text{overweight})+0.29(\text{end digit preference})\end{aligned}$$

Reduced Model 3

$$\text{Weight}_{(\text{measured})} = -2.14+1.07(\text{weight}_{\text{reported}})$$
$$\text{Height}_{(\text{measured})} = 8.05+0.95(\text{height}_{\text{reported}})$$

Reduced Model 4

$$\text{BMI}_{(\text{measured})} = -0.12+1.05(\text{BMI}_{\text{reported}})$$

These equations were applied to data in split-sample B in order to generate corrected estimates of height, weight and BMI. Mean values of the measured, reported and corrected data from split sample B are displayed in Table 3-1. In all cases reported estimates were statistically different from the measured values and the modeled estimates were closer than the reported estimates to the true measured values. In all but one case (the difference in BMI for females in model 3) the modeled and measured means were not statistically different.

Table 3-1

Mean values of weight, height and BMI for measured, reported and corrected data, generated from split-sample B

	Sample size	Measured	Reported	Corrected			
				Model 1 (Full) Height and Weight	Model 2 (Full) BMI	Model 3 (Reduced) Height and Weight	Model 4 (Reduced) BMI
Mean height (cm)							
Males	942	175.21	176.35*	175.42	…	175.44	…
Females	1087	161.71	162.28*	161.73	…	161.73	…
Mean weight (kg)							
Males	947	83.24	81.44*	83.26	…	83.27	…
Females	1080	66.91	64.47*	66.76	…	66.75	…
Mean BMI (kg/m^2)							
Males	949	27.09	26.12*	27.00	27.05	26.98	27.03
Females	1080	25.73	24.55*	25.60	25.69	25.58*	25.68

… not applicable

* significantly different from measured estimate ($p<0.05$)

Obesity prevalence is reported in Table 3-2. For males, 23.1% were obese by the measured data, 13.8% by the reported data while the corrected estimates generated prevalence estimates of 19-22%. Measured, reported and modeled rates were similar for the overweight category for males but self-report overestimated the numbers who were in the normal weight range. The corrected estimates decreased this reporting bias by 9 to 11 percentage points so that the modeled and measured estimates were similar. For females, 18.9% were obese by measurement compared to 12.5% for reported values. The modeled estimates generated obesity prevalence estimates of 18.7% (model 1), 18.3% (model 2), 18.2% (model 3) and 18.3% (model 4). Similarly, for the overweight estimates, modeled values were closer than the self-reported values to the measured prevalence, with a slight 1-2% overestimate in the modeled values. Sample sizes were too small in the underweight categories to generate reliable estimates.

Sensitivity and specificity values for reported and corrected data were also calculated. Sensitivity values in the normal weight category for self-reported data were 93.9% for males and 91.8% for females, meaning that in most cases reported estimates correctly classified people of normal weight into the normal weight category. Sensitivities for the overweight and obese categories fell to 71.1% and 58.7% respectively for males and to 62.6% and 68.5% for females. When the data were corrected, the sensitivities increased for both the overweight and obese categories; the corrected numbers accurately classified as many as 86.1% of obese females, 76% of obese males, 79.7% of overweight females and 82.8% of overweight males. Corrected estimates decreased sensitivities for those in the normal weight range, however. Specificities were the highest for the underweight and obese categories, indicating that it is rare for someone to be classified into these groups unless they actually are underweight or obese.

Table 3-2

Percentage of the population in different weight categories based on reported, measured and corrected data from split-sample B

BMI Category	Measured	Reported	Corrected Model 1 (Full) Height and Weight	Corrected Model 2 (Full) BMI	Corrected Model 3 (Reduced) Height and Weight	Corrected Model 4 (Reduced) BMI
Males						
Underweight	F	F	F	F	F	F
Normal weight	32.2	43.1*	33.6	32.2	32.8	33.8
Overweight	44.0	42.5	44.1	45.6	48.0	45.7
Obese (I-III)	23.1	13.8*	21.9	21.6	18.9*	20.1
Females						
Underweight	3.1^{E}	4.7*^{E}	2.7^{E}	1.5*^{E}	2.7^{E}	1.9^{E}
Normal weight	46.9	58.2*	46.8	47.0	46.6	47.1
Overweight	31.1	24.6*	31.8	33.2	32.4	32.7
Obese (I-III)	18.9	12.5*	18.7	18.3	18.2	18.3

^{E} interpret with caution (coefficient of variation between 16.6% and 33.3%)
F too unreliable to be published (coefficient of variation greater than 33.3%)
* significantly different from measured estimate (p<0.05)

Data in Table 4-1 display the adjusted odds ratios relating measured, reported and corrected BMI to six obesity-related health conditions. The reported and measured models were previously published in a paper that demonstrated that self-reported BMI exaggerates the relationship between obesity and these obesity-related health conditions (Shields et al., 2008). Unique to this analysis is that the models have been re-generated based on the corrected estimates. When compared to the odds ratios from the reported models, the ratios for the corrected models are reduced in most cases (i.e., are more similar to the measured values). Arthritis is an exception, with the corrected estimates inflating the relationship for those who are overweight or obese (class II or III, BMI≥35 kg/m^2) even higher than what they would be if based on self-report. In addition, the odds ratios for obese class I are higher than the reported odds ratios for diabetes in models 1 and 2 and for high blood pressure in models 3 and 4.

The data on measured height and weight were available on only a sub-sample of the 2005 CCHS. However, the ultimate goal of developing correction equations is to be able to apply them to the broader survey. When applied to the full sample of the 2005 CCHS respondents (without different adjustments for phone and in-person interviews) who were 18 years and older and who were not pregnant or breastfeeding (n=118,383), the models generated estimates of obesity that were similar to, although slightly lower than, the measured values (see Table 4-2). Based on data from both split sample A and B, measured obesity prevalence was 25.6% in males and 22.3% in females while reported prevalence was 16% for both males and females. The models generated prevalence rates of approximately 23% for males and of 21% for females.

4. Conclusion

Although measured data for height and weight provide the most accurate estimates of the prevalence of obesity based on the BMI, the costs of collecting directly measured data are often prohibitive on large population based studies. Corrected estimates, though not identical to the measured values of BMI, are a significant improvement over the self-reported estimates, which substantially underestimate obesity prevalence and overestimate the relationship between obesity and disease.

Table 4-1

Adjusted odds ratios relating measured, self-reported and corrected Body Mass Index (BMI) to selected health conditions, household population aged 40 years or older

BMI category (range kg/m²)	Based on measured values: Adjusted odds ratio	Based on measured values: 95% confidence interval	Based on self-reported values: Adjusted odds ratio	Based on self-reported values: 95% confidence interval	Based on corrected values Model 1 - Full Height and weight: Adjusted odds ratio	Based on corrected values Model 1 - Full Height and weight: 95% confidence interval	Based on corrected values Model 2 - Full BMI: Adjusted odds ratio	Based on corrected values Model 2 - Full BMI: 95% confidence interval	Based on corrected values Model 3 - Reduced Height and weight: Adjusted odds ratio	Based on corrected values Model 3 - Reduced Height and weight: 95% confidence interval	Based on corrected values Model 4 - Reduced BMI: Adjusted odds ratio	Based on corrected values Model 4 - Reduced BMI: 95% confidence interval
Diabetes												
Normal weight (18.5 to 24.9)	1.0	...	1.0	...	1.0	...	1.0	...	1.0	...	1.0	...
Overweight (25.0 to 29.9)	1.4	0.7 to 2.8	2.6 *	1.5 to 4.3	1.8	0.9 to 3.3	2.0 *	1.1 to 3.8	1.8 *	1.1 to 3.0	2.0 *	1.2 to 3.3
Obese class I (30.0 to 34.9)	2.2 *	1.0 to 4.5	3.2 *	1.8 to 5.6	3.3 *	1.8 to 6.0	3.9 *	2.1 to 7.0	3.1 *	1.7 to 5.7	3.2 *	1.8 to 5.8
Obese class II & III (>= 35.0)	5.9 *	2.5 to 14.0	9.0 *	4.5 to 17.9	6.8 *	3.7 to 12.5	7.3 *	3.9 to 13.9	7.6 *	4.0 to 14.2	7.4 *	4.0 to 13.7
High blood pressure												
Normal weight (18.5 to 24.9)	1.0	...	1.0	...	1.0	...	1.0	...	1.0	...	1.0	...
Overweight (25.0 to 29.9)	2.1 *	1.5 to 3.0	2.7 *	1.9 to 3.8	2.3 *	1.6 to 3.2	2.5 *	1.8 to 3.5	2.5 *	1.7 to 3.5	2.4 *	1.7 to 3.3
Obese class I (30.0 to 34.9)	3.4 *	2.3 to 5.2	4.2 *	2.9 to 6.3	4.0 *	2.8 to 5.9	4.1 *	2.8 to 6.0	4.5 *	3.0 to 6.6	4.7 *	3.2 to 7.0
Obese class II & III (>= 35.0)	5.2 *	2.9 to 9.3	6.8 *	3.2 to 14.8	6.0 *	3.3 to 10.7	6.0 *	3.4 to 10.5	6.1 *	3.4 to 10.9	5.6 *	3.2 to 9.8
Heart disease												
Normal weight (18.5 to 24.9)	1.0	...	1.0	...	1.0	...	1.0	...	1.0	...	1.0	...
Overweight (25.0 to 29.9)	1.0	0.6 to 1.7	1.4	0.9 to 2.3	1.3	0.8 to 2.2	1.3	0.8 to 2.2	1.2	0.7 to 2.0	1.4	0.8 to 2.2
Obese class I (30.0 to 34.9)	1.5	0.8 to 2.9	1.6	1.0 to 2.6	1.2	0.7 to 2.0	1.4	0.8 to 2.4	1.3	0.8 to 2.2	1.5	0.9 to 2.5
Obese class II & III (>= 35.0)	2.1	1.0 to 4.4	3.7 *	1.8 to 7.7	3.3 *	1.8 to 6.2	3.4 *	1.8 to 6.5	2.9 *	1.5 to 5.6	2.8 *	1.5 to 5.5
Arthritis												
Normal weight (18.5 to 24.9)	1.0	...	1.0	...	1.0	...	1.0	...	1.0	...	1.0	...
Overweight (25.0 to 29.9)	1.2	0.8 to 1.7	1.2	0.8 to 1.7	1.5 *	1.1 to 2.0	1.5 *	1.1 to 2.1	1.5 *	1.1 to 2.0	1.4 *	1.0 to 1.9
Obese class I (30.0 to 34.9)	1.2	0.8 to 1.8	2.0 *	1.3 to 3.0	1.7 *	1.2 to 2.5	1.9 *	1.3 to 2.8	1.9 *	1.3 to 2.8	1.7 *	1.2 to 2.5
Obese class II & III (>= 35.0)	2.7 *	1.6 to 4.6	3.1 *	1.5 to 6.3	3.5 *	2.0 to 5.8	3.2 *	1.8 to 5.4	3.2 *	1.9 to 5.6	3.4 *	1.9 to 6.0
Activity limitation												
Normal weight (18.5 to 24.9)	1.0	...	1.0	...	1.0	...	1.0	...	1.0	...	1.0	...
Overweight (25.0 to 29.9)	1.2	0.9 to 1.6	1.2	0.9 to 1.6	1.2	0.9 to 1.7	1.1	0.8 to 1.5	1.0	0.8 to 1.4	1.1	0.8 to 1.5
Obese class I (30.0 to 34.9)	1.5 *	1.1 to 2.2	2.0 *	1.3 to 3.0	1.4	0.9 to 2.0	1.4	1.0 to 2.1	1.5 *	1.0 to 2.1	1.5 *	1.0 to 2.2
Obese class II & III (>= 35.0)	2.9 *	1.7 to 4.7	4.3 *	2.2 to 8.2	4.2 *	2.6 to 6.8	3.7 *	2.3 to 6.1	3.9 *	2.4 to 6.5	3.1 *	1.8 to 5.2
Fair/poor self-perceived health												
Normal weight (18.5 to 24.9)	1.0	...	1.0	...	1.0	...	1.0	...	1.0	...	1.0	...
Overweight (25.0 to 29.9)	0.8	0.5 to 1.2	1.3	0.9 to 2.0	1.1	0.7 to 1.6	1.1	0.8 to 1.7	1.0	0.7 to 1.5	1.0	0.7 to 1.5
Obese class I (30.0 to 34.9)	1.7 *	1.0 to 2.7	2.8 *	1.8 to 4.3	1.6 *	1.0 to 2.5	1.7 *	1.1 to 2.7	2.1 *	1.3 to 3.3	2.1 *	1.4 to 3.3
Obese class II & III (>= 35.0)	2.9 *	1.6 to 5.2	4.5 *	2.0 to 10.2	4.1 *	2.4 to 7.0	4.3 *	2.4 to 7.8	3.5 *	1.9 to 6.5	3.6 *	2.0 to 6.6

... not applicable

* significantly different from estimate for normal weight category ($p < 0.05$)

Note: Models control for age (continuous) and sex. Odds ratios for underweight group not reported due to low sample sizes.

Table 4-2

Percentage of the population in different weight categories when corrected estimates were applied to the full 2005 Canadian Community Health Survey Sample

BMI Category	Measured*	Reported*	Corrected Model 1 (Full) Height and Weight	Corrected Model 2 (Full) BMI	Corrected Model 3 (Reduced) Height and Weight	Corrected Model 4 (Reduced) BMI
Males						
Underweight	0.9[E]	0.7[E]	1.0	1.2	0.9	1.0
Normal weight	32.4	41.8	31.2	30.0	31.2	33.1
Overweight	41.1	41.2	44.3	45.4	44.9	42.9
Obese (I-III)	25.6	16.3	23.5	23.4	23.0	23.1
Females						
Underweight	2.6[E]	4.3	2.7	2.1	2.5	2.0
Normal weight	46.1	54.0	46.5	46.4	46.8	46.7
Overweight	29.1	26.1	29.9	30.6	30.1	30.6
Obese (I-III)	22.3	15.7	20.9	21.0	20.7	20.8

[E] interpret with caution (coefficient of variation between 16.6% and 33.3%)

* measured and reported values were generated based on the full sample of respondents who had their height and weight measured

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