

Accuracy of Self-Reported Height, Weight, and BMI Over Time in Emerging Adults



Leah M. Lipsky, PhD,¹ Denise L. Haynie, PhD,¹ Christine Hill, BS,¹ Tonja R. Nansel, PhD,¹ Kaigang Li, PhD,² Danping Liu, PhD,³ Ronald J. Iannotti, PhD,⁴ Bruce Simons-Morton, PhD¹

Introduction: Self-reported height and weight may lead to inaccurate estimates of associations between BMI and health indicators. The purpose of this study is to assess anthropometric misreporting in emerging adults, compare weight classification by self-reported and direct measures, and examine associations of self-reported and direct measures with cardiometabolic biomarkers.

Methods: Self-reported and directly measured height and weight were obtained in five waves of a nationally representative cohort study of U.S. tenth graders ($n=2,785$) conducted in 2010–2016; data were analyzed in 2018. Cardiometabolic biomarkers were assessed in three waves in a systematically recruited subsample ($n=567$). Pearson correlations (r) and Lin's concordance correlations (ρ_c) evaluated misreporting. Gwet agreement coefficient-1 evaluated weight classification agreement by self-reported and direct measures. Generalized estimating equations examined associations of cardiometabolic biomarkers with self-reported and direct measures.

Results: Participants overreported height by 1.0–1.7 cm and underestimated weight by 0.6–1.7 kg. Self-reported BMI was 0.6–1.0 lower than measured. Self-reported and measured height, weight, and BMI were strongly correlated ($r=0.88$ – 0.97 , 0.86 – 0.98 , and 0.65 – 0.96 , respectively) and concordant ($\rho_c=0.82$ – 0.96 , 0.94 – 0.97 , and 0.65 – 0.95 , respectively). Agreement of weight classification by self-reported and direct measures ranged from Gwet agreement coefficient-1= 0.79 – 0.94 . Associations of ten cardiometabolic biomarkers with self-reported BMI, measured BMI, and waist circumference were similar in magnitude, direction, and precision.

Conclusions: Self-reported and measured BMI were strongly correlated and concordant, providing substantial to near-perfect agreement in weight classification. Findings suggest self-reported BMI in U.S. emerging adults provides nearly identical estimates of associations with cardiometabolic biomarkers.

Am J Prev Med 2019;56(6):860–868. Published by Elsevier Inc. on behalf of American Journal of Preventive Medicine.

INTRODUCTION

The transition from adolescence to young adulthood (emerging adulthood) is a critical period in the development of excess body weight.^{1,2} Overweight/obesity prevalence in adults aged 20–39 years (70%) is roughly double that in adolescents (30%).³ Weight gain from ages 18 to 55 years commonly exceeds 20 kg and is positively associated with risk of multiple adverse health outcomes.⁴ BMI from self-reported values are widely used in large population studies, which have important strengths for investigating determinants and consequences of excess body weight in emerging adults.

From the ¹Social and Behavioral Sciences Branch, Division of Intramural Population Health Research, Eunice Kennedy Shriver National Institute of Child Health and Human Development, Bethesda, Maryland; ²Department of Health and Exercise Science, Colorado State University, Fort Collins, Colorado; ³Biostatistics Branch, Division of Cancer Epidemiology and Genetics, National Cancer Institute, Rockville, Maryland; and ⁴CDM Group, Bethesda, Maryland

Address correspondence to: Leah M. Lipsky, PhD, Social and Behavioral Sciences Branch, Division of Intramural Population Health Research, Eunice Kennedy Shriver National Institute of Child Health and Human Development, 6710B Rockledge Drive, Room 3139C MSC 7004, Bethesda MD 20817. E-mail: lipskylm@mail.nih.gov.

0749-3797/\$36.00

<https://doi.org/10.1016/j.amepre.2019.01.004>

However, questions remain concerning whether BMI misreporting biases estimates of associations with predictors and health outcomes.⁵

In adolescents^{5–9} and adults,¹⁰ self-reported BMI underestimates measured BMI because of overreported height and underreported weight, with more underreporting of BMI in those with higher measured BMI.^{6,8,9,11–14} Although some studies have reported differences in misreporting by sex and race/ethnicity, findings are variable.^{12,13,15–21} Additionally, only four studies have examined misreporting in emerging adults,^{22–25} and these have limited generalizability to the current population, given the use of non-contemporaneous data^{23,25} or inclusion of only college²² or female samples.²⁴ Furthermore, to the authors' knowledge, no studies have obtained repeated self-reported and measured values in youths or young adults.¹¹

Another critical knowledge gap concerns whether BMI misreporting yields inaccurate estimates of associations with health indicators. Three studies found similar associations of diabetes diagnosis and cardiometabolic biomarkers with self-reported and measured BMI in older adults,^{14,21,26} but these relationships have not been evaluated in younger samples. In addition, it is unknown whether associations of cardiometabolic biomarkers with self-reported BMI in this population differ from associations with alternative objective adiposity measures, such as waist circumference (WC), which is considered a more direct measure of central adiposity.^{27,28}

The objectives of this study are to investigate in U.S. emerging adults: (1) the extent of height, weight, and BMI misreporting; (2) the stability of misreporting over time; (3) comparisons of weight classification by self-reported BMI, measured BMI, and measured WC; and (4) comparisons of associations of cardiometabolic biomarkers with self-reported BMI, measured BMI, and measured WC.

METHODS

Study Sample

Data come from the NEXT Generation Health Study,^{29,30} a prospective study of a nationally representative cohort of U.S. emerging adults assessed at seven annual waves from 2010 to 2016 (83% retention in Wave 7). Prespecified endpoints included health behaviors (e.g., eating behaviors, physical activity, sedentary behavior, substance use, driving behavior) and health status indicators (e.g., BMI, WC, serum cardiometabolic biomarkers). Sampling and recruitment have been described elsewhere.^{29,31} Briefly, a total of 2,785 tenth graders were enrolled using a three-stage stratified sampling method. A national subsample (NEXT Plus, $n=567$) of an approximately equal number of normal weight (≥ 5 th BMI percentile, < 85 th BMI percentile, $n=286$) and overweight participants (≥ 85 th BMI percentile, $n=281$) was enrolled

to contribute additional assessments beginning in Wave 1. The participant assessment timeline is provided in [Appendix Table 1](#) (available online). Parental informed consent and youth assent were obtained at baseline, and youth provided informed consent upon reaching age 18 years. The IRB at the Eunice Kennedy Shriver National Institute of Child Health and Human Development approved the study.

Participants completed an annual survey that queried height (in feet and inches) and weight (in pounds). Participants were asked: *How tall are you without shoes?* and *How much do you weigh without clothes?* Questions were validated in adolescents in the Youth Risk Behavior Survey.¹³ Responses in inches and pounds were converted to centimeters (cm) and kilograms (kg) for analyses. Participants reported sociodemographic characteristics (age, race/ethnicity, SES) at baseline, and annually reported past-month alcohol use and smoking. Parent education was ascertained during the consent process.

Measures

Trained and certified health researchers measured height, weight, and WC of all participants at baseline and Wave 3, and for all participants attending NEXT Plus schools (both main study and NEXT Plus participants) in Wave 2. Anthropometrics of NEXT Plus participants were additionally obtained in Wave 4 and Wave 7. Anthropometrics were obtained for most participants (99%) after survey completion. After removing shoes and bulky layers of clothing, height was measured to the nearest 0.1 cm, and weight to the nearest 0.1 kg. WC was measured at the iliac crest with the waist fully exposed. Anthropometrics were obtained in duplicate; a third measurement was taken if the first two measures exceeded prespecified differences (1.0 cm for height and WC, 0.2 kg for weight). The mean of the two closest measures was used for analyses.

Home visits were conducted in NEXT Plus participants during Wave 1, Wave 4, and Wave 7 to measure blood pressure and collect blood samples that were analyzed in a central laboratory. Fasting blood glucose (mmol/L), HbA1c (mmol/mol), serum C-reactive protein (nmol/L), triglycerides (mmol/L), total cholesterol (mmol/L), high-density lipoprotein cholesterol (mmol/L), low-density lipoprotein cholesterol (mmol/L), and uric acid ($\mu\text{mol/L}$) were measured in Wave 1, Wave 4, and Wave 7.

Weight status was determined by measured and self-reported BMI. Until participants reached age 20 years, weight status was determined using sex- and age-specific percentile cut offs.³² From age 20 years, weight status was determined according to adult BMI cut offs.²⁷ National Heart, Lung, and Blood Institute cut offs for WC (>102 cm for males; >88 cm for females) were used to classify central adiposity.²⁷

Statistical Analysis

Analyses described below were performed in 2018 using Stata/SE, version 14.2. Analyses of the full sample accounted for the complex sampling design.

Misreporting was determined by subtracting measured from self-reported values. Analyses were conducted both including and excluding biologically implausible values (BIV), determined using published cut offs for youths aged ≤ 20 years³³ and adults.³⁴ Misreporting was summarized (mean and 95% CI) for each wave. To enable comparisons with previous research, Pearson's correlation

coefficients between self-reported and measured values were calculated.³⁵ However, because the Pearson method is an inadequate indicator of reliability,³⁶ concordance was evaluated using Lin's concordance coefficient, a reliability measure that indicates how closely the line of correlation passes through the line of concordance (slope of 1),^{37,38} and Bland and Altman's limits of agreement, which gives the mean and 95% prediction interval of the difference between objective measurements and self-reported values.³⁹ In the NEXT Plus subsample, generalized estimating equations examined differences in misreporting across all waves, and longitudinal relationships of misreporting with participant characteristics.

The authors compared classification of participants into categories of weight status (using measured and self-reported BMI) and central adiposity (using measured WC). Agreement of (1) self-reported with measured weight status, (2) self-reported obesity with central adiposity, and (3) measured obesity with central adiposity was estimated using Gwet's agreement coefficient-1 (Gwet AC1),⁴⁰ a weighted agreement coefficient that is resistant to the paradoxes of κ and accommodates individuals rated by only one rater. The method calculates the probability that the agreement coefficient falls within benchmark levels defined by Landis and Koch⁴¹; values of 0–0.20, 0.21–0.40, 0.41–0.60, 0.61–0.80, and >0.80 are interpreted as slight, fair, moderate, substantial, and near-perfect agreement, respectively.

Outcomes with skewed distributions were ln-transformed. Linear regression analyses examined cross-sectional relationships of cardiometabolic biomarkers with self-reported BMI, measured BMI, and measured WC to provide findings comparable with previous studies. Additionally, to improve statistical efficiency and power, generalized estimating equation models estimated longitudinal associations of cardiometabolic biomarkers with self-reported BMI, measured BMI, and measured WC using data from all assessments in the NEXT Plus subsample. Models adjusted for height, sex, concurrent age, race/ethnicity, smoking, and alcohol use.

RESULTS

The sample was aged \cong 16 years at baseline, and 54% female (Appendix Table 2, available online). Approximately half the participants were non-Hispanic white, and 40% of the full sample (49% of the NEXT Plus subsample) were overweight or obese.

In each wave, between 1.0% and 1.4% of self-reported heights and 0.2% and 0.8% of self-reported weights were biologically implausible. In the full sample, height was overreported by 1.4–1.5 cm and weight underreported by 0.92–1.8 kg, leading to underreporting of BMI by up to 1 kg/m² (Table 1). NEXT Plus participants overreported height by 1.00–1.56 cm and underreported weight by 0.63–1.36 kg, leading to BMI underreporting of 0.53–0.86 kg/m².

Measured and self-reported height, weight, and BMI in each wave were strongly correlated. As shown in Appendix Table 3 (available online), Pearson's correlations were $r \geq 0.94$ for self-reported and measured height, ≥ 0.96 for weight, and ≥ 0.93 for BMI (excluding BIV). Lin's concordance correlations were $\rho_c \geq 0.93$ for height (except for Wave 1 in the NEXT Plus subsample, $\rho_c = 0.83$), ≥ 0.95 for weight, and ≥ 0.92 for BMI. Including BIV had minimal effect on estimates of correlation or concordance, except for Wave 1 height (full sample and NEXT Plus subsample) and BMI (full sample) because of the sensitivity of correlation and concordance measures to outliers. Limits of agreement were within 3–4 for BMI and were smaller in analyses excluding BIV.

Models examining longitudinal associations of participant characteristics with misreporting (Table 2) indicate that height overreporting was stable over time; the positive coefficients of wave in models estimating weight and BMI misreporting reflect less underreporting over time. Baseline age was not associated with height misreporting, but older age was associated with greater weight and BMI underreporting.

Mean misreporting for each covariate group was calculated from the regression coefficients, holding other covariates fixed at the referent values. Normal-weight participants overreported height by an average of 1.01 (SE=0.11 cm), accurately reported their weight (misreporting= 0.007 [SE=0.15 kg]), and underreported their BMI by 0.25 (SE=0.06 kg/m²). Relative to normal-weight participants, overweight and obese participants, respectively, had

Table 1. Misreporting^a Over Time in U.S. Emerging Adults

Wave	Full sample, ^b Mean (95% CI)			Subsample, ^c Mean (95% CI)		
	Height, cm	Weight, kg	BMI	Height, cm	Weight, kg	BMI
1	1.39 (1.07, 1.7)	-1.77 (-2.4, -1.2)	-1.04 (-1.3, -0.7)	1.24 (0.9, 1.6)	-1.36 (-1.7, -1.0)	-0.86 (-1.0, 0.7)
2	1.45 (1.2, 1.7)	-0.92 (-1.2, -0.6)	-0.73 (-0.8, -0.6)	1.30 (1.1, 1.5)	-1.09 (-1.5, -0.7)	-0.80 (-1.0, -0.6)
3	1.48 (1.3, 1.7)	-0.97 (-1.3, -0.7)	-0.77 (-0.9, -0.6)	1.56 (1.3, 1.8)	-0.76 (-1.1, -0.4)	-0.74 (-0.9, -0.6)
4	—	—	—	1.25 (1.0, 1.5)	-0.63 (-1.1, -0.2)	-0.53 (-0.7, -0.4)
7	—	—	—	1.00 (0.7, 1.3)	-0.93 (-1.4, -0.4)	-0.64 (-0.8, -0.4)

^aMeasured subtracted from self-reported values; estimates exclude biologically implausible values for self-reported height or weight.

^b $n=2,784$, Mean \pm SD wave 1 age=16.3 \pm 0.5 years.

^c $n=567$.

Table 2. Misreporting^a Over Time, and Associations With Participant Characteristics in the NEXT Plus Subsample

Independent variables	Height, cm		Weight, kg		BMI	
	β (SE)	p-value	β (SE)	p-value	β (SE)	p-value
Wave	−0.04 (0.04)	0.29	0.20 (0.06)	0.002	0.10 (0.03)	<0.001
Baseline age, years	0.22 (0.16)	0.16	−0.77 (0.21)	<0.001	−0.26 (0.08)	0.002
Measured weight status ^b						
Underweight	0.75 (0.55)	0.18	1.13 (0.81)	0.16	0.64 (0.33)	0.06
Normal weight (ref)						
Overweight	0.61 (0.16)	<0.001	−1.11 (0.24)	<0.001	−0.65 (0.10)	<0.001
Obese	0.42 (0.18)	0.02	−3.10 (0.25)	<0.001	−1.40 (0.10)	<0.001
Sex						
Male (ref)						
Female	−0.98 (0.17)	<0.001	−0.33 (0.22)	0.13	0.08 (0.09)	0.35
Race/ethnicity						
Non-Hispanic white (ref)						
Non-Hispanic black	−0.46 (0.24)	0.05	0.14 (0.31)	0.64	0.27 (0.12)	0.03
Hispanic	−0.04 (0.19)	0.83	−0.22 (0.25)	0.36	−0.06 (0.10)	0.52
Other	−0.13 (0.40)	0.74	−0.37 (0.52)	0.48	−0.19 (0.20)	0.37

Note: Boldface indicates statistical significance ($p < 0.05$).

^aEstimates from longitudinal generalized estimating equations excluding biologically implausible self-reported values.

^bWeight classification according to Centers for Disease Control and Prevention age- and sex-specific BMI percentile cut offs until age 20 years (underweight= <5 ; normal weight= ≥ 5 , <85 ; overweight= ≥ 85 , <95 ; obese= ≥ 95). From age ≥ 20 years, underweight=BMI <18.5 ; normal weight=BMI ≥ 18.5 , <25 ; overweight=BMI ≥ 25 , <30 ; obese=BMI ≥ 30 .

greater height overreporting (by 1.69 [SE=0.14] and 1.51 [SE=0.15 cm]), weight underreporting (by −1.10 [SE=0.21] and −3.10 [SE=0.21 kg]), and BMI underreporting (by −0.90 [SE=0.08] and −1.65 [SE=0.08 kg/m²]). Males had greater height overreporting (1.85 [SE=0.12 cm]) than females (0.87 [SE=0.11 cm]) and less weight underreporting (−0.80 [SE=0.16 kg]) than females (−1.13 [SE=0.15 kg]); BMI underreporting was similar across sexes (−0.77 [SE=0.06 kg/m²] for males and −0.69 [SE=0.06 kg/m²] for females). Misreporting was not associated with race/ethnicity (Table 2), except that BMI underreporting was lower (more accurate) in black relative to white participants.

From measured BMI, the prevalence of normal weight was slightly lower, and obesity slightly higher, than estimates from self-reported BMI (Table 3). The estimated prevalence of overweight was similar according to measured and self-reported BMI.

Agreement between self-reported and measured weight status in each wave was $\geq 94\%$, with Gwet AC1 ≥ 0.90 (Appendix Table 4, available online). Agreement between measured central adiposity versus self-reported and measured overweight/obesity was $\geq 83\%$, with Gwet AC1 ranging from 0.72 to 0.96. Probabilistic benchmarks were between 0.80 and 1.00, indicating near-perfect agreement for all comparisons other than the agreement of central adiposity with measured and self-reported obesity in Wave 4 and Wave 7 (which were between 0.60 and 0.80,

indicating substantial agreement). In Wave 2 and Wave 3, Gwet AC1 of central adiposity with self-reported obesity was equivalent to that with measured obesity; Gwet AC1 of central adiposity with self-reported obesity was greater than that with measured obesity in Wave 1, Wave 4, and Wave 7.

Longitudinal model estimates (Table 4) indicated similar associations of cardiometabolic biomarkers with measured and self-reported BMI. Two noticeable differences include: (1) the positive association of fasting glucose with measured BMI was larger than the association with self-reported BMI; (2) systolic blood pressure was positively associated with both measured and self-reported BMI, but the association was stronger for measured BMI. Furthermore, associations of cardiometabolic biomarkers with measured and self-reported BMI were similar to those with measured WC. Fasting glucose was also not associated with measured WC. Estimates were similar in the unadjusted and adjusted models.

In cross-sectional analyses (Appendix Table 5, available online), comparison of nearly 30 wave-specific associations of measured and self-reported BMI with cardiometabolic biomarkers yielded only two noticeable differences: (1) Wave 1 HbA1c was positively associated with both measured and self-reported BMI, but the association with self-reported BMI was smaller and had a larger SE; and (2) the positive association in Wave 7 of fasting blood glucose with self-reported BMI had a larger

Table 3. Weight Classification Based on Measured and Self-Reported BMI

Weight classification	Full sample, ^a %, prevalence (95% CI)		NEXT Plus subsample, %, prevalence (95% CI)	
	Measured BMI	Self-reported BMI ^b	Measured BMI	Self-reported BMI
Wave 1				
Underweight ^c	1.4 (0.8, 2.6)	1.7 (0.9, 3.2)	0	1.6 (0.8, 3.3)
Normal weight	59.5 (55.9, 63.0)	68.2 (64.2, 71.9)	51.0 (46.8, 55.1)	61.0 (56.3, 65.5)
Overweight	18.5 (16.5, 20.7)	16.9 (14.4, 19.7)	22.8 (19.5, 26.4)	19.0 (15.6, 23.0)
Obese	20.6 (17.9, 23.5)	13.2 (10.9, 15.9)	26.3 (22.8, 30.1)	18.3 (15.0, 22.3)
Wave 2				
Underweight	1.9 (1.1, 3.3)	2.9 (1.7, 4.9)	1.2 (0.5, 0.03)	1.5 (0.7, 3.2)
Normal weight	63.6 (59.9, 67.2)	67.7 (63.4, 71.8)	55.7 (51.4, 59.9)	62.8 (58.3, 67.1)
Overweight	16.0 (13.3, 19.0)	16.5 (13.5, 19.9)	20.0 (16.7, 23.6)	16.8 (13.7, 20.6)
Obese	18.5 (15.6, 21.8)	12.9 (11.2, 15.0)	23.2 (19.8, 27.1)	18.8 (15.5, 22.7)
Wave 3				
Underweight	2.2 (1.4, 3.6)	3.3 (2.2, 5.0)	1.0 (0.4, 2.4)	1.5 (0.6, 3.7)
Normal weight	61.9 (57.6, 65.9)	66.0 (60.5, 71.2)	55.7 (51.3, 60.0)	62.2 (56.8, 67.4)
Overweight	15.4 (12.6, 18.5)	16.3 (13.0, 20.2)	19.9 (16.6, 23.7)	19.8 (15.8, 24.5)
Obese	20.6 (17.1, 24.5)	14.4 (11.6, 17.7)	23.3 (19.8, 27.3)	16.4 (12.7, 20.9)
Wave 4				
Underweight	—	—	2.3 (1.3, 4.3)	2.4 (1.3, 4.6)
Normal weight	—	—	52.9 (48.2, 57.6)	56.5 (51.4, 61.5)
Overweight	—	—	21.3 (17.7, 25.5)	22.6 (18.6, 27.1)
Obese	—	—	23.4 (19.6, 27.7)	18.5 (14.8, 22.8)
Wave 5				
Underweight	—	—	2.5 (1.1, 4.5)	2.3 (1.1, 4.5)
Normal weight	—	—	31.4 (27.1, 36.1)	36.4 (31.5, 41.5)
Overweight	—	—	31.7 (27.3, 36.4)	33.0 (28.2, 38.1)
Obese	—	—	34.4 (29.9, 39.2)	28.4 (23.9, 33.4)

^aWeighted estimates are presented for the full sample.

^bBiologically implausible self-reported values excluded from analyses.

^cWeight classification according to Centers for Disease Control and Prevention age- and sex-specific BMI percentile cut offs until age 20 years (underweight=<5; normal weight= \geq 5, <85; overweight= \geq 85, <95; obese= \geq 95). From age \geq 20 years, underweight=BMI <18.5; normal weight=BMI \geq 18.5, <25; overweight=BMI \geq 25, <30; obese=BMI \geq 30.

SE than with measured BMI. Estimates give similar interpretations of the direction, magnitude, and precision for the relationships of cardiometabolic biomarkers with BMI regardless of whether BMI was measured or self-reported. Associations of cardiometabolic biomarkers with measured WC were similar in direction, magnitude, and precision to those of self-reported and measured BMI.

DISCUSSION

In this cohort of U.S. emerging adults, findings demonstrate modest weight underreporting and height overreporting leading to BMI underestimation by 0.5–1, consistent with previous studies.¹⁰ Self-reported and measured values were strongly correlated and had high concordance. There was near-perfect agreement in weight classification by measured and self-reported BMI, and overweight/obesity classification from both

measures had substantial or near-perfect agreement with central adiposity calculated from measured WC. Few differences were observed between associations of measured and self-reported BMI with ten cardiometabolic biomarkers assessed at three time points, and estimates were similar to associations with measured WC.

Several measures of correlation, concordance, and agreement reflect strong similarities between self-reported and measured height, weight, and BMI, supporting findings of previous investigations. Pearson correlations in adults generally exceed $r=0.73$, whereas those in youth exceed $r=0.90$.^{5,22,42–45} Although underestimation of overweight prevalence is typical, evidence consistently shows strong agreement of weight classification according to self-reported and measured BMI.^{22,45} Furthermore, findings from this study indicate substantial or near-perfect agreement (Gwet ACI ≥ 0.73) of central adiposity calculated from measured WC with obesity classification based on measured and self-reported BMI, consistent

Table 4. Associations of Self-Reported and Measured BMI With Cardiometabolic Biomarkers^a

Dependent variables	Measured BMI		Self-reported BMI		Waist circumference, cm	
	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value
CRP, nmol/L ^b						
Unadjusted	0.13 (0.007)	<0.001	0.12 (0.008)	<0.001	0.05 (0.003)	<0.001
Adjusted	0.13 (0.007)	<0.001	0.13 (0.008)	<0.001	0.05 (0.003)	<0.001
Triglycerides, mmol/L ^b						
Unadjusted	0.02 (0.002)	<0.001	0.02 (0.003)	<0.001	0.01 (0.0009)	<0.001
Adjusted	0.02 (0.002)	<0.001	0.02 (0.003)	<0.001	0.01 (0.0009)	<0.001
HbA1c, mmol/mol ^b						
Unadjusted	0.003 (0.0006)	<0.001	0.003 (0.0007)	<0.001	0.001 (0.0003)	<0.001
Adjusted	0.003 (0.0006)	<0.001	0.003 (0.0007)	<0.001	0.001 (0.0003)	<0.001
Fasting glucose, mmol/L ^b						
Unadjusted	0.002 (0.0006)	0.005	0.001 (0.0007)	0.07	0.0004 (0.0002)	0.07
Adjusted	0.002 (0.0006)	0.007	0.001 (0.0007)	0.07	0.0004 (0.0002)	0.11
Total cholesterol, mmol/L						
Unadjusted	0.03 (0.003)	<0.001	0.03 (0.005)	<0.001	0.01 (0.002)	<0.001
Adjusted	0.03 (0.004)	<0.001	0.03 (0.005)	<0.001	0.01 (0.002)	<0.001
HDL, mmol/L						
Unadjusted	−0.02 (0.002)	<0.001	−0.02 (0.002)	<0.001	−0.008 (0.0006)	<0.001
Adjusted	−0.02 (0.002)	<0.001	−0.02 (0.002)	<0.001	−0.007 (0.0006)	<0.001
LDL, mmol/L						
Unadjusted	0.03 (0.003)	<0.001	0.03 (0.004)	<0.001	0.01 (0.001)	<0.001
Adjusted	0.03 (0.003)	<0.001	0.03 (0.004)	<0.001	0.01 (0.001)	<0.001
Uric acid, μ mol/L						
Unadjusted	3.90 (0.37)	<0.001	3.90 (0.41)	<0.001	1.78 (0.15)	<0.001
Adjusted	3.73 (0.31)	<0.001	3.78 (0.35)	<0.001	1.65 (0.13)	<0.001
Systolic BP, mmHg						
Unadjusted	0.16 (0.06)	0.005	0.13 (0.06)	0.04	0.08 (0.02)	<0.001
Adjusted	0.11 (0.05)	0.03	0.09 (0.06)	0.09	0.05 (0.02)	0.02
Diastolic BP, mmHg						
Unadjusted	0.41 (0.04)	<0.001	0.36 (0.05)	<0.001	0.17 (0.02)	<0.001
Adjusted	0.40 (0.04)	<0.001	0.35 (0.05)	<0.001	0.17 (0.02)	<0.001

Note: Boldface indicates statistical significance ($p < 0.05$).

^aEstimates from generalized estimating equation models examining longitudinal associations. Analyses include data from three assessment waves, and exclude biologically implausible self-reported BMI values. Models were adjusted for adjusted for time, baseline age, sex, race/ethnicity, and time-varying height, past-month alcohol consumption and smoking.

^bIndicates continuous outcomes were transformed using the natural logarithmic function.

BP, blood pressure; CRP, C-reactive protein; HDL, high-density lipoprotein cholesterol; LDL, low-density lipoprotein cholesterol.

with findings from one previous study examining agreement of central adiposity with self-reported BMI ($\kappa=0.79$).²⁶ The totality of the evidence thus indicates that, on a population level, self-reported BMI is a reliable and valid indicator of measured BMI and weight status in adolescents and young adults.

Height misreporting did not change from ages 16 to 23 years, although self-reported weight and BMI became more accurate over time. Age was unassociated with height misreporting, but older baseline age was associated with greater weight and BMI underreporting. This is the first study to examine misreporting longitudinally in this age group and is somewhat

contrasting to cross-sectional studies showing greater misreporting of height and BMI in older versus younger adolescents,^{8,12,13,42} although findings are mixed.^{46–48}

Cross-sectional studies of older adults indicated positive associations of age with greater height overreporting.^{15,17,18,49} In the present study, the association of older baseline age with greater weight and BMI underreporting replicate previous findings, whereas reduced misreporting over time is a novel finding that may reflect a practice effect wherein the repeated experience may have improved self-reporting accuracy.

Misreporting differed by measured weight status and sex in multivariable longitudinal models. Greater height

overreporting, weight underreporting, and BMI underreporting in those with measured overweight and obesity is consistent with the literature.^{6,17,18,50–52} The mean difference in BMI underreporting between obese versus normal-weight participants was less than 1.5, comparable with previous estimates.^{10,11} Additionally, although there was more height overreporting in males and weight underreporting in females, BMI misreporting was similar between sexes. Several studies have reported greater weight underreporting in females relative to males,¹¹ leading to greater BMI underreporting,⁴⁴ although greater BMI reporting accuracy in females has also been observed.⁷ Findings are mixed regarding racial/ethnic differences in misreporting.^{9,13,19} In this study, BMI was more accurately reported in black versus white participants. Discrepancies with previous studies may relate to different sample characteristics (e.g., racial/ethnic representation) and analytic methods (e.g., bivariate versus multivariable models). This is also the first study to present findings from longitudinal models. Taken together, available evidence does not indicate a consistent association of BMI misreporting with socio-demographic characteristics.

Associations of cardiometabolic biomarkers with measured and self-reported BMI were similar in magnitude, direction, and precision. Both BMI measures were associated with worse cardiometabolic biomarkers, comparable with cross-sectional associations in adults.^{14,26} Additionally, the comparable associations of cardiometabolic biomarkers with self-reported BMI and WC support previous findings in adults showing similar associations with percentage body fat assessed by bioelectrical impedance analysis.¹⁴ The present study extends previous work to adolescents and young adults and demonstrates consistent findings across multiple cross-sectional analyses and longitudinal repeated measures models. Findings thus indicate that measured BMI, self-reported BMI, and measured WC lead reliably to similar conclusions regarding associations with multiple cardiometabolic biomarkers.

Study strengths include the large, diverse, national sample; the repeated assessment of self-reported and objective measures over five assessment waves spanning 7 years; and the 83% retention rate. Self-reported values were predominantly obtained prior to technician-obtained anthropometrics, and the proximity of the measures was uncorrelated with the degree of misreporting. The repeated measures of WC and multiple cardiometabolic biomarkers in the subsample enabled an in-depth investigation of the validity of self-reported BMI with respect to these known risk factors that has not been undertaken previously.

Limitations

Although availability of measured values at all waves in the full sample rather than the subsample would strengthen this study, missingness by design can be regarded as missing-at-random, such that analyses based on the subsample provided valid estimates. One limitation is that because participants were required to report whole units, this likely biased (increased) misreporting estimates, maximally for participants with true values at the half measure. Future research may improve reporting accuracy by providing the option to report unit fractions. Another consideration is that self-reported values were not cleaned other than identifying BIV to conduct sensitivity analyses; studies that assess height and weight in multiple ways (e.g., self-report and measured) and repeatedly over time may employ additional data cleaning steps to further reduce error introduced by self-reported values.

CONCLUSIONS

Even though it will be important to replicate these findings in other studies, these findings suggest that self-reported BMI provides reliable and valid estimates of measured BMI in U.S. adolescents and young adults, and produced similar estimates of associations with cardiometabolic biomarkers that were comparable to associations with measured WC. Although self-reported obesity prevalence was modestly underestimated versus measured values, there was strong concordance between self-reported and measured height, weight, and BMI, and strong to near-perfect agreement in classification of self-reported weight status and measured central adiposity.

ACKNOWLEDGMENTS

This research (contract number HHSN275201200001I) was supported in part by the Intramural Research Program of the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development, and the National Heart, Lung, and Blood Institute; the National Institute on Alcohol Abuse and Alcoholism; and the Maternal and Child Health Bureau of the Health Resources and Services Administration, with supplemental support from the National Institute on Drug Abuse.

Author contributions: LML, BSM, RJI, DLH designed research; LML analyzed data; LML and CH wrote the paper; and BSM, RJI, and DLH performed study oversight. LML had primary responsibility for final content. All authors interpreted data and revised and approved the final manuscript.

No financial disclosures were reported by the authors of this paper.

SUPPLEMENTAL MATERIAL

Supplemental materials associated with this article can be found in the online version at <https://doi.org/10.1016/j.amepre.2019.01.004>.

REFERENCES

- Lewis CE, Jacobs DR Jr, McCreath H, et al. Weight gain continues in the 1990s: 10-year trends in weight and overweight from the CARDIA study. *Am J Epidemiol*. 2000;151(12):1172–1181. <https://doi.org/10.1093/oxfordjournals.aje.a010167>.
- Viner RM, Cole TJ. Who changes body mass between adolescence and adulthood? Factors predicting change in BMI between 16 year and 30 years in the 1970 British Birth Cohort. *Int J Obes (Lond)*. 2006;30(9):1368–1374. <https://doi.org/10.1038/sj.ijo.0803183>.
- Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the United States, 2011–2012. *JAMA*. 2014;311(8):806–814. <https://doi.org/10.1001/jama.2014.732>.
- Zheng Y, Manson JE, Yuan C, et al. Associations of weight gain from early to middle adulthood with major health outcomes later in life. *JAMA*. 2017;318(3):255–269. <https://doi.org/10.1001/jama.2017.7092>.
- Powell-Young YM. The validity of self-report weight and height as a surrogate method for direct measurement. *Appl Nurs Res*. 2012;25(1):25–30. <https://doi.org/10.1016/j.apnr.2010.06.001>.
- Ekstrom S, Kull I, Nilsson S, Bergstrom A. Web-based self-reported height, weight, and body mass index among Swedish adolescents: a validation study. *J Med Internet Res*. 2015;17(3):e73. <https://doi.org/10.2196/jmir.3947>.
- Jayawardene W, Lohrmann D, YoussefAgha A. Discrepant body mass index: behaviors associated with height and weight misreporting among U.S. adolescents from the National Youth Physical Activity and Nutrition Study. *Child Obes*. 2014;10(3):225–233. <https://doi.org/10.1089/chi.2014.0002>.
- Brettschneider AK, Rosario AS, Ellert U. Validity and predictors of BMI derived from self-reported height and weight among 11- to 17-year-old German adolescents from the KiGGS study. *BMC Res Notes*. 2011;4:414. <https://doi.org/10.1186/1756-0500-4-414>.
- Morrissey SL, Whetstone LM, Cummings DM, Owen LJ. Comparison of self-reported and measured height and weight in eighth-grade students. *J Sch Health*. 2006;76(10):512–515. <https://doi.org/10.1111/j.1746-1561.2006.00150.x>.
- Connor Gorber S, Tremblay M, Moher D, Gorber B. A comparison of direct vs. self-report measures for assessing height, weight and body mass index: a systematic review. *Obes Rev*. 2007;8(4):307–326. <https://doi.org/10.1111/j.1467-789X.2007.00347.x>.
- Sherry B, Jefferds ME, Grummer-Strawn LM. Accuracy of adolescent self-report of height and weight in assessing overweight status: a literature review. *Arch Pediatr Adolesc Med*. 2007;161(12):1154–1161. <https://doi.org/10.1001/archpedi.161.12.1154>.
- De Vriendt T, Huybrechts I, Ottevaere C, Van Trimont I, De Henauw S. Validity of self-reported weight and height of adolescents, its impact on classification into BMI-categories and the association with weighing behaviour. *Int J Environ Res Public Health*. 2009;6(10):2696–2711. <https://doi.org/10.3390/ijerph6102696>.
- Brener ND, McManus T, Galuska DA, Lowry R, Wechsler H. Reliability and validity of self-reported height and weight among high school students. *J Adolesc Health*. 2003;32(4):281–287. [https://doi.org/10.1016/S1054-139X\(02\)00708-5](https://doi.org/10.1016/S1054-139X(02)00708-5).
- McAdams MA, Van Dam RM, Hu FB. Comparison of self-reported and measured BMI as correlates of disease markers in U.S. adults. *Obesity (Silver Spring)*. 2007;15(1):188–196. <https://doi.org/10.1038/oby.2007.504>.
- Grossschadl F, Haditsch B, Strongegger WJ. Validity of self-reported weight and height in Austrian adults: sociodemographic determinants and consequences for the classification of BMI categories. *Public Health Nutr*. 2012;15(1):20–27. <https://doi.org/10.1017/S1368980011001911>.
- Mozumdar A, Liguori G. Corrective equations to self-reported height and weight for obesity estimates among U.S. adults: NHANES 1999–2008. *Res Q Exerc Sport*. 2016;87(1):47–58. <https://doi.org/10.1080/02701367.2015.1124971>.
- Ikeda N. Validity of self-reports of height and weight among the general adult population in Japan: findings from National Household Surveys, 1986. *PLoS One*. 2016;11(2):e0148297. <https://doi.org/10.1371/journal.pone.0148297>.
- Bostrom G, Diderichsen F. Socioeconomic differentials in misclassification of height, weight and body mass index based on questionnaire data. *Int J Epidemiol*. 1997;26(4):860–866. <https://doi.org/10.1093/ije/26.4.860>.
- Gillum RF, Sempos CT. Ethnic variation in validity of classification of overweight and obesity using self-reported weight and height in American women and men: the Third National Health and Nutrition Examination Survey. *Nutr J*. 2005;4:27. <https://doi.org/10.1186/1475-2891-4-27>.
- Magnusson K, Haugen IK, Osteras N, Nordsetten L, Natvig B, Hagen KB. The validity of self-reported body mass index in a population-based osteoarthritis study. *BMC Musculoskelet Disord*. 2014;15:442. <https://doi.org/10.1186/1471-2474-15-442>.
- Yannakoulia M, Panagiotakos DB, Pitsavos C, Stefanadis C. Correlates of BMI misreporting among apparently healthy individuals: the ATTICA study. *Obesity (Silver Spring)*. 2006;14(5):894–901. <https://doi.org/10.1038/oby.2006.103>.
- Quick V, Byrd-Bredbenner C, Shoff S, et al. Concordance of self-reported and measured height and weight of college students. *J Nutr Educ Behav*. 2015;47(1):94–98. <https://doi.org/10.1016/j.jneb.2014.08.012>.
- Richmond TK, Thurston I, Sonnevile K, Milliren CE, Walls CE, Austin SB. Racial/ethnic differences in accuracy of body mass index reporting in a diverse cohort of young adults. *Int J Obes (Lond)*. 2015;39(3):546–548. <https://doi.org/10.1038/ijo.2014.147>.
- Meyer C, McPartlan L, Sines J, Waller G. Accuracy of self-reported weight and height: relationship with eating psychopathology among young women. *Int J Eat Disord*. 2009;42(4):379–381. <https://doi.org/10.1002/eat.20618>.
- Gooding HC, Milliren C, Shay CM, Richmond TK, Field AE, Gillman MW. Achieving cardiovascular health in young adulthood—which adolescent factors matter? *J Adolesc Health*. 2016;58(1):119–121. <https://doi.org/10.1016/j.jadohealth.2015.09.011>.
- Xie YJ, Ho SC, Liu ZM, Hui SS. Comparisons of measured and self-reported anthropometric variables and blood pressure in a sample of Hong Kong female nurses. *PLoS One*. 2014;9(9):e107233. <https://doi.org/10.1371/journal.pone.0107233>.
- NHLBI Obesity Education Initiative Expert Panel. *Identification, Evaluation, and Treatment of Overweight and Obesity in Adults: The Practical Guide*. Washington, DC: HHS, 2000 NIH Publication No. 00-4084.
- Babiarczyk B, Sternal D. Accuracy of self-reported and measured anthropometric data in the inpatient population. *Int J Nurs Pract*. 2015;21(6):813–819. <https://doi.org/10.1111/ijn.12314>.
- Conway KP, Vullo GC, Nichter B, et al. Prevalence and patterns of polysubstance use in a nationally representative sample of 10th graders in the United States. *J Adolesc Health*. 2013;52(6):716–723. <https://doi.org/10.1016/j.jadohealth.2012.12.006>.
- Hingson RW, Zha W, Iannotti RJ, Simons-Morton B. Physician advice to adolescents about drinking and other health behaviors. *Pediatrics*. 2013;131(2):249–257. <https://doi.org/10.1542/peds.2012-1496>.
- Li K, Haynie D, Lipsky L, Iannotti RJ, Pratt C, Simons-Morton B. Changes in moderate-to-vigorous physical activity among older adolescents. *Pediatrics*. 2016;138(4):e20161372. <https://doi.org/10.1542/peds.2016-1372>.

32. Kuczumski RJ, Ogden CL, Grummer-Strawn LM, et al. CDC growth charts: United States. *Adv Data*. 2000;314:1–27.
33. CDC. A SAS Program for the 2000 CDC Growth Charts (ages 0 to <20 years). www.cdc.gov/nccdphp/dnpao/growthcharts/resources/sas.htm. Published 2016. Accessed May 9, 2018.
34. Das SR, Kinsinger LS, Yancy WS Jr, et al. Obesity prevalence among Veterans at Veterans Affairs medical facilities. *Am J Prev Med*. 2005;28(3):291–294. <https://doi.org/10.1016/j.amepre.2004.12.007>.
35. Sribney B. Estimating correlations with survey data. www.stata.com/support/faqs/statistics/estimate-correlations-with-survey-data/. Published 2001. Accessed May 1, 2018.
36. Engstrom JL. Assessment of the reliability of physical measures. *Res Nurs Health*. 1988;11(6):383–389. <https://doi.org/10.1002/nur.4770110606>.
37. Lin LI. Corrections. *Biometrics*. 2000;56(1):324–325. <https://doi.org/10.1111/j.0006-341X.2000.00324.x>.
38. Lin LI. A concordance correlation coefficient to evaluate reproducibility. *Biometrics*. 1989;45(1):255–268. <https://doi.org/10.2307/2532051>.
39. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet*. 1986;1(8476):307–310. [https://doi.org/10.1016/S0140-6736\(86\)90837-8](https://doi.org/10.1016/S0140-6736(86)90837-8).
40. Gwet KL. *Handbook of Inter-Rater Reliability*. 4th ed Columbia, MD: Advanced Analytics, LLC, 2014.
41. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics*. 1977;33(1):159–174. <https://doi.org/10.2307/2529310>.
42. Brault MC, Turcotte O, Aime A, Cote M, Begin C. Body mass index accuracy in preadolescents: can we trust self-report or should we seek parent report? *J Pediatr*. 2015;167(2):366–371. <https://doi.org/10.1016/j.jpeds.2015.04.043>.
43. Goodman E, Hinden BR, Khandelwal S. Accuracy of teen and parental reports of obesity and body mass index. *Pediatrics*. 2000;106(1 Pt 1):52–58. <https://doi.org/10.1542/peds.106.1.52>.
44. Perez A, Gabriel K, Nehme EK, Mandell DJ, Hoelscher DM. Measuring the bias, precision, accuracy, and validity of self-reported height and weight in assessing overweight and obesity status among adolescents using a surveillance system. *Int J Behav Nutr Phys Act*. 2015;12 (suppl 1):S2. <https://doi.org/10.1186/1479-5868-12-S1-S2>.
45. Yoshitake N, Okuda M, Sasaki S, Kunitsugu I, Hobara T. Validity of self-reported body mass index of Japanese children and adolescents. *Pediatr Int*. 2012;54(3):397–401. <https://doi.org/10.1111/j.1442-200X.2011.03541.x>.
46. Davis H, Gergen PJ. The weights and heights of Mexican-American adolescents: the accuracy of self-reports. *Am J Public Health*. 1994;84 (3):459–462. <https://doi.org/10.2105/AJPH.84.3.459>.
47. Himes JH, Faricy A. Validity and reliability of self-reported stature and weight of U.S. adolescents. *Am J Hum Biol*. 2001;13(2):255–260. [https://doi.org/10.1002/1520-6300\(200102/03\)13:2<255:AID-AJHB1036>3.0.CO;2-E](https://doi.org/10.1002/1520-6300(200102/03)13:2<255:AID-AJHB1036>3.0.CO;2-E).
48. Himes JH, Hannan P, Wall M, Neumark-Sztainer D. Factors associated with errors in self-reports of stature, weight, and body mass index in Minnesota adolescents. *Ann Epidemiol*. 2005;15(4):272–278. <https://doi.org/10.1016/j.annepidem.2004.08.010>.
49. Kuczumski MF, Kuczumski RJ, Najjar M. Effects of age on validity of self-reported height, weight, and body mass index: findings from the Third National Health and Nutrition Examination Survey, 1988–1994. *J Am Diet Assoc*. 2001;101(1):28–34. [https://doi.org/10.1016/S0002-8223\(01\)00008-6](https://doi.org/10.1016/S0002-8223(01)00008-6).
50. Stommel M, Schoenborn CA. Accuracy and usefulness of BMI measures based on self-reported weight and height: findings from the NHANES & NHIS 2001–2006. *BMC Public Health*. 2009;9:421. <https://doi.org/10.1186/1471-2458-9-421>.
51. Dekkers JC, van Wier MF, Hendriksen IJ, Twisk JW, van Mechelen W. Accuracy of self-reported body weight, height and waist circumference in a Dutch overweight working population. *BMC Med Res Methodol*. 2008;8:69. <https://doi.org/10.1186/1471-2288-8-69>.
52. Spencer EA, Appleby PN, Davey GK, Key TJ. Validity of self-reported height and weight in 4808 EPIC-Oxford participants. *Public Health Nutr*. 2002;5(4):561–565. <https://doi.org/10.1079/PHN2001322>.