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# Errors in body mass index from self-reported data by sex and across waves of Add Health

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ABSTRACT

*Purpose:* Body mass index (BMI) derived from self-reported height and weight is often used to study adiposity and its health implications. However, misestimates of BMI from self-reported data have been observed. This study adds to the literature by demonstrating how anthropometric misreporting patterns differed by sex and changed across time in a nationally representative cohort, as well as examining behavioral/psychological correlates of biases in BMI.
*Methods:* Misreporting of height and weight (and thus BMI) from adolescence to adulthood in the United States was studied using the National Longitudinal Study of Adolescent to Adult Health (1996–2008). Behavioral/psychological characteristics possibly associated with errors in BMI were analyzed with fixed-effects models.
*Results:* Different patterns of anthropometric misreporting resulted in larger underestimation of BMI among females than males at the beginning waves, but females saw a reduction by the last wave. Males did not see such a decrease, and their error, at 0.75 BMI units by 2008, was comparable to that of females. For both sexes, body image perception was a significant predictor of biases in BMI.
*Conclusions:* From adolescence to adulthood, anthropometric reporting patterns changed, and its variation differed by sex. Nevertheless, errors in BMI were similarly associated with behavioral/psychological characteristics.



## Purpose

Health-related surveys often ask participants to self-report characteristics that would otherwise take excessive effort to measure, but the accuracy of such self-reported information has often been called into question [1–11]. Research looking into anthropometric misreporting in the United States and other high-income countries has typically found overreported height and underreported weight [3,5,11]. Differences in misreporting patterns by sex have also been observed [12,13]. Such misreporting has implications for body mass index (BMI), an elevated level of which is a risk factor for many chronic diseases [14–18]. From a clinical perspective, it could be argued that misreporting might not be problematic as height and weight are easily assessed, but misreporting could become more critical in survey-based epidemiological studies.

Although anthropometric misreporting might change over time, not many studies have investigated it using longitudinal data. A paper using the longitudinal Swedish Adoption/Twin Study of Aging concluded that BMI derived from measured data exceeded that from self-reported data and that there was a small increase in underestimation over time [19]. However, it would be ideal to study this for a nationally representative sample. In the National Longitudinal Study of Adolescent to Adult Health (Add Health), a survey that follows a nationally representative sample of American adolescents to adulthood, both self-reported and measured height and weight are collected at several time points. Clarke et al. [12] exploited this feature to study self-reported versus measured weight over time and concluded that while there was no evidence of misreporting by boys, adolescent girls increasingly underreported their weights over adulthood. In addition, there were differences in reporting by race and educational attainment subgroups for females, but not for males [12]. However, the authors did not consider height, a necessary component in studying adiposity.

The purpose of this study was to use Add Health to explore differences between height, weight, and BMI from self-reported and measured data, and how misreporting had changed from adolescence to adulthood for both sexes. Furthermore, characteristics

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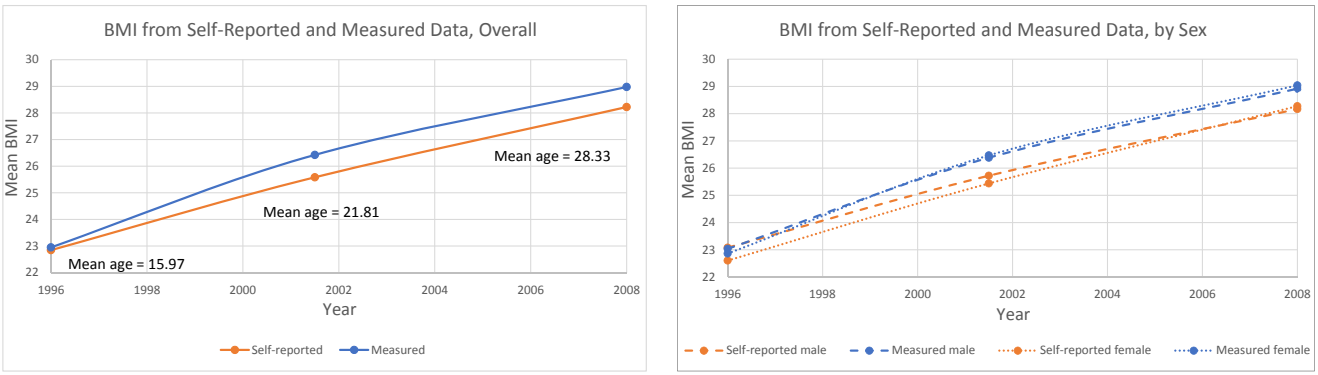


**Fig. 1.** Mean BMI from self-reported and measured data at waves II through IV (mean ages 16 through 28).
Data: National Longitudinal Study of Adolescent to Adult Health.

associated with errors in BMI were analyzed. Beyond just demographic characteristics, behavioral and psychological factors were also considered in this study, as they have not been adequately studied in such a context. Identifying characteristics associated with biases in BMI is important, as this information allows researchers to account for such errors either by direct measurement or by assessing their influence on observed results.

## Methods

Add Health is a nationally representative longitudinal study of American adolescents in grades 7 through 12 during the 1994–1995 school year [20]. Since then, three more waves of data have been released. At the first wave, adolescents were asked to self-report their heights and weights. At the second (1996, mean age 16), third (2001–2002, mean age 22), and fourth (2008, mean age 28) waves, interviewers also measured the participants' heights and weights, resulting in both self-reported and measured data for this analysis. BMI was then calculated using self-reported and measured inputs.

Heights of seven feet or taller, weights of 700 pounds or heavier, and BMI values < 10 kg/m$^2$ or >75 kg/m$^2$ were coded as missing, due to their biological implausibility. The number of anthropometric values that were not missing but coded as missing based on the aforementioned criteria was minimal. Ultimately, missing data amounted to at most around 10% at each of the three waves and three anthropometric values under study. Furthermore, survey participants with available anthropometric information and those without were similar with respect to the basic demographic characteristics, sex and age. Therefore, disregarding the small subsets with missing data likely would not distort overall conclusions.

At each wave, differences in height, weight, and BMI from self-reported and measured data were calculated. Then, misreporting patterns between consecutive waves for the overall sample, as well as for the two sex strata, were studied. Paired *t*-tests were conducted to determine whether differences were significant, with the Bonferroni correction applied for multiple testing.

In addition to exploring biases in BMI, behavioral and psychological characteristics associated with these biases were analyzed. A dichotomous variable of whether a survey participant had a routine physical examination in the previous year was included, as anthropometric measurements are typically taken at such appointments. Responses to self-perception of body image were grouped into underweight, about the right weight, slightly overweight, and very overweight to mirror conventional BMI categorizations. Self-rated general health was on a scale from poor to excellent. How people perceived their body image and health might have affected BMI misestimation. Finally, a dichotomous variable of whether the respondents were perceived by their interviewers to be candid or not was included. Candidness could be indicative of better self-reporting, at least to the extent that the respondents knew their anthropometric measurements.

Fixed-effects models were run with the difference (BMI from self-reported data − BMI from measured data) as the dependent variable, where a negative value would denote underestimation and a positive value overestimation. The emphasis here was on BMI, a proxy for adiposity commonly used in analyses of health, not height and weight. When fixed-effects and random-effects models were compared, Hausman tests suggested that random-effects models should be rejected in favor of fixed-effects models, so only results from fixed-effects models are presented.

Wave, recency of a routine physical examination, body image perception, self-rated general health, and candidness were time-varying covariates in the fixed-effects models. Wave, not age, was selected as the time unit of analysis as wave was the statistical unit in which data were collected. Again, these analyses were performed for the overall sample as well as for the two sex strata. The effects of variables such as race, place of residence, and parental education, which might be expected to have a relationship with BMI misestimation, were not estimated because these characteristics produced no within-subject variation necessary for fixed-effect model estimation.

For all analyses, the complex survey design of Add Health was taken into account with stratification, clustering, and survey weight variables [20]. For the descriptive statistics by wave, cross-sectional survey weights for the corresponding wave were used. For the fixed-effects models, longitudinal survey weights were used. All analyses were performed in Stata 15.1 (StataCorp) [21]. Missing data were excluded using listwise deletion. When results were discussed, the term “significant” meant significant at the level of five percent.

## Results

Figure 1 displays mean BMI from self-reported and measured data at waves II through IV (mean ages 16 through 28), for both the overall sample and the male/female subsamples.

Both mean BMI from self-reported data and measured data increased over time. For the overall sample, mean measured BMI increased from 23 kg/m$^2$ at wave II (mean age 16) to 29 kg/m$^2$ by wave IV (mean age 28). The extent of underestimation also increased. Although the gap between BMI from self-reported and measured data was narrower for adolescent males than females in 1996, the gap became similar for the sexes by adulthood in 2008. However, it is unascertainable from Figure 1 whether these discrepancies were due to misreporting of height or weight. Table 1

**Table 1**
Mean difference, self-reported-measured, at waves II through IV (mean ages 16 through 28) for the overall sample

| | Height (in) | Weight (lb) | BMI (kg/m$^2$) |
|---|---|---|---|
| Wave II (mean age 16) | −0.131 | −1.308 | −0.104 |
| Wave III (mean age 22) | 0.516 | −2.753 | −0.841 |
| Wave IV (mean age 28) | 0.452 | −2.438 | −0.754 |

Data: National Longitudinal Study of Adolescent to Adult Health.

exhibits the mean differences between self-reported and measured height, weight, and BMI at all three waves.

The mean (BMI from self-reported data−BMI from measured data) for the overall sample was negative at all three waves. At wave II (mean age 16), underestimation of BMI was about 0.1 unit. The bias increased to 0.84 at wave III (mean age 22) and decreased to 0.75 at wave IV (mean age 28). Weight was also consistently underreported, but height was neither consistently overreported nor underreported. In adolescence, height was underreported but was not enough to compensate for the underreporting of weight, as mean BMI difference was still significantly negative. At both waves III and IV, both overreporting of height and underreporting of weight contributed to the underestimation of BMI, with the magnitude being more extreme at wave III than wave IV. Paired *t*-tests showed that all these mean differences were significantly different from zero, even after adjusting for multiple testing.

Table 2 displays the mean differences stratified by sex. Bold and italic represent statistical significance between sex and consecutive waves, respectively.

Although the directions of anthropometric biases were usually the same for both sexes at all waves, their magnitudes of misreporting varied greatly. Generally, males misreported their height more, and females misreported their weight and BMI more. Exceptions to this were height in wave II (mean age 16) and BMI in wave IV (mean age 28), where there were no significant differences between males and females. Although both sexes underreported height and weight at wave II, males on average overestimated, albeit insignificantly, their BMI and females significantly underestimated it. These are due to the facts that although height was slightly underreported for both sexes, weight was much more under-reported by females than males.

As with the overall sample, biases increased between waves II and III (mean ages 16 and 22), and for the most part, decreased between waves III and IV (mean ages 22 and 28). The exception to this was that errors in height and BMI for males did not decrease from waves III to IV. Between these last two waves, BMI from self-reported data became more accurate for females, but not for males. Besides weight and BMI between waves III and IV for males, all other male mean misreporting and all female mean misreporting significantly changed between each pair of consecutive waves.

Fixed-effects models were then run to analyze behavioral and psychological characteristics associated with errors in BMI using the overall, male, and female samples. The results are exhibited in Table 3.

Participants were more likely to underestimate their BMI rather than overestimate, so the results are discussed in the context of underestimation. A positive coefficient would suggest less underestimation, whereas a negative coefficient more underestimation. For the overall sample, both wave and body image perception were significant. On average, wave III (mean age 22) was associated with an additional 0.757 units of BMI underestimation, and wave IV (mean age 28) an additional 0.580 units underestimation, both relative to wave II (mean age 16). This would suggest that BMI from self-reported data had become less accurate since adolescence, though the extent of underestimation decreased from wave III to wave IV. The negative coefficients of the body image variables suggest that those who saw themselves as overweight underestimated more. The increasingly negative coefficients suggest that the more overweight one's self-perception was, the more one would underestimate BMI.

The substantive results hold across the overall sample and the two sex strata, but the differences between coefficients were nonnegligible between males and females. The coefficients for wave III (mean age 22) were between −0.8 and −0.7 for all models. For wave IV (mean age 28), the coefficient became −0.4 for females but remained −0.8 for males. This suggests that females at wave IV underestimated less than at wave III, though still more relative to wave II (mean age 16), while males continued to underestimate to about the same extent between waves III and IV. From Table 1, females underestimated their BMI values more than males at both waves II and III, but the decrease in underestimation between waves III and IV placed males and females at similar levels of underestimation.

## Conclusions

Although rising BMI is a serious public health concern, the goal of this paper was not to explore this phenomenon, but rather, to investigate how anthropometric misreporting had changed. BMI was generally underestimated, mostly due to an overreporting of height and an underreporting of weight. Males typically overreported their heights more, whereas females underreported their weights more. Although these results had been found in prior cross-sectional studies [22–24], this study showed the persistency of these trends across waves. The exception to this was at wave II (mean age 16), when heights were underreported by both sexes. Underreporting of height has been observed before among younger people [13]; this could be because the survey participants were at a life stage when they were still growing and might not have realized how much their heights had changed.

For the overall sample, mean BMI from self-reported and measured data were different at each wave, and their differences also varied between waves. There was a large jump in BMI underestimation between waves II and III (mean ages 16 and 22)—adolescence to early adulthood, and then a small decrease between waves III and IV (mean ages 22 and 28)—early adulthood to adulthood. This finding was driven by the female subsample, as the

**Table 2**
Mean difference, self-reported—measured, at waves II through IV (mean ages 16 through 28) stratified by sex

| | Height (in) | | Weight (lb) | | BMI (kg/m$^2$) | |
|---|---|---|---|---|---|---|
| | Male | Female | Male | Female | Male | Female |
| Wave II (mean age 16) | *−0.137* | *−0.126* | ***−0.389*** | ***−2.259*** | ***0.044*** | ***−0.257*** |
| Wave III (mean age 22) | ***0.571*** | ***0.459*** | ***−1.611*** | ***−3.955*** | ***−0.660*** | ***−1.031*** |
| Wave IV (mean age 28) | ***0.689*** | ***0.207*** | **−1.382** | ***−3.547*** | −0.747 | *−0.762* |

Bold represents statistically significant male/female differences at the 5% level after adjustment using Bonferroni correction.
Italic represents statistically significant differences between consecutive waves at the 5% level after adjustment using Bonferroni correction.
Thus, bold with italic represents statistically significant male/female and wave differences.
Data: National Longitudinal Study of Adolescent to Adult Health.

**Table 3**
Coefficients of time-varying covariates from the fixed-effects models of the difference (BMI from self-reported data − BMI from measured data)

| Variable | Overall sample ($n$ = 22,778) | Male sample ($n$ = 10,573) | Female sample ($n$ = 12,205) |
|---|---|---|---|
| Wave (reference = II, mean age 16) | | | |
| III, mean age 22 | −0.757 (−0.877, −0.636) | −0.736 (−0.898, −0.574) | −0.791 (−0.938, −0.645) |
| IV, mean age 28 | −0.580 (−0.691, −0.469) | −0.761 (−0.919, −0.602) | −0.395 (−0.546, −0.244) |
| Physical examination (reference = no) | | | |
| Yes | 0.039 (−0.059, 0.137) | −0.006 (−0.133, 0.122) | 0.036 (−0.083, 0.156) |
| Body image perception (reference = underweight) | | | |
| About the right weight | −0.073 (−0.205, 0.058) | −0.033 (−0.191, 0.126) | −0.115 (−0.330, 0.099) |
| Slightly overweight | −0.333 (−0.489, −0.177) | −0.330 (−0.530, −0.131) | −0.326 (−0.573, −0.079) |
| Very overweight | −0.421 (−0.746, −0.096) | −0.550 (−1.322, 0.222) | −0.438 (−0.769, −0.107) |
| General health (reference = poor) | | | |
| Fair | −0.431 (−1.362, 0.500) | 0.294 (−0.257, 0.844) | −0.838 (−2.173, 0.496) |
| Good | −0.649 (−1.610, 0.312) | −0.003 (−0.574, 0.568) | −0.991 (−2.364, 0.382) |
| Very good | −0.703 (−1.661, 0.255) | −0.075 (−0.654, 0.504) | −1.048 (−2.428, 0.332) |
| Excellent | −0.667 (−1.660, 0.327) | −0.062 (−0.629, 0.504) | −1.010 (−2.478, 0.457) |
| Candidness (reference = no) | | | |
| Yes | 0.082 (−0.102, 0.266) | 0.012 (−0.249, 0.274) | 0.191 (−0.090, 0.472) |
| Overall $R^2$ | 0.041 | 0.054 | 0.034 |

Sex, race, place of residence, and parental education from wave I were also controlled for, but estimates of their coefficients were not produced as fixed-effects models use within-subject variation.
95% confidence intervals are listed below coefficient estimates.
Data: National Longitudinal Study of Adolescent to Adult Health.

male subsample actually did not see such decrease between waves III and IV. Because females underestimated more than males in waves II and III, their decrease in underestimation at wave IV and the lack of a similar decrease for males resulted in about the same level of underestimation for both sexes—about 0.75 units by 2008. Although this might not seem large in magnitude, small errors in BMI could result in misclassification of BMI categories and underestimated prevalence of risky BMI. Furthermore, because of differences by sex and time, the amount of BMI underestimation could vary depending on the population and time of study. It would be interesting to observe how patterns of underestimation change using future waves of Add Health.

Because progressing wave amounted to increasing age, the aforementioned observations could be an age or a period phenomenon. An age explanation would be that older people tend to underestimate more, whereas a period explanation would be that people in more recent years tend to underestimate more. Within each wave, there was about a decade separating the ages of the youngest and the oldest. In an attempt to disentangle age from period, regression models of error in BMI were run for each wave on age in addition to the same set of covariates. At each wave, age was never a significant variable for the overall, male, or female samples. Thus, at least within each wave, there was not a significant relationship between age and error in BMI. Perhaps, this evidence points to more of a period phenomenon and is all the more reason to use wave and not age as the unit of time. However, more research is needed to tease out the complexities of period versus age.

Random-effect models were estimated as another sensitivity test and they provided similar substantive conclusions. Because neither the regression models by wave nor the random-effects models relied on within-subject variation, coefficient estimates and standard errors for the time-invariant variables sex, race, place of residence, and parental education at wave I could be estimated. Sex was the only variable that was consistently significant across all the models, further validating the decision to stratify models by sex and not by other covariates.

In addition to wave, body image perception was also a significant characteristic associated with the underestimation of BMI. Those who perceived themselves to be overweight underestimated their BMI more, which was not surprising as misreporting height/weight might be a means of compensating. Having had a physical examination, self-rated general health, and candidness were not significant in any of the fixed-effects models. It might be easier and less expensive to perform numerical adjustments than to collect anthropometric measurements. Perhaps, asking people about their body image, in addition to their height and weight, together with a good mathematical model for BMI error, might give an acceptable estimate of actual BMI.

The main strengths of this study were twofold. First, anthropometric misreporting was studied, both across time and by sex, with a nationally representative sample. Although biases in BMI from self-reported data had been examined before, not many studies had considered error beyond a cross-section. Within a cohort, BMI had been observed to increase across waves [25,26], but this study additionally provides information on how biases in BMI have changed over time. Furthermore, differences in such errors by sex could be critical as models of health outcomes have shown sex differentials [27], and it could perhaps be the case that these differentials are caused by biases in BMI, an input in the models. Second, beyond just contextual characteristics, behavioral and psychological characteristics were considered to understand biases in BMI from self-reported data, which could help to identify subgroups with greater propensity to misreport.

However, the behavioral and psychological covariates considered were certainly not exhaustive. To be included, variables had to be potentially associated with misestimation, time-varying, and available across all waves. In fact, using a small set of covariates might have caused the $R^2$ values for the fixed-effects models to be relatively low. However, the objective of these models was not to obtain a high $R^2$ or to optimize predictive performance, but to ascertain which variables were associated with biases in BMI derived from self-reported height and weight.

In conclusion, it is well established that high BMI is a risk factor for many adverse health conditions. The general underestimation of BMI might result in incorrect estimation of both obesity prevalence and the impact of high BMI on health outcomes. Studying how different segments of the population misestimate their BMI and understanding how these patterns change over time could be useful for researchers using survey data for epidemiologic studies. Not considered in this study is the fact that apparent differences by sex or period/age in the association of high BMI with risk of disease could simply reflect differences in height and weight misreporting. In addition, many of the covariates researchers care about in studies on the impact of BMI on health outcomes, such as smoking, are also

associated with sex and period/age. These could produce intricate patterns of differential bias. Further research is needed to explore differential biases in BMI estimation, and the effect of such biases on epidemiologic studies.

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