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Authors
Thompson, Hannah R
Linchey, Jennifer K
King, Benjamin
et al.

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Accuracy of school staff-measured height and weight used for BMI screening and reporting

Hannah R. Thompson, PhD, MPH [Research Scientist],
UC Berkeley School of Public Health, 2115 Milvia Street, Third Floor, Berkeley, California, 94704

Jennifer K. Linchey, MPH [Research Specialist],
University of California at Berkeley, School of Public Health, 50 University Hall, Berkeley, California 94720

Benjamin King, BA [Project Policy Analyst],
University of California at Berkeley, School of Public Health, 50 University Hall, Berkeley, California 94720

John H. Himes, PhD, MPH [Professor Emeritus],
University of Minnesota, School of Public Health, Mayo A301, 420 Delaware St SE Minneapolis, MN 55455

Kristine A. Madsena, MD, MPH [Associate Professor]
University of California at Berkeley, School of Public Health, 50 University Hall, Berkeley, California 94720

Abstract

BACKGROUND: The accuracy of students' heights and weights measured by school staff for BMI screening/reporting has not been established. This study examined school staffs' measurement accuracy, comparing accuracy by staff- and student-level characteristics.

METHODS: School staff and researchers measured the height and weight of 1,008 4th-8th grade students, within one month of each other. Bland-Altman plots, mean differences, and intraclass correlation coefficients (ICCs) were calculated to examine measurement accuracy. Linear mixed effects models assessed accuracy by staff- and student-level characteristics.

RESULTS: Bland-Altman plots revealed no appreciable bias in differences between researcher and staff measurements. The mean absolute difference between researcher and school staff measurements were 1.0α1.6 cm (height), 0.7α1.8 kg (weight), and 0.4α0.8 kg/m^2 (BMI). Interrater ICC values were ≥ 0.97, demonstrating "excellent" reliability. Categorical weight status was correctly classified for 94% of students (kappa 0.90), and for 96% with a BMI ≥95th% (kappa 0.94). PE teachers were slightly less accurate than school nurses in measuring height (0.4 cm less accurate; p = .045) and weight (0.4 kg; p = .015).

Corresponding Author thompsonh@berkeley.edu.

Human Subjects Approval Statement
This research was approved by the UC Berkeley Committee for the Protection of Human Subjects, protocol ID 2012-07-4472.

CONCLUSION: School staff conducted height/weight measurements on 4th-8th grade students with high accuracy. Resultant school-based BMI reports using similar protocols should validly reflect weight status for almost all students.

Keywords

Body mass index (BMI); Screening and Reporting; Measurement accuracy; school nurses; PE teachers

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Childhood obesity remains a persistent problem in the U.S.,[1] with widening disparities by race/ethnicity.[2] The National Academy of Medicine recommends school-based body mass index (BMI) screening and reporting as an obesity-prevention strategy.[3] As of 2015, 25 states required BMI screening in schools, 11 of which mandated reporting results to parents.[4] However, the impact of school-based BMI reporting on student weight status remains unknown[5] and the practice remains controversial.[6,7] Evidence is still needed to support the wide-scale use of such programs.

The potential effects of school-based BMI screening and reporting rely on the accuracy of the school staff who conduct height and weight measurements among students. However, few studies have systematically examined the reliability of school staff in assessing these outcomes.[8-10] Prior studies had long gaps (up to 4 months) between measurements by teachers and health professionals[10] or did not measure BMI, which limits our ability to discern how measurement accuracy might impact BMI reporting.[9] Further, no studies have examined measurement differences between staff types; however different types of school personnel, like school nurses or PE teachers, may routinely collect height and weight data. There is also a lack of research on whether staff characteristics, such as level of height and weight training, or student characteristics, like race/ethnicity, sex, grade, and weight category, impact measurement accuracy. Additional evidence regarding the accuracy of school staff-measured height and weight is critical to informing the debate on school-based BMI screening and reporting practices.

This study sought to determine the accuracy of height and weight measurements collected by school staff among California public school students participating in The Fit Study, a statewide cluster randomized controlled trial (RCT) to rigorously determine the impact of BMI screening and reporting on childhood obesity.

METHODS

The present cross-sectional study used data from the final year of the Fit Study,[11] a 3-year cluster-RCT conducted in 79 California public schools, to determine if school-based BMI screening and reporting reduces childhood obesity. Details of the study design have been described previsouly.[11]

Participants

Twenty schools from the Fit Study were randomly selected to participate in the present validation study. A total of 41 classrooms were randomly selected from among the 20 schools, stratifying by grade to ensure similar representation of students across grades 4 through 8 (excluding classrooms with fewer than 15 students). All 1,140 students enrolled in the Fit Study in participating classrooms were eligible for participation in the present study.

Measurements

School staff assessed student height and weight between February and May 2017 as part of the Fit Study. While 15% of measurements for the larger Fit Study were conducted by classroom teachers or administrators, in the random sample for this validation study, only PE teachers and school nurses were represented. Nevertheless, because of the strict randomization procedures carried out, the results of these analyses can be fairly considered representative of the total Fit Study sample of schools. Height and weight were measured by two trained researchers within approximately 1 month of measurements taken by school staff (3% occurred on the same day).

As part of the Fit Study, schools received research-grade measuring equipment and school staff were asked to register for, and complete, online training on how to accurately measure height and weight using the same protocol used by the researchers. A laminated card providing detailed protocol instructions (accompanied by photos) was included with all scales and stadiometers. Height (in stocking feet) was measured to the nearest 0.1 cm using the ShorrBoard® Infant/Child/Adult Measuring Board (Weigh and Measure, LLC, Maryland). Height was measured twice; if the 2 measures differed by more than 0.5 cm, a third height measurement was taken. The average of the 2 closest heights was used for analysis. Weight was measured to the nearest 0.1 lb with shoes, sweatshirts/jackets, and materials in pockets removed, using a Tanita BWB 800S Digital Scale. Researchers used a Tanita SC-331S Total Body Composition Analyzer, under the pretense that researchers were collecting body composition data on the students, in order to blind school staff to the BMI validation assessment. Both researchers underwent a 2-hour training, involving detailed review of the research protocol and Fit Study training video, as well as practice measurements on the same participants (chosen specifically for their varying heights and weights).

Data Analysis

Biologically implausible height and weight values, as defined by the 25^{th} percentile less 3 times the interquartile range (for sex and age), or the 75^{th} percentile plus 3 times the interquartile range, were flagged. No heights were considered biologically implausible. While 4 students' weights were above the biologically plausible upper limit, researcher and school-staff measurements were consistent, and it was determined that these reflected accurate measurements for very heavy students.

Bland-Altman (B-A) plots compared the relative differences between researcher and school-staff measurements against the averages of the two measurements.[12] These plots facilitate the visual assessment of measurement agreement and bias (present when the line of equality (zero difference) falls outside the 95% limits of agreement).

Mean relative differences (researcher measure less school-staff measure) and absolute differences were calculated for height and weight measures and for body mass index (BMI - weight in kilograms/ height in meters squared). Intraclass correlation coefficients (ICCs), which account for both random and systematic measurement errors, were calculated to estimate overall reliability of the measurements. Shrout and Fleiss benchmarks were used to interpret ICC values: excellent (> 0.75), fair to good (0.40 to 0.75), and poor reliability (< 0.40).[13] Students were classified according to BMI percentile for age and sex in accordance with the Centers for Disease Control and Prevention's growth charts: (1) underweight (BMI < 5th percentile); (2) normal weight (BMI 5th to < 85th percentile); (3) overweight (BMI ≥ 85th and < 95th percentile; and (4) obese (BMI ≥ 95th percentile).[14] (Reports sent home to parents used the term "At risk for overweight" for students with BMI ≥ 85th and < 95th percentile and "Overweight" for students with BMI ≥ 95th percentile, based on feedback from focus groups.[15] Kappa (k) statistics assessed categorical agreement (adjusted for chance) for BMI between researchers and school staff, with the researcher measure considered the gold standard. Altman's κ benchmark scale was used in interpreting the κ statistics: poor (< 0.20); fair (0.21 - 0.40); moderate (0.41 - 0.60); good (0.610 - 0.80); and very good (0.81 - 0.99) agreement.[16]

Linear mixed effects models including random effects for school and teacher determined if measurement accuracy was influenced by any of the following factors: (1) days elapsed between researcher and school staff measurements; (2) school staff type (PE teacher vs. school nurse); (3) whether the school staff member reported watching the Fit Study BMI measurement training video (yes/no); (4) student race/ethnicity (African American, Asian, Latino, white, Other); (5) student sex (male/female); (6) student grade (4th – 8th); and (7) student BMI category. All statistical analyses were performed using Stata v15 (StataCorp, College Station, Texas).

RESULTS

A total of 1,008 students in grades 4 to 8 (52% male; mean age 12.0 ± 1.5 years) had their height and weight measured by both school staff and a researcher (Table 1). Median time elapsed between the researcher and school-staff measurements was 5 days (IQR −5 to 9 days; maximum 33 days). Students were racially/ethnically diverse (68% Latino, 12% White, 11% Asian, and 6% African American) and predominantly came from low-income families (67% qualified for free or reduced-price meals, a proxy for socio-economic status).

Table 2 presents the mean relative and absolute differences for all measures. The mean absolute difference between researcher and school-staff measurements was 1.0 cm (SD 1.4) for height, 0.7 kg (SD 1.8) for weight, and 0.4 kg/m^2 (SD 0.8) for BMI. Mean relative differences were even smaller. Inter-rater ICC values were very high, ≥ 0.97 for height, weight, BMI, and BMI percentile, demonstrating "excellent" reliability. The number of days elapsed between the school-staff measurement and the researcher measurement influenced the difference in weight and BMI, but not height; each additional day elapsed was associated with a +0.02 kg increase in the absolute difference in weight (p = .005) and a +0.01 kg/m^2 increase in BMI (p = .034).

B-A plots (Figure 1) do not indicate systematic bias in measurement differences, however reveal that most measurements that fell outside the 95% limits of agreement ("outliers") were conducted by PE teachers rather than nurses. Mixed-effects models corroborated this observation: as measured by PE teachers, the average absolute difference in height was 0.4 cm less accurate (p = .045), weight was 0.4 kg less accurate (p = .015), and BMI was 0.2 kg/m^2 (p = .15) less accurate than measurements made by school nurses. There were 26 height outliers (2.6% of total measures), 12 weight outliers (1.2% of total), and 19 BMI outliers (1.9%; only 10 of which led to BMI misclassification).

Overall, categorical agreement for BMI was high, with 94% of students having their weight status correctly classified by school staff (Table 3; researcher classification was the gold standard). Agreement was lowest for underweight students (71%) and highest for normal weight and obese students (96%). Only 10 of the 60 students whose BMI was misclassified were outliers on B-A plots. Among the remaining 50 students, school-staff classifications were within one BMI category of the gold standard (for example, obese students were only misclassified as overweight). Additionally, misclassified BMIs fell close to the category cut-points (Figure 2). The kappa for agreement within the underweight category (0.76) shows "good" agreement, while the kappas for normal (0.92), overweight (0.87), and obese (0.94) demonstrate "excellent" BMI categorization agreement.

In mixed effects models, staff who watched the training video were more likely to accurately measure student weight (absolute difference = 0.35 vs. 0.80, p = .034), with a trend for improved accuracy in height (absolute difference = 0.71 vs. 1.06, p = .071), but with no difference in BMI. Compared to 4^{th} graders, 7^{th} graders were less likely to have their height measured accurately (absolute difference = 1.26 vs. 0.72, p = .048) and 8^{th} graders were less likely to have their weight (absolute difference = 1.11 vs. 0.37, p = .001) and BMI (absolute difference = 0.26 vs 0.55, p = .013) measured accurately.

There were no significant differences in measurement accuracy by student race/ethnicity. School staff tended to be less accurate in measuring girls' weight than boys' weight (absolute difference = 0.77 kg vs 0.60 kg, p = .094), however this did not lead to differences in BMI measurement accuracy by student sex.

There were slight differences in measurement accuracy by student weight category, though these differences were influenced by a handful of outliers. Students classified as underweight by researchers were less likely to have their height (relative difference 0.4 vs. −0.3 cm; p = .010; absolute difference 1.4 vs 1.0 cm, p = .028) and weight (relative difference 0.9 vs. 0.2 kg, p = .075) accurately measured by school staff than were normal weight students. Compared to normal weight students, obese students were less likely to have their weight (relative difference = −0.3 vs 0.2 kg, p = .002; absolute difference 0.9 vs 0.6 kg, p = .032) and BMI (absolute difference 0.6 vs 0.4 kg/m^2, p = .004) accurately measured by school staff.

DISCUSSION

This is one of a few studies to rigorously assess the accuracy of school staff in measuring student height and weight and is the first to examine whether staff- and student-level factors impact measurement reliability. Our findings demonstrate that school staff are able to measure the height and weight of 4th through 8th grade students with a high degree of accuracy.

On average, school staffs' height measurements were 0.3 cm higher and weight measurements were 0.1 kg lower than researchers' measurements. Notably, standard deviations between heights and weights measured by researchers and school staff were identical, indicating that in following the Fit Study measurement protocol, school staff measured student height and weight with no additional random variation beyond that of researchers.

The mean absolute differences between researcher and school-staff measurements (1.0 cm (SD 1.4) for height and 0.7 kg (SD 1.8) for weight) in this study, were slightly higher than the differences between researcher and PE teacher measurements reported by Berkson et al[10] (0.6 cms (SD 0.5) and 0.3 kgs (SD 0.4)). However, both researcher and PE teacher measurements in the Berkson study were taken on the same day. Based on our data, each month lapsed between measurements equates to a 0.6 kg/m^2 difference in BMI measurement, which suggests that the greater time elapsed between measurements in the present study likely contributed to our reported measurement differences. Further, Berkson's measurements were taken on a small group (N = 105) of primarily 1st – 4th grade students, whereas our study sample was large (N = 1,008) and comprised older (3rd – 8th) grade students.

Importantly, the measurement differences seen in the present study have only minor implications for student BMI and BMI categorization. For example, for a 12-year-old girl who is 153.1 cm tall and weighs 50.3 kg (mean age, height, and weight for girls from this study sample), a measurement difference of 0.3 cm and −0.1 kg would equate to a 0.01% percent difference in BMI (21.5 vs. 21.3) and would not impact her BMI categorization.

Other studies that have found high measurement accuracy for PE teachers[8,10] or for nurses[9] did not compare accuracy by school-staff type. While we observed excellent measurement accuracy for school staff overall, we did find that nurses were more likely to accurately measure student height, weight, and BMI than PE teachers. Controlling for watching the training video, PE teachers were still statistically significantly less likely than nurses to accurately measure weight (0.36 kg less accurate, p = .049) and BMI (0.21 kg/m^2, p = .035). This may reflect that nurses typically have additional training and practice in collecting anthropometric measurements, or could result from differences in location and timing of measurements. PE teachers collected measurements during PE class, a setting with both a limited time-period and a potential lack of privacy for measuring height and weight, both of which could lead to hurried measurements. Nurses, in contrast, may have the advantage of greater privacy and control over timing of measurements.

Misclassification of BMI undermines the value of BMI screening and reporting. Overall, weight status was misclassified for 6% of students in the present study. This is slightly higher than the 2% BMI category misclassification reported by Berkson et al,[10] who examined the reliability of PE teachers' versus expert raters' measurements that were taken on the same day, (which likely contributed to higher measurement accuracy). Less than 1%

of students in the present study whose BMI was misclassified were outliers based on B-A plots. These measurements likely represent erroneous data, such as errors in visualizing or recording a measurement, rather than variability in measurement technique. These errors could lead to large misclassifications, eg, labelling an underweight child obese, and are probably difficult to avoid in the real-world school setting. However, achieving only 1% erroneous measures in the often-chaotic school setting is notable. All other misclassifications occurred in students close to BMI category cut-points (Figure 2), such that the students at greatest risk (ie, those most obese) were correctly classified.

We did observe small, but statistically significant, differences in measurement accuracy by grade; compared to 4th grade students, 7th grade students were less likely to have their height measured accurately, and 8th grade students less likely to have their weight and BMI measured accurately. It could be that as students age (and as body image issues increase), they become more self-conscious about having their height and weight measured, so are less likely to comply with school staff regarding measurement protocol.[17] Further, 7th and 8th grade classes were, on average, larger than 4th grade classes (32 students vs. 24 students/class); thus, PE teachers measuring older students may feel more rushed to complete the protocol, leading to more error.

Limitations

Several study limitations warrant mentioning. First, up to 33 days elapsed between researcher and school-staff measurements; thus, natural growth (or daily weight fluctuation) could have contributed to measurement differences. Second, by chance, no classroom teachers were selected into this sub-study sample, so we were not able to look at differences in measurement accuracy between classroom teachers, PE teachers, and school nurses. Finally, because nurses only measured students in grades 4-6 and PE teachers only measured students in grades 6-8, we could not examine grade as an effect modifier of the relationship between staff type and accuracy.

Conclusion

Our findings demonstrate that BMI determined by school-staff measurements among elementary and middle school students is highly accurate. School nurses collect these data with slightly more accuracy than do PE teachers. These findings ensure the validity of the height and weight data that will be used in the Fit Study, enabling us to better assess the impact of school-based BMI screening and reporting on childhood obesity.

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IMPLICATIONS FOR SCHOOL HEALTH

School-based BMI screening and reporting programs depend on the accuracy of student height and weight data collected by school staff members. This was the first study to assess measurement differences between staff types (school nurses vs. PE teachers) who routinely collect student height and weight data for such programs. While, overall, both nurses and PE teachers conducted measurements with a high degree of accuracy, PE teachers' measurements were slightly less accurate. As PE teachers typically do not have previous training in conducting anthropometric measurements, they would likely benefit more from additional training and practice to ensure the accuracy of their height and weight measurements taken on students. When possible, districts and schools should take advantage of nurses to train PE (and classroom) teachers to conduct these measurements. Further, nearly all school staff in this study (95%) said that both the height and weight training video and laminated protocol cards provided with the scales and stadiometers were useful. Offering accessible training materials (including instructional materials that can be easily used at the time of measurements), as well as the appropriate equipment, would likely help increase the accuracy of measurements taken by school staff. Both the training video and protocol cards used in this study are available for public use, at no cost, upon request.

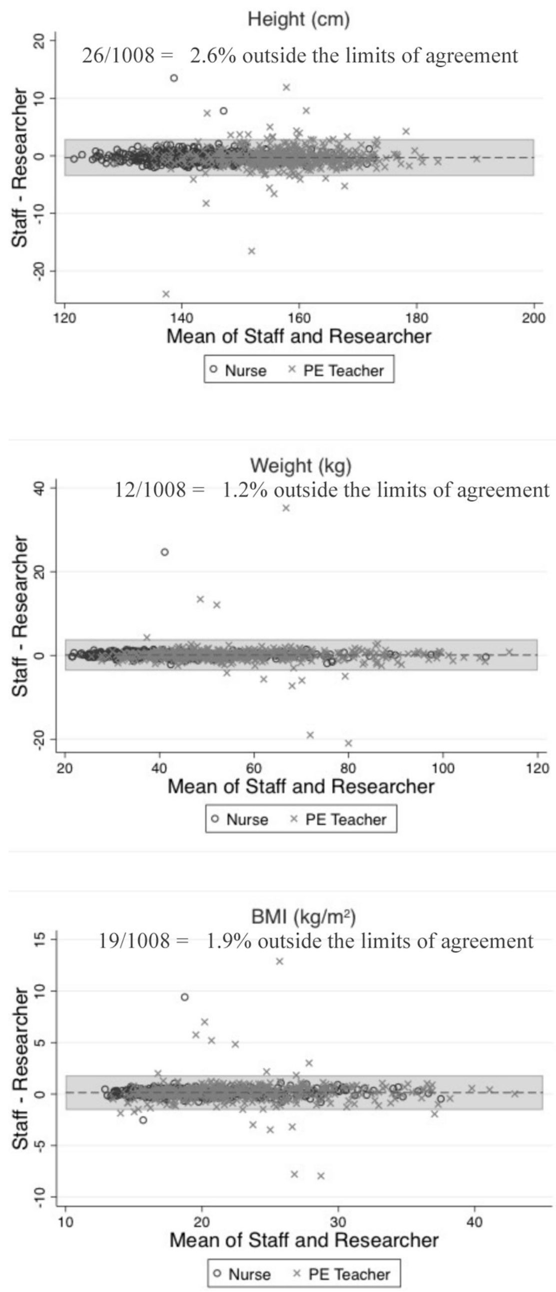

Figure 1:

Bland-Altman Plots of Height, Weight, and Body Mass Index (BMI)

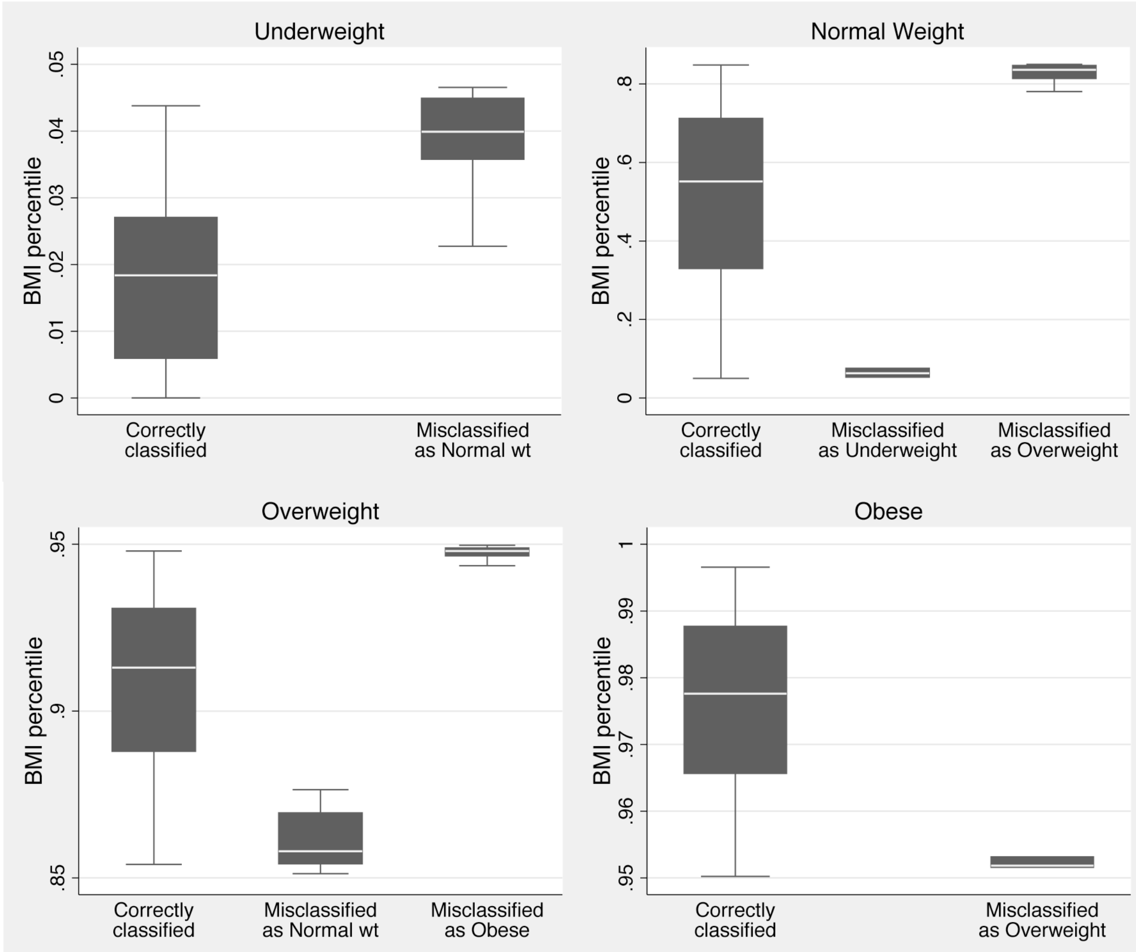

Figure 2: Body Mass Index (BMI) Category Misclassification by School Staff

Graphs exclude students (N = 19) whose body mass index (BMI) was an outlier according to Bland-Altman plots.

Table 1:

Participant Characteristics

Characteristic	**N (%) N = 1,008**
Sex	
Male	521 (51.7)
Female	487 (48.3)
Age, mean (SD)	12.0 (1.5)
Grade	
4th	179 (17.8)
5th	194 (19.3)
6th	182 (18.1)
7th	243 (24.1)
8th	210 (20.8)
Race/ethnicity	
Asian	113 (11.2)
African American	61 (6.1)
Hispanic/Latino	680 (67.5)
White	122 (12.1)
Other/Unknown	32 (3.2)
Qualifies for free or reduced price meals	529 (66.7)

Table 2:

Mean Measurement and Measurement Differences by Rater Type

	Researcher measurement		School staff measurement		Relative difference		Absolute difference		ICC
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	
Height (cm)	151.1 (11.1)	121.9, 190.5	150.8 (11.1)	121.4, 190.0	−0.3 (1.6)	−24.0, 13.5	1.0 (1.4)	0, 24.0	0.989
Weight (kg)	49.3 (16.2)	21.6, 113.6	49.4 (16.1)	21.3, 114.4	0.1 (1.9)	−21.0, 35.2	0.7 (1.8)	0, 35.2	0.993
BMI	21.2 (5.0)	12.7, 42.9	21.3 (5)	13.0, 42.9	0.1 (0.9)	−7.9, 12.9	0.4 (0.8)	0, 12.9	0.985

BMI = Body Mass Index; ICC = Intraclass correlation coefficient

Table 3:

Number and Percent of Students in Each Body Mass Index (BMI) Category, by Measurer Type (N = 1008)

	Researcher-measured, N (%)	**Staff-measured, N (%)**	**% Agreement[a] 94.1% (Overall)**	**κ coefficient 0.90 (Overall)**
Underweight (BMI < 5^{th} percentile)	38 (3.8)	32 (3.2)	71.1	0.76
Normal weight (BMI 5^{th} to <85^{th} percentile)	556 (55.2)	553 (54.9)	96.0	0.92
Overweight (BMI ≥ 85^{th} and < 95^{th} percentile)	201 (19.9)	207 (20.5)	90.6	0.87
Obese (BMI ≥ 95^{th} percentile)	213 (21.1)	216 (21.4)	96.2	0.94

[a]% of students in Researcher categories correctly classified by School Staff.