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Utility of BMI in Identifying Excess Adiposity in Youth across the Obesity Spectrum

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Abstract

Objectives—To determine the proportion of youth within a given body mass index (BMI) obesity category with excess adiposity using DXA. Furthermore, to examine whether mean differences in cardiometabolic risk factors based upon various excess adiposity cut-points were present.

Methods—DXA data from NHANES 1999-2006 (n=10,465, aged 8-20 years old) were utilized for this analysis. Obesity categories were defined using Center for Disease Control definitions for age and gender. Excess adiposity was defined using cohort-specific cut-points at 75th, 85th, and 90th percentile of DXA body fat (%) by age and gender using quantile regression models. Additionally, we examined differences in cardiometabolic risk factors among youth (BMI-percentile >85th) above and below various excess adiposity cut-points.

Results—Nearly all youth with class 3 obesity (100% M, 100% F; 97% M, 99% F; and 95% M, 96% F; using the 75th, 85th, and 90th DXA-percentile, respectively) and a high proportion of those with class 2 obesity (98% M, 99% F; 92% M, 91% F; and 76% M, 76% F) had excess adiposity. Significant discordance was observed between BMI categorization and DXA-derived excess adiposity among youth with class 1 obesity or overweight. Elevated cardiometabolic risk factors were present in youth with excess adiposity, regardless of the cut-point used.

Conclusions—BMI correctly identifies excess adiposity in most youth with class 2 and 3 obesity but a relatively high degree of discordance was observed in youth with obesity and

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overweight. Cardiometabolic risk factors are elevated in the presence of excess adiposity regardless of the cut-point used.

Keywords

NHANES; Dual energy X-ray absorptiometry; Obesity; Adiposity; Children

Introduction

In the clinical setting, body mass index (BMI) is used to determine obesity status and as a means of risk stratification in children and adolescents.¹ Despite its widespread application as a surrogate measure of adiposity, BMI is derived from the ratio of weight and height without accounting for different distributions in fat or fat-free mass.² To further compound this issue, normal growth and maturation as children transition through puberty into young adulthood skew the relationship between BMI and adiposity, a phenomenon not fully addressed by BMI percentiles.³ Therefore, BMI-based obesity categories may misclassify some youth who either do or do not have excess adiposity in terms of body fatness (e.g., 95th BMI percentile without excess adiposity).³⁻⁵ Since excess adiposity is thought to drive the pathophysiology of chronic diseases such as type 2 diabetes and cardiovascular disease,^{6, 7} and is more closely associated with all-cause mortality than BMI alone in adults,⁸ defining ideal cut-points for excess adiposity in youth is important.

Studies using skinfolds as a measure of body fatness suggest that a relatively low proportion of youth with BMI <95th percentile have excess levels of body fatness; however, the presence of excess adiposity becomes more prevalent among those with BMI 95th percentile, although some level of misclassification occurs.^{4, 5, 9} Studies utilizing more direct measures of adiposity [e.g. dual energy X-ray absorptiometry (DXA)] to address this question are lacking.¹⁰ One factor complicating this issue is the lack of a consensus definition of excess adiposity.^{4, 5} Thus, normative data for levels of body fatness using DXA measures within various age, gender, and racial groups are needed in order to evaluate multiple excess adiposity cut-points across the range of BMI from normal weight to severe obesity.

Therefore, we examined the ability of BMI to correctly identify excess adiposity by generating pediatric body fat distribution curves using DXA data from the National Health and Nutrition Examination Survey (NHANES). We developed normative data for body fatness by age, gender, and race and utilized multiple cut-points to describe the proportion of youth with excess adiposity within various BMI-based obesity categories ranging from normal weight to severe obesity. Furthermore, we evaluated whether specific cardiometabolic risk factors were elevated in the presence of excess adiposity using multiple cut-points.

Methods

Study Population

We utilized data from NHANES 1999-2006 for this analysis. We included all participants with completed or imputed DXA data from 8 through 20 years old (mean age = 14.6 ± 3.3 years old; males = 5,933; females = 4,532). NHANES is a representative, cross-sectional sample of the U.S. civilian, non-institutionalized population involving a combination of interviews and physical examinations.¹¹ Parental consent and child assent were obtained. Race and ethnicity were self-reported, and in the current study we classified participants as Hispanic, non-Hispanic white, non-Hispanic black, and other.

Dual Energy X-Ray Absorptiometry Examinations

DXA scans were completed for all participants who met inclusion criteria of being at least 8 years of age, not pregnant, and weighing less than 300 pounds (scanner weight-limit). Body fat % was calculated based on the DXA estimates of total fat versus total mass. In cases where DXA scans could not be completed or values were missing, NHANES provides five imputed values for each individual to enable their inclusion in statistical analysis. DXA values are imputed by NHANES through sequential regression multivariate imputation as implemented via a SAS callable software package.¹² We used these imputed values in all our analyses (n=1187).

BMI Classification

BMI was calculated as the body weight in kilograms divided by the height in meters squared. BMI percentiles were determined using age- and gender-based definitions from the Centers for Disease Control and Prevention. Individuals were classified as normal weight (<85th BMI percentile), overweight (85th-<95th BMI percentile), obese class 1 (95th BMI percentile-<1.2 times the 95th percentile, obese class 2 (1.2-<1.4 times the 95th BMI-percentile), and obese class 3 (1.4 times the 95th percentile).

Excess Adiposity

We utilized 3 different cohort-specific cut-points to define excess adiposity based on the 75th, 85th, and 90th percentile of the age- and gender-specific DXA body fat %. These were calculated separately for males and females using quantile regression models with natural cubic splines on age to determine the 75th, 85th, and 90th percentile curves. We then applied each excess adiposity cut-point to determine the proportion of children and adolescents who met the criterion for excess adiposity within each BMI classification (normal weight, overweight, class 1 obese, class 2 obese, and class 3 obese).

Cardiometabolic Risk Factors

Differences in mean levels of cardiometabolic risk factors between those with and without excess adiposity were examined among individuals 85th BMI-percentile for each of the three percentile cut-points to define excess adiposity. Cardiometabolic risk factors (obtained after participants had been fasting for 8 hours) included: triglycerides, low-density lipoprotein cholesterol (LDL-c), high-density lipoprotein cholesterol (HDL-c), total

cholesterol (TC), glucose, insulin, homeostatic model of insulin resistance (HOMA-IR), C-reactive protein (CRP), glycosylated hemoglobin (HbA1C), systolic blood pressure (BP) percentile, and diastolic BP percentile.

Statistical Analyses

Subject characteristics were summarized by gender with means and standard deviations provided for continuous variables while counts and percentage within each group are displayed for categorical variables: sampling weights were not incorporated in the descriptive table. Quantile regression was used with natural cubic splines to allow flexible, non-linear trajectories in estimates over the range of values of the predictor of interest (varied across age, BMI percentile, or multiple of the 95th BMI percentile at different times). Natural cubic splines were used with 6 degrees of freedom when all races/ethnicities were included and 4 degrees of freedom within subgroup analyses for races/ethnicities due to smaller sample size. The estimated 75th, 85th, and 90th percentile for DXA body fat % across age (evaluated separately for each gender) was used as the candidate cutoff for defining excess adiposity. NHANES sample weights were incorporated to determine the percentage of individuals classified as having excess adiposity for a given BMI category. This categorization of excess adiposity was used for the proportion of youth with excess adiposity at different BMI percentile cut-offs. Differences in specific cardiometabolic risk factors between individuals with and without excess adiposity were evaluated using two sided t-tests with unequal variance and Welch degrees of freedom. All analyses were conducted in R v3.2.0.¹³ Quantile regression was performed using the *quantreg* package v5.11.¹⁴ Multiply imputed data and survey weights were incorporated in all analyses using the *mitools* package v2.3.¹⁵ and the *survey* package v3.30.¹⁶ Each of the 5 imputation groups from NHANES was fit to the model separately before being combined.

Results

The characteristics of children and adolescents utilized in our analysis are displayed in Table 1. During this NHANES data collection period, over-sampling was performed for Mexican Americans (33.8% and 32.6%, male and female, respectively) and non-Hispanic Blacks (32.9% and 31.8%, male and female, respectively) relative to non-Hispanic Whites (25.7% and 27.2%, male and female, respectively). The majority of participants were classified as having normal weight (64.0% and 62.8%, male and female, respectively), with similar distributions by gender. Despite having similar BMI and BMI-percentile values as the males, females had higher DXA total fat (g) and DXA body fat (%). Analyses herein are presented on the cohort as a whole with gender splits where necessary.

Figure 1 (Panel A and B) displays curves for DXA body fat % for females and males plotted over the entire age range (8-20 years old). Each plot contains lines that demarcate the 10th, 25th, 50th (median), 75th, 85th, and 90th percentiles for DXA body fat % for each gender. The data derived from these gender-specific growth curves from every 0.5 year from age 8 - 19.5 years old are presented by race/ethnicity specific distributions (All races combined, Hispanic, Caucasian, and African-American) and are displayed in Tables 3, 4, 5, and 6.

Curves for DXA body fat % for females and males across BMI percentiles are shown in Figure 1 (Panel C and D). Specific cut-points (10th, 25th, 50th (median), 75th, 85th, and 90th percentiles) were derived using DXA body fat % across the BMI percentile for age and gender. Since there is no clear consensus definition of excess adiposity, we utilized multiple gender- and age-specific excess adiposity cut-points (75th, 85th, and 90th DXA-percentile) to determine the proportion of individuals with excess adiposity within a given BMI percentile-based obesity category (Figure 2). Nearly all youth with class 3 obesity has excess adiposity (100% M, 100% F; 97% M, 99% F; and 95% M, 96% F; for 75th, 85th, and 90th DXA-percentile respectively) and a high proportion of those with class 2 obesity (98% M, 99% F; 92% M, 91% F; and 76% M, 76% F). A high degree of discordance was observed between BMI classification and DXA-derived excess adiposity among youth with class 1 obesity (81% M, 86% F; 53% M, 60% F; and 33% M, 37% F) and overweight (42% M, 44% F; 16% M, 16% F; and 7% M, 6% F). Only a small proportion of those in the normal weight classification (4% M, 4% F; 1% M, 1% F; and 0% M, 0% F) had excess adiposity.

Differences in mean levels of specific cardiometabolic risk factors were examined among individuals 85th BMI-percentile using various cut-points to define excess adiposity (Table 2). Statistically significant differences between those with and with excess adiposity were observed for many specific cardiometabolic risk factors, except diastolic BP percentile, at each excess adiposity cut-point ($p < 0.01$ all). Diastolic BP percentile were statistically different at 85th ($p < 0.05$) but not the 90th ($p > 0.05$) excess adiposity cut-points.

Discussion

Using data from NHANES, we have developed normative body fat percentile curves across age for each gender, using a large nationally-representative sample of children and adolescents, from DXA measurements of fat mass. Various excess adiposity cut-points (age- and sex-specific 75th, 85th, or 95th percentile) were used to determine the proportion of youth with excess adiposity within a given BMI percentile-based obesity category. Findings from our study suggest that the vast majority of youth with severe obesity (class 2 and 3) have excess adiposity regardless of the cut-point used to define excess adiposity. However, we observed significant discordance between DXA-derived excess adiposity and BMI status in youth with class 1 obesity and overweight, suggesting a high degree of misclassification using BMI-based definitions. Excess adiposity was rare among youth of normal weight. Our findings were consistent within males and females. Finally, we observed that levels of specific cardiometabolic risk factors were significantly higher in children and adolescents with excess adiposity regardless of the excess adiposity cut-point used.

Approximately 6% of all children and adolescents in the United States have severe obesity (class 2 and 3 obese), an obesity subclass that continues to increase in prevalence.¹⁷ Unfortunately, youth afflicted by this disease have a high prevalence of cardiometabolic risk factors and co-morbidities.^{18, 19} Data using skinfolds showed that 94% of youth with a BMI 99th percentile, an historically-used definition of severe obesity, had excess adiposity using a 90th percentile body fat cut-point. However, use of the 99th BMI percentile to define severe obesity has its limitations and the use of 120% to <140% of the 95th BMI percentile for class 2 obesity and 140% of the 95th BMI percentile for class 3 obesity has been

recommended.^{19, 20} Our analysis using these classifications, along with the inclusion of DXA data, show that excess adiposity is ubiquitous in class 3 obesity and highly prevalent in class 2 obesity. Indeed, using the cut-points of 75th and 85th percentile for excess adiposity, greater than 90% of youth with class 2 obesity exhibit excess adiposity. These data demonstrate that in the context of severe obesity, BMI is an accurate indicator of excess adiposity and that only in rare cases will youth with BMI percentile-classified severe obesity not have excess adiposity.

To the contrary, youth with class 1 obesity (95th BMI percentile to <120% of 95th BMI percentile) and overweight exhibited large discrepancies between BMI classification and the presence of excess adiposity. Although at the highest DXA-derived cut-point (90th percentile) a relatively high proportion (81% M/86% F) of youth with class 1 obesity were above the threshold, there is a step-wise decrease as the threshold defining excess adiposity becomes less rigid (53% M, 60% F; and 33% M, 37% F, for 85th and 75th percentile respectively). Misclassification is even more common in youth with overweight. These findings suggest that the use of BMI as a surrogate measure of excess adiposity is somewhat questionable when utilized among youth with class 1 obesity and can be highly inaccurate when applied to youth with overweight. However, it should be noted that the designation of overweight by BMI should not be construed as the absence of excess adiposity. In the clinical setting, healthcare providers may choose to use an overweight diagnosis as rationale for further evaluation and possible intervention. Nevertheless, these results underscore the need for a more accurate and reliable estimate of excess adiposity in youth beyond the use of BMI alone.

We observed that individuals with excess adiposity, regardless of the cut-point used, had significantly elevated levels of numerous cardiometabolic risk factors compared to those without excess adiposity. The association between increased body fatness and adverse cardiometabolic disease risk factors is well documented in children and adolescents.^{21–26} However, we found that the mean levels of specific cardiometabolic risk factors were relatively similar regardless of the excess adiposity cut-point used (75th, 85th or 90th). From a clinical standpoint, these findings suggest that the lowest cut-point, the 75th percentile, may be the most useful for risk stratification purposes.

There are a few limitations of this study which are worthy of note. Using pubertal stages rather than age may have yielded more robust estimates of normative body fat distribution curves; however, Tanner staging was not collected as part of NHANES. DXA estimates of body fatness are known to vary across manufacturers, machines, and software versions.^{27–29} In NHANES, body fatness was measured using the Hologic QDR-4500-A device, which has been shown to overestimate lean mass among adults.^{30, 31} To address this issue, the National Center for Health Statistics decreased the recorded DXA lean mass values by 5% and added an equivalent weight to each subject's fat mass.³² While DXA is a practical and reliable approach for estimating body composition, it does have limitations in comparison with gold-standard methods of body composition such as the 4 compartment model.³³ Furthermore, we did not examine the ability of other indexes such as the fat mass index,³⁴ to predict excess adiposity nor its relationship with cardiometabolic risk factors. While we examined many cardiometabolic risk factors available within the NHANES database, the analysis was not

all-encompassing and did not include all cardiometabolic risk factors. Furthermore, we did not account for lifestyle factors such as dietary quality or physical activity, which may have influenced the results.

In conclusion, the vast majority of youth with severe obesity defined by BMI-based obesity categories have excess adiposity, regardless of the cut-point used. Significant discordance was observed between DXA-derived excess adiposity in youth with obesity and overweight suggesting a high degree of misclassification using BMI-based definitions. Elevated levels of many specific cardiometabolic risk factors were present in youth with excess adiposity compared to those without, regardless of the cut-point used to define excess adiposity. The 75th percentile for body fatness appears to be a useful threshold for identifying youth most likely to have adverse levels of most cardiometabolic risk factors. Clinicians need to be aware of the limitations of using BMI as a surrogate measure of adiposity in youth with overweight and class 1 obesity, where misclassification is most prominent. Moreover, researchers studying youth in these categories may wish to consider quantifying body fatness with more direct assessments like DXA to accurately classify adiposity levels. Development of a measure that has greater accuracy in identifying excess adiposity than BMI yet is clinically practical, is clearly needed.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations

DXA	Dual energy X-ray absorptiometry
BMI	Body mass index
NHANES	National Health and Nutrition Examination Survey

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Figure 1.

Curves for DXA body fat (%) for a given age (years) for females (A) and males (B) and by BMI-percentile (the vertical dashed lines demarcate the 85th and 95th BMI percentiles) for females (C) and males (D). Based on splines with $df=6$. Each plot contains lines that demarcate the 10th, 25th, 50th (median), 75th, 85th, and 90th percentiles for DXA body fat (%) for each age 8 to 20.

Figure 2.

Proportion of individuals within a given BMI-based obesity category with excess adiposity at three cut-points (75th, 85th, and 90th percentile) determined by DXA body fat (%).

Table 1

Sample characteristics split by gender with values expressed as mean (SD) or N (%) where indicated.

	Males (N=5933)	Females (N=4532)
Age (years)	14.6 (3.3)	14.6 (3.4)
Race/Ethnicity		
– Mexican American	2004 (33.8%)	1485 (32.8%)
– Other Hispanic	212 (3.6%)	169 (3.7%)
– Non-Hispanic White	1525 (25.7%)	1234 (27.2%)
– Non-Hispanic Black	1952 (32.9%)	1440 (31.8%)
– Other Race	240 (4.0%)	204 (4.5%)
Height (cm)	163 (16.2)	156 (11.5)
Weight (kg)	61.7 (23.0)	57.4 (19.5)
BMI (kg/m ²)	22.6 (5.85)	23.2 (6.24)
BMI-Percentile	63.3 (31.1)	66.6 (28.8)
BMI Category Distribution		
– Normal-weight	3800 (64.0%)	2846 (62.8%)
– Overweight	925 (15.6%)	771 (17.0%)
– Class 1 Obese	760 (12.8%)	583 (12.9%)
– Class 2 Obese	318 (5.4%)	240 (5.3%)
– Class 3 Obese	130 (2.2%)	92 (2.0%)
DXA Total Fat (g)	16.3 (10.5)	20.5 (11.0)
DXA Body Fat (%)	25% (8%)	34% (7%)

Definitions: BMI = Body Mass Index; Normal-weight = 0th to <85th BMI-percentile; Overweight = 85th to <95th BMI-percentile; Class 1 Obese = 95th to <1.2 × 95th BMI-percentile; Class 2 Obese = 1.2 × 95th to <1.4 × 95th BMI-percentile; Class 3 Obese = 1.4 × 95th BMI-percentile; DXA = Dual energy X-ray absorptiometry.

Specific cardiometabolic risk factors in those defined as having excess adiposity versus not for each percentile cut-point (Only participants 85th BMI Percentile).

Table 2

Measurement	Excess Adiposity Cut-point Percentile	N: Not Excess Adiposity	Mean (SD): Not Excess	N: Excess Adiposity	Mean (SD): Excess	Difference (Excess-Not Excess)	Difference 95% CI	p-value
Triglycerides (mg/dL)	75th	424	90.6 (57.8)	791	112.2 (69.4)	-21.6	(-28.9, -14.3)	<0.001
	85th	688	95.8 (57.9)	527	116.2 (74.5)	-20.4	(-28.1, -12.7)	<0.001
	90th	846	98.9 (60.4)	369	117.9 (76.7)	-19.1	(-27.9, -10.2)	<0.001
LDL-c (mg/dL)	75th	402	95.9 (28.4)	763	100.4 (27.2)	-4.6	(-8, -1.2)	0.008
	85th	659	96.5 (27.9)	506	101.9 (27.3)	-5.4	(-8.6, -2.2)	0.001
	90th	812	97.6 (28.2)	353	101.9 (26.4)	-4.3	(-7.7, -0.9)	0.013
HDL-c (mg/dL)	75th	428	49.8 (11.9)	791	45.3 (10.3)	4.5	(3.1, 5.8)	<0.001
	85th	692	48.6 (11.7)	527	44.6 (9.7)	4.0	(2.8, 5.2)	<0.001
	90th	850	48 (11.5)	369	44.3 (9.6)	3.6	(2.4, 4.9)	<0.001
Total Cholesterol (mg/dL)	75th	428	163.5 (33)	791	167.8 (30.8)	-4.3	(-8.1, -0.5)	0.028
	85th	692	163.9 (31.9)	527	169.4 (31.1)	-5.5	(-9, -1.9)	0.003
	90th	850	164.8 (31.9)	369	169.8 (30.8)	-5.0	(-8.8, -1.2)	0.011
Glucose (mg/dL)	75th	433	92.1 (7.7)	798	93.7 (8.7)	-1.6	(-2.6, -0.7)	0.001
	85th	698	92.5 (8.1)	533	93.9 (8.7)	-1.4	(-2.3, -0.4)	0.005
	90th	857	92.4 (8)	374	94.6 (9)	-2.2	(-3.3, -1.1)	<0.001
Insulin (uU/mL)	75th	428	13.8 (7.6)	789	23.1 (15.5)	-9.3	(-10.6, -8)	<0.001
	85th	690	15.9 (10.4)	527	24.9 (16.2)	-8.9	(-10.5, -7.3)	<0.001
	90th	848	16.7 (10.7)	369	27.1 (17.5)	-10.4	(-12.3, -8.5)	<0.001
HOMA-IR	75th	428	3.18 (1.92)	789	5.45 (4.04)	-2.26	(-2.6, -1.93)	<0.001
	85th	690	3.71 (2.68)	527	5.88 (4.25)	-2.17	(-2.58, -1.75)	<0.001
	90th	848	3.86 (2.7)	369	6.46 (4.65)	-2.60	(-3.11, -2.09)	<0.001
CRP (mg/dL)	75th	433	0.22 (0.63)	794	0.35 (0.63)	-0.13	(-0.21, -0.06)	<0.001

Measurement	Excess Adiposity Cut-point Percentile	N: Not Excess Adiposity	Mean (SD): Not Excess	N: Excess Adiposity	Mean (SD): Excess	Difference (Excess-Not Excess)	Difference 95% CI	p-value
	85th	698	0.22 (0.57)	529	0.42 (0.7)	-0.20	(-0.27, -0.12)	<0.001
	90th	857	0.23 (0.56)	370	0.48 (0.75)	-0.24	(-0.33, -0.16)	<0.001
HbA1c	75th	433	5.16 (0.29)	793	5.2 (0.28)	-0.04	(-0.08, -0.01)	0.009
	85th	698	5.17 (0.28)	528	5.21 (0.29)	-0.05	(-0.08, -0.02)	0.003
	90th	857	5.17 (0.28)	369	5.24 (0.3)	-0.07	(-0.11, -0.04)	<0.001
Systolic BP Percentile	75th	384	48.7 (27.4)	669	55.7 (27.7)	-7.0	(-10.4, -3.5)	<0.001
	85th	608	49.6 (27.6)	445	58 (27.2)	-8.4	(-11.8, -5)	<0.001
	90th	739	50.3 (27.8)	314	59.9 (26.5)	-9.6	(-13.2, -6)	<0.001
Diastolic BP Percentile	75th	379	36 (27.5)	665	37.4 (25.5)	-1.4	(-4.8, 2)	0.420
	85th	601	35.5 (26.1)	443	38.8 (26.4)	-3.3	(-6.5, 0)	0.047
	90th	732	35.9 (26.1)	312	39.2 (26.5)	-3.3	(-6.8, 0.2)	0.066

Abbreviations (in order of appearance): TG = triglycerides; LDL-c = low-density lipoprotein cholesterol; HDL-c = high-density lipoprotein cholesterol; TC = total cholesterol; HOMA-IR = homeostatic model of insulin resistance; CRP = c-reactive protein; HbA1c = glycosylated hemoglobin.

Table 3
Estimated DXA body fat % by age from quantile regression, according to gender and all races.

Age (years)	Percentile for Boys					Percentile for Girls						
	10th	25th	50th	75th	90th	10th	25th	50th	75th	85th	90th	
8.0	19.2	21.3	24.9	31.0	35.1	38.5	23.3	25.2	29.5	35.3	37.6	39.4
8.5	19.5	21.7	25.3	31.8	35.6	38.6	23.3	25.7	30.2	35.9	38.6	40.2
9.0	19.7	22.1	25.7	32.6	36.0	38.8	23.2	26.1	30.8	36.5	39.5	41.0
9.5	19.9	22.4	26.1	33.4	36.5	39.0	23.2	26.4	31.4	37.0	40.4	41.6
10.0	19.9	22.7	26.4	34.0	37.0	39.2	23.2	26.7	31.8	37.4	41.0	42.1
10.5	19.9	22.8	26.7	34.6	37.6	39.6	23.2	26.9	32.0	37.7	41.3	42.5
11.0	19.6	22.8	26.8	34.9	38.2	40.0	23.2	27.0	32.0	37.7	41.4	42.5
11.5	19.3	22.6	26.7	35.1	38.7	40.4	23.2	27.0	31.9	37.6	41.1	42.4
12.0	18.8	22.2	26.5	34.9	39.0	40.7	23.2	26.9	31.6	37.4	40.7	42.2
12.5	18.2	21.6	26.0	34.5	38.8	40.6	23.2	26.9	31.4	37.3	40.4	42.0
13.0	17.6	20.9	25.2	33.5	38.0	39.9	23.3	26.9	31.3	37.2	40.2	41.9
13.5	17.1	20.0	24.2	32.1	36.3	38.5	23.3	27.1	31.5	37.3	40.4	42.0
14.0	16.6	19.1	23.1	30.5	34.3	36.8	23.4	27.3	31.8	37.5	40.7	42.2
14.5	16.1	18.2	22.0	29.2	32.6	35.2	23.6	27.5	32.1	37.6	40.9	42.4
15.0	15.7	17.6	21.3	28.3	31.5	34.3	24.1	27.8	32.3	37.5	40.9	42.4
15.5	15.4	17.2	21.0	28.1	31.3	34.0	24.7	28.0	32.4	37.3	40.6	42.4
16.0	15.1	16.9	20.9	28.1	31.4	34.0	25.4	28.3	32.5	37.2	40.4	42.4
16.5	14.9	16.8	20.8	28.1	31.5	33.9	26.0	28.6	32.5	37.2	40.4	42.7
17.0	14.8	16.6	20.6	27.9	31.1	33.7	26.4	29.0	32.8	37.6	40.9	43.3
17.5	14.8	16.6	20.4	27.5	30.6	33.2	26.7	29.4	33.1	38.2	41.7	44.2
18.0	14.9	16.6	20.4	27.2	30.3	32.9	26.9	29.9	33.7	39.0	42.6	45.0
18.5	15.0	16.8	20.5	27.1	30.5	33.0	26.9	30.3	34.3	39.8	43.4	45.7
19.0	15.2	17.2	20.8	27.1	31.2	33.4	27.0	30.6	35.2	40.5	43.9	46.0
19.5	15.3	17.6	21.2	27.3	32.3	34.0	27.1	30.9	36.1	41.1	44.3	46.0

Table 4

Estimated DXA body fat % by age for Hispanics from quantile regression, according to gender.

Age	Percentile for Boys						Percentile for Girls					
	10th	25th	50th	75th	85th	90th	10th	25th	50th	75th	85th	90th
8.0	20.1	21.8	27.2	33.2	36.8	39.4	24.4	28.0	33.4	39.2	42.1	44.1
8.5	20.3	22.5	27.9	34.4	37.8	40.1	24.4	27.9	33.6	39.4	42.2	44.1
9.0	20.4	23.2	28.7	35.5	38.7	40.8	24.4	27.8	33.8	39.6	42.2	44.0
9.5	20.5	23.7	29.3	36.6	39.5	41.4	24.5	27.8	33.9	39.7	42.3	44.0
10.0	20.5	24.2	29.9	37.4	40.3	41.8	24.5	27.8	34.1	39.9	42.3	43.9
10.5	20.5	24.4	30.2	38.0	40.8	42.2	24.6	27.8	34.3	39.9	42.3	43.8
11.0	20.4	24.5	30.3	38.3	41.0	42.3	24.7	27.9	34.4	39.9	42.3	43.7
11.5	20.2	24.3	30.2	38.3	41.0	42.2	24.8	28.0	34.5	39.8	42.2	43.6
12.0	19.9	23.9	29.8	37.9	40.7	41.8	25.0	28.3	34.6	39.6	42.0	43.5
12.5	19.4	23.1	29.0	37.0	40.0	41.2	25.2	28.6	34.6	39.3	41.9	43.4
13.0	18.9	22.2	27.9	35.7	39.0	40.2	25.4	29.0	34.6	39.0	41.6	43.3
13.5	18.3	21.0	26.8	34.3	37.8	39.2	25.6	29.4	34.6	38.6	41.4	43.2
14.0	17.6	19.9	25.6	32.8	36.6	38.2	25.9	29.9	34.6	38.3	41.3	43.2
14.5	17.0	19.0	24.5	31.5	35.4	37.4	26.3	30.3	34.6	38.2	41.3	43.2
15.0	16.5	18.3	23.7	30.6	34.5	36.8	26.6	30.6	34.6	38.3	41.4	43.4
15.5	16.0	18.0	23.1	30.0	33.9	36.6	27.0	30.8	34.7	38.7	41.8	43.6
16.0	15.7	17.9	22.8	29.7	33.5	36.5	27.4	30.9	34.8	39.3	42.3	44.0
16.5	15.4	17.9	22.7	29.5	33.1	36.4	27.7	31.0	34.9	39.9	42.8	44.4
17.0	15.3	18.0	22.6	29.4	32.8	36.2	28.1	31.0	34.9	40.6	43.4	44.8
17.5	15.3	18.2	22.7	29.1	32.4	35.8	28.3	31.1	35.0	41.1	43.9	45.2
18.0	15.5	18.3	22.7	28.7	32.0	35.2	28.5	31.2	35.1	41.4	44.2	45.7
18.5	15.8	18.4	22.7	28.1	31.4	34.3	28.6	31.3	35.1	41.4	44.4	46.1
19.0	16.1	18.5	22.7	27.5	30.9	33.3	28.6	31.4	35.1	41.2	44.5	46.4
19.5	16.5	18.6	22.7	26.8	30.3	32.2	28.6	31.5	35.1	41.0	44.4	46.8

Table 5
Estimated DXA body fat % by age for African Americans from quantile regression, according to gender.

Age	Percentile for Boys						Percentile for Girls					
	10th	25th	50th	75th	85th	90th	10th	25th	50th	75th	85th	90th
8.0	18.5	19.7	22.2	26.4	32.4	35.4	20.8	23.6	27.8	34.2	37.2	38.4
8.5	18.2	19.7	22.6	27.8	33.4	36.3	20.9	23.7	28.4	34.8	38.2	39.5
9.0	17.9	19.7	23.0	29.1	34.4	37.1	21.0	23.8	29.0	35.4	39.2	40.5
9.5	17.6	19.7	23.3	30.4	35.3	37.9	21.2	24.0	29.6	35.9	40.1	41.4
10.0	17.2	19.6	23.5	31.4	36.1	38.6	21.3	24.1	30.1	36.4	40.8	42.3
10.5	16.9	19.5	23.6	32.2	36.6	39.1	21.4	24.3	30.5	36.8	41.5	42.9
11.0	16.6	19.3	23.6	32.7	36.9	39.5	21.6	24.6	30.9	37.1	41.9	43.4
11.5	16.3	19.1	23.4	32.7	37.0	39.7	21.9	24.9	31.2	37.4	42.1	43.7
12.0	16.0	18.7	23.0	32.3	36.6	39.6	22.2	25.3	31.4	37.5	42.1	43.7
12.5	15.8	18.3	22.3	31.5	35.9	39.3	22.5	25.7	31.5	37.4	41.8	43.5
13.0	15.5	17.8	21.5	30.2	35.0	38.7	22.9	26.2	31.5	37.4	41.3	43.1
13.5	15.2	17.3	20.6	28.8	33.8	38.0	23.2	26.7	31.5	37.3	40.8	42.6
14.0	14.9	16.8	19.7	27.4	32.7	37.1	23.5	27.2	31.5	37.3	40.5	42.3
14.5	14.6	16.3	18.9	26.3	31.7	36.3	23.8	27.5	31.5	37.3	40.4	42.3
15.0	14.3	15.8	18.3	25.7	31.1	35.4	24.0	27.8	31.7	37.6	40.6	42.5
15.5	14.1	15.5	17.8	25.5	30.7	34.7	24.2	27.9	32.0	38.0	41.2	43.1
16.0	13.8	15.2	17.6	25.6	30.5	34.0	24.3	28.0	32.3	38.5	42.0	43.8
16.5	13.6	15.0	17.5	25.8	30.4	33.5	24.4	28.1	32.8	39.0	42.8	44.6
17.0	13.4	14.9	17.5	26.0	30.3	33.0	24.5	28.2	33.2	39.6	43.6	45.4
17.5	13.4	14.9	17.5	26.0	30.1	32.7	24.7	28.3	33.7	40.3	44.3	46.1
18.0	13.4	14.9	17.6	25.7	29.7	32.5	24.9	28.6	34.2	40.9	44.8	46.5
18.5	13.5	14.9	17.8	25.2	29.2	32.4	25.2	28.9	34.8	41.4	45.1	46.8
19.0	13.7	15.0	17.9	24.5	28.6	32.3	25.6	29.2	35.3	42.0	45.3	46.9
19.5	13.9	15.2	18.1	23.7	27.9	32.3	25.9	29.6	35.8	42.5	45.3	46.9

Table 6

Estimated DXA body fat % by age for Caucasians from quantile regression, according to gender.

Age	Percentile for Boys					Percentile for Girls						
	10th	25th	50th	75th	90th	10th	25th	50th	75th	90th		
8.0	19.9	21.7	24.1	29.0	32.0	35.9	24.2	25.4	29.4	34.4	38.2	39.6
8.5	20.1	22.1	24.8	30.2	33.2	37.0	24.2	25.7	29.8	34.9	38.7	40.1
9.0	20.3	22.5	25.4	31.4	34.5	38.0	24.2	26.0	30.1	35.4	39.1	40.6
9.5	20.4	22.9	26.0	32.5	35.6	39.0	24.2	26.3	30.4	35.9	39.6	41.0
10.0	20.4	23.2	26.4	33.4	36.6	39.8	24.1	26.5	30.7	36.3	39.9	41.4
10.5	20.4	23.3	26.7	34.1	37.3	40.4	24.0	26.8	30.9	36.7	40.3	41.7
11.0	20.2	23.3	26.9	34.6	37.8	40.8	23.9	27.0	31.1	37.0	40.5	42.0
11.5	20.0	23.2	26.8	34.7	38.1	40.8	23.8	27.1	31.3	37.2	40.7	42.2
12.0	19.6	22.8	26.5	34.5	37.9	40.6	23.6	27.1	31.4	37.4	40.8	42.3
12.5	19.1	22.2	25.9	33.9	37.4	40.0	23.3	27.1	31.4	37.4	40.8	42.3
13.0	18.4	21.4	25.1	32.9	36.6	39.1	23.1	27.1	31.4	37.3	40.8	42.2
13.5	17.7	20.5	24.2	31.8	35.5	38.0	22.9	27.0	31.4	37.2	40.7	42.0
14.0	17.0	19.6	23.3	30.6	34.4	36.8	22.9	27.0	31.3	37.0	40.5	41.9
14.5	16.4	18.7	22.4	29.5	33.2	35.7	23.1	27.1	31.3	36.9	40.4	41.8
15.0	15.9	18.0	21.6	28.6	32.1	34.7	23.5	27.3	31.4	36.8	40.2	41.8
15.5	15.5	17.4	21.1	28.0	31.2	33.9	24.1	27.7	31.5	36.7	40.1	42.0
16.0	15.3	16.9	20.7	27.7	30.6	33.3	24.9	28.1	31.7	36.8	40.1	42.2
16.5	15.2	16.7	20.5	27.5	30.1	32.9	25.7	28.6	32.0	37.0	40.2	42.6
17.0	15.1	16.6	20.4	27.5	30.0	32.8	26.5	29.1	32.5	37.3	40.5	43.0
17.5	15.1	16.6	20.4	27.5	30.1	32.8	27.0	29.5	33.0	37.8	41.0	43.5
18.0	15.2	16.8	20.5	27.6	30.5	32.9	27.3	29.9	33.7	38.4	41.6	44.0
18.5	15.3	17.2	20.7	27.7	31.2	33.2	27.3	30.2	34.5	39.2	42.4	44.7
19.0	15.3	17.6	20.9	27.9	32.1	33.6	27.2	30.5	35.3	40.1	43.3	45.3
19.5	15.5	18.1	21.2	28.1	33.0	34.1	26.9	30.7	36.2	41.0	44.4	46.0