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Smoothed Percentage Body Fat Percentiles for U.S. Children and Adolescents, 1999–2004

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Abstract

Background—The high prevalence of obesity (defined by body mass index) among children and adolescents in the United States and elsewhere has prompted increased attention to body fat in childhood and adolescence.

Objective—This report provides smoothed estimates of major percentiles of percentage body fat for boys and girls aged 8–19 years in the United States.

Methods—Percentage body fat was obtained from whole-body, dual-energy x-ray absorptiometry (DXA) scans conducted during the 1999–2004 National Health and Nutrition Examination Survey. A nonparametric double-kernel method was employed to smooth percentile curves for the DXA data.

Results—The pattern of body fat development differs between boys and girls aged 8–19 years. In most age groups, girls have a higher percentage of body fat than boys. Among boys, there is a drop in body fat percentage in early adolescence that is especially pronounced at the higher percentiles. Among girls this pattern is not seen; percentage body fat increases slightly with age.

Conclusions—These results provide a smoothed reference distribution of percentage body fat for U.S. children and adolescents aged 8–19 years.

Keywords: DXA scan • National Health and Nutrition Examination Survey

Methods

Data were obtained from NHANES, a complex, multistage probability sample of the U.S. civilian noninstitutionalized population (2) conducted by the Centers for Disease Control and Prevention's (CDC) National Center for Health Statistics (NCHS). NHANES consists of a household interview followed by a physical examination conducted in a mobile examination center. Data from three NHANES (1999–2000, 2001–2002, and 2003–2004) are used in the present analysis. The overall examination response rate for children aged 6–19 years in NHANES 1999–2004 was 85%. Adolescents aged 12–19 and non-Hispanic black and Mexican-American persons were oversampled during these years.

Fat mass was determined from whole-body DXA scans using the Hologic QDR 4500A fan-beam densitometer (Hologic; Bedford, Mass.), following the manufacturer's acquisition procedures and NHANES study-specific procedures. Hologic DOS software version 8.26:a3 was used to acquire all scans, and scanning was done in the "fast" mode. Hologic Discovery

Introduction

The high prevalence of obesity, defined by body mass index (BMI), among children and adolescents in the United States (1) and elsewhere has prompted increased attention to body composition in childhood. Measurements of body composition for persons aged 8 years and over using whole-body, dual-energy x-ray absorptiometry

(DXA) scans were included in the 1999–2004 National Health and Nutrition Examination Survey (NHANES). These data make it possible to estimate percentage body fat for the U.S. pediatric population. This report provides smoothed estimates of selected percentiles of total percentage body fat for boys and girls aged 8–19 years in the United States in 1999–2004.



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software version 12.1 was used to analyze the scans (3).

Percentage body fat was calculated by dividing total fat mass by total DXA mass (fat mass and fat-free mass) and multiplying by 100. Multiple imputation methods were used to impute missing DXA data. Five DXA values were imputed for each missing DXA data point. Details of the DXA procedures and the imputation process for the NHANES 1999–2004 DXA Multiple Imputation Data Files have been published previously (3–6). The analytic data set consisted of 8,864 boys and girls aged 8–19. The data set includes 4,520 boys and 4,344 girls. Of these NHANES participants, percentage body fat was imputed for 931 girls and 412 boys. In 1999, females aged 8–17 did not receive DXA examinations because of concerns about handling the reporting of pregnancy test results for minors. As a result, more data were imputed for girls than for boys. In 2000, this issue was resolved and females aged 8–17 began receiving DXA scans (4). The analyses used the five NHANES 1999–2004 DXA Multiple Imputation Data Files (6). Pregnant females were excluded.

The nonparametric double-kernel method of Li et al. (7) was employed to smooth percentage body fat percentile curves. This approach extends a method of Yu and Jones (8) by incorporating sample weights in the curve estimation, along with bandwidth selection, so that the approach is applicable to NHANES data. In the curve estimation, percentage body fat for boys and girls is smoothed separately along both the age axis and the percentage body fat axis using kernel smoothing and using local linear weighting in the age axis direction. In the bandwidth selection procedure, a bandwidth for the conditional mean is selected first and then modified to obtain the age axis and percentage body fat axis bandwidths according to the percentile being estimated. In the analysis, a bandwidth of 11 years (132 months) is used for the conditional mean. The approach of Li and colleagues used in this analysis also uses a median correction to reduce smoothing bias and a bandwidth

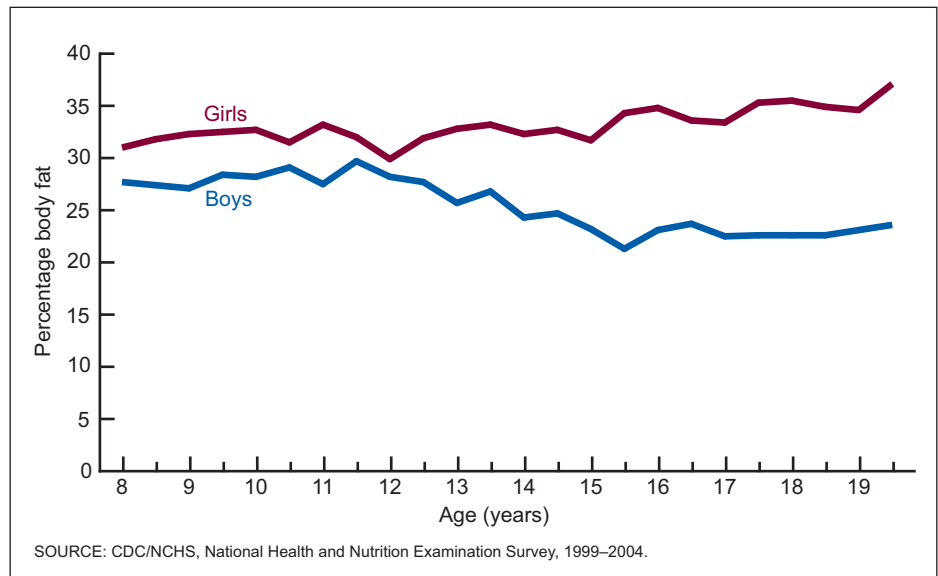


Figure 1. Mean percentage body fat, by sex and age: United States, 1999–2004

rescaling procedure to make the bandwidth selection scale invariant. Age in months at time of examination was used in the smoothing process.

Selected smoothed percentiles of percentage body fat for boys and girls, by 6-month age groups, are presented. Every fifth percentile of percentage body fat is shown.

All analyses, including the initial smoothing of the body fat percentiles, were done using SAS version 9.1.2 (SAS Institute, Cary, N.C.) and SAS-callable SUDAAN version 9 (RTI International, Research Triangle Park, N.C.). Sample examination weights were used to account for differential nonresponse and noncoverage and to adjust for planned oversampling of some groups. Because of the complex survey design, standard errors were estimated with SUDAAN using Taylor series linearization. All estimates, including the smoothed percentiles, were calculated separately from each of the five imputed data sets and then averaged together to account for the multiple imputations.

Results

Sample sizes for sex-specific 6-month age groups are presented in Table 1. The table also contains means and standard errors for percentage body fat in these groups. In general, the sex

difference in mean levels of percentage body fat increased with age after age 12 (Figure 1). The mean levels of percentage body fat at age 8 were 28% for boys and 31% for girls, and at age 19 were 23% for boys and 35% for girls.

Table 2 contains the smoothed estimates of percentage body fat for every fifth percentile from the 5th to 95th percentiles for the sex-specific 6-month age groups. Figures 2 and 3 show the smoothed estimates for the 5th, 15th, 50th, 85th, and 95th percentiles, for boys and girls, respectively. The pattern of body fat development differs for boys and girls between ages 8 and 19. Among boys, there is a drop in body fat percentage in early adolescence that is especially pronounced at the higher percentiles. Among girls this pattern is not seen; percentage body fat increases slightly with age.

Discussion

The shapes of the percentage body fat curves for children and adolescents in the U.S. population, based on NHANES data, match expected changes in human body composition (9,10). Normal patterns of body fat include a decrease in body fat percentage after infancy and subsequent increase in body

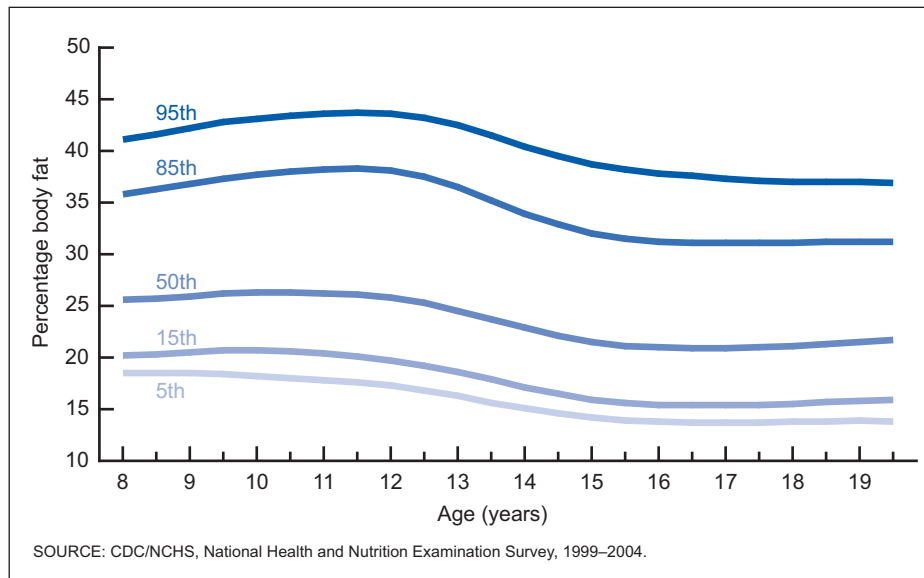


Figure 2. Selected percentiles of smoothed percentage body fat among boys aged 8–19 years: United States, 1999–2004

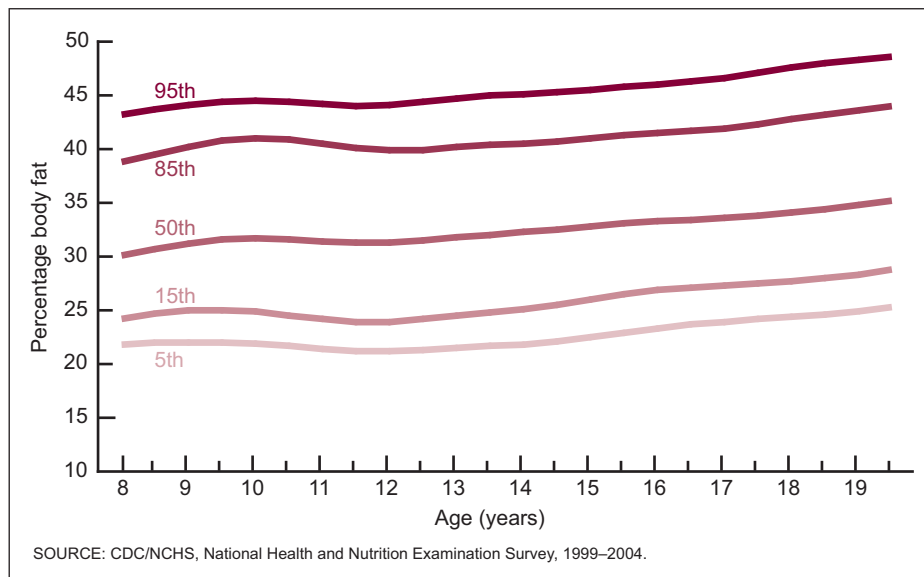


Figure 3. Selected percentiles of smoothed percentage body fat among girls aged 8–19 years: United States, 1999–2004

fat percentage until puberty. In normal growth and development in children, males gain more muscle and lean tissue than fat at puberty while girls gain more fat. Because the U.S. curves presented here begin at age 8, they do not show patterns of body fat percentage during infancy and early childhood. The changes that occur at puberty, however, are reflected in the U.S. curves.

There are differences between the shape of the smoothed percentage body

fat curves and the BMI curves from the U.S. population. Compared with percentage body fat, which decreases and then remains level in boys, BMI in boys increases between ages 8 and 19. In girls, both percentage body fat and BMI increase with age. These differences can be seen when comparing the percentage body fat percentile curves with CDC's BMI-for-age growth charts (11).

Body fat percentage reference curves based on bioelectrical impedance measurements have been published for children and adolescents in England (12) and Turkey (13). These curves have shapes similar to those based on DXA data from this nationally representative sample of U.S. children. The U.S. values are higher than those published from England or Turkey, perhaps because of differences in the population or because of methodological differences (12,13).

Reference values based on the NHANES percentage body fat data from DXA have been published previously. Empirical percentiles are available (4), and Kelly et al. (14) used the LMS method (15) to smooth a variety of body composition data, not just percentage body fat, in both adults and children. In that report (14), no overall total population smoothed reference values are available. The present report provides smoothed reference values for percentage body fat for the overall population of boys and girls.

An analysis of Hologic QDR 4500A DXA data from seven research laboratories (16) indicated that the QDR 4500A algorithm underestimated fat mass and overestimated lean mass. Because Hologic QDR 4500A was used in NHANES, NHANES data on lean soft tissue mass was decreased by 5% and an equivalent weight (in kilograms) was added to the fat mass so the total mass did not change. This adjustment increased the median level of percentage body fat by approximately 3 percentage points.

These results provide a reference distribution of percentage body fat for U.S. school-aged children and adolescents in 1999–2004 when percentage body fat is measured using DXA methods. These smoothed curves were used to show differences in body fat between racial and ethnic groups at the same BMI level (17) and in analyses related to body fat and lipids in children (18). The association between BMI—an indirect measure of body fat—and health conditions in children may be different than the relationship between body fat and health outcomes. These curves provide a tool for examining the

relationship between directly measured body fat and health conditions in children.

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Table 1. Mean (SE) percentage body fat, by sex and age: United States, 1999–2004

Age (years)	Boys			Girls		
	Sample size	Body fat (percent)	SE	Sample size	Body fat (percent)	SE
8.0	132	27.7	0.9	136	31.0	1.0
8.5	131	27.4	1.0	124	31.8	0.9
9.0	130	27.1	0.8	136	32.3	0.6
9.5	131	28.4	0.7	128	32.5	0.7
10.0	131	28.2	0.8	133	32.7	1.0
10.5	135	29.1	0.9	124	31.5	0.8
11.0	125	27.5	0.9	140	33.2	0.9
11.5	130	29.7	1.0	138	32.0	0.8
12.0	231	28.2	0.8	205	29.9	0.7
12.5	210	27.7	0.8	235	31.9	0.6
13.0	227	25.7	0.7	240	32.8	0.7
13.5	217	26.8	0.9	235	33.2	0.6
14.0	180	24.3	0.8	226	32.3	0.7
14.5	227	24.7	0.7	243	32.7	0.7
15.0	218	23.2	0.6	180	31.7	0.7
15.5	204	21.3	0.6	201	34.3	0.6
16.0	228	23.1	0.6	205	34.8	0.6
16.5	233	23.7	0.6	182	33.6	0.7
17.0	238	22.5	0.7	206	33.4	0.5
17.5	229	22.6	0.6	199	35.3	0.6
18.0	204	22.6	0.8	198	35.5	0.8
18.5	218	22.6	0.6	181	34.9	0.8
19.0	213	23.1	0.7	188	34.6	0.6
19.5	198	23.6	0.8	161	37.1	0.7

NOTES: SE is standard error. Ages represent the low end of the group (for example, 8.0 is 8.0–8.49 years).

SOURCE: CDC/NCHS, National Health and Nutrition Examination Survey, 1999–2004.

Table 2. Smoothed percentiles of percentage body fat, by sex and age: United States, 1999–2004

Sex and age (years)	Smoothed percentile																		
	5th	10th	15th	20th	25th	30th	35th	40th	45th	50th	55th	60th	65th	70th	75th	80th	85th	90th	95th
Boys	Percent																		
8.0–8.49	18.5	19.4	20.2	21.0	21.6	22.3	23.0	23.8	24.7	25.6	26.6	27.8	28.9	30.3	31.7	33.4	35.8	38.9	41.1
8.5–8.99	18.5	19.5	20.3	21.1	21.8	22.4	23.1	23.9	24.8	25.7	26.8	27.9	29.2	30.6	32.2	33.9	36.4	39.0	41.6
9.0–9.49	18.5	19.7	20.5	21.4	22.0	22.7	23.4	24.2	25.1	26.0	27.1	28.3	29.7	31.2	32.8	34.5	36.8	39.2	42.2
9.5–9.99	18.4	19.8	20.7	21.6	22.3	23.0	23.7	24.5	25.4	26.2	27.4	28.7	30.2	31.8	33.4	35.2	37.3	39.5	42.8
10.0–10.49	18.2	19.8	20.7	21.7	22.4	23.1	23.9	24.7	25.5	26.3	27.6	29.0	30.5	32.2	33.8	35.7	37.7	39.8	43.2
10.5–10.99	18.0	19.6	20.6	21.6	22.4	23.1	23.9	24.7	25.5	26.3	27.6	29.2	30.8	32.5	34.1	36.1	38.0	40.1	43.4
11.0–11.49	17.8	19.3	20.4	21.4	22.2	23.0	23.8	24.6	25.4	26.2	27.6	29.2	30.9	32.6	34.3	36.3	38.2	40.4	43.6
11.5–11.99	17.6	19.0	20.1	21.1	22.0	22.8	23.6	24.4	25.3	26.1	27.6	29.2	30.8	32.6	34.3	36.3	38.3	40.5	43.7
12.0–12.49	17.3	18.6	19.7	20.7	21.6	22.4	23.2	24.1	25.0	25.8	27.3	29.0	30.6	32.3	34.0	36.0	38.1	40.4	43.6
12.5–12.99	16.8	18.1	19.2	20.1	21.0	21.8	22.7	23.5	24.4	25.3	26.8	28.4	30.1	31.7	33.4	35.3	37.5	39.9	43.3
13.0–13.49	16.3	17.5	18.6	19.5	20.3	21.1	21.9	22.7	23.6	24.6	25.9	27.4	29.2	30.9	32.5	34.2	36.5	39.1	42.5
13.5–13.99	15.6	16.9	17.9	18.7	19.5	20.2	21.0	21.8	22.6	23.7	24.9	26.3	28.1	29.9	31.5	33.1	35.2	38.0	41.5
14.0–14.49	15.1	16.2	17.1	17.9	18.6	19.3	20.1	20.9	21.7	22.9	23.8	25.2	26.9	28.8	30.4	32.0	33.9	36.7	40.5
14.5–14.99	14.6	15.6	16.5	17.2	17.9	18.6	19.3	20.1	20.9	22.1	22.9	24.2	25.8	27.7	29.5	31.1	32.9	35.6	39.5
15.0–15.49	14.2	15.2	15.9	16.6	17.3	18.0	18.7	19.5	20.3	21.5	22.2	23.3	24.9	26.9	28.6	30.2	32.1	34.7	38.7
15.5–15.99	13.9	14.8	15.6	16.3	17.0	17.7	18.4	19.1	19.9	21.1	21.8	22.9	24.4	26.3	28.1	29.7	31.5	34.1	38.2
16.0–16.49	13.8	14.7	15.4	16.1	16.8	17.5	18.3	19.0	19.8	21.0	21.7	22.8	24.2	26.2	27.9	29.4	31.2	33.8	37.8
16.5–16.99	13.7	14.7	15.4	16.1	16.8	17.5	18.3	19.0	19.9	20.9	21.7	22.9	24.4	26.2	27.8	29.3	31.1	33.7	37.6
17.0–17.49	13.7	14.6	15.4	16.1	16.8	17.6	18.3	19.1	19.9	20.9	21.8	23.0	24.5	26.1	27.7	29.3	31.1	33.6	37.3
17.5–17.99	13.7	14.7	15.4	16.2	16.9	17.6	18.3	19.1	19.9	21.0	21.9	23.1	24.6	26.0	27.6	29.2	31.1	33.5	37.2
18.0–18.49	13.8	14.7	15.5	16.3	17.0	17.7	18.5	19.2	20.1	21.1	22.1	23.3	24.6	26.0	27.4	29.1	31.1	33.4	37.0
18.5–18.99	13.8	14.9	15.7	16.5	17.2	17.9	18.7	19.4	20.3	21.3	22.3	23.5	24.8	26.0	27.4	29.1	31.2	33.5	37.0
19.0–19.49	13.9	15.0	15.8	16.6	17.4	18.1	18.9	19.6	20.5	21.5	22.6	23.7	24.9	26.1	27.4	29.1	31.3	33.5	37.0
19.5–19.99	13.8	15.0	15.9	16.7	17.5	18.3	19.0	19.8	20.7	21.7	22.7	23.8	25.0	26.1	27.4	29.0	31.2	33.6	36.9

See footnote at end of table.

Table 2. Smoothed percentiles of percentage body fat, by sex and age: United States, 1999–2004—Con.

Sex and age (years)	Smoothed percentile																		
	5th	10th	15th	20th	25th	30th	35th	40th	45th	50th	55th	60th	65th	70th	75th	80th	85th	90th	95th
Girls	Percent																		
8.0–8.49	21.8	23.2	24.2	25.0	25.7	26.4	27.2	28.0	28.9	30.1	31.1	32.3	33.5	34.8	36.1	37.4	38.8	40.6	43.3
8.5–8.99	22.0	23.5	24.7	25.6	26.4	27.1	27.9	28.7	29.7	30.7	31.8	32.9	34.1	35.3	36.7	38.0	39.5	41.3	43.7
9.0–9.49	22.0	23.6	25.0	26.0	26.9	27.6	28.5	29.4	30.3	31.2	32.5	33.6	34.7	35.9	37.2	38.7	40.2	42.0	44.1
9.5–9.99	22.0	23.6	25.0	26.1	27.1	27.9	28.8	29.8	30.8	31.6	33.0	34.1	35.2	36.4	37.7	39.2	40.8	42.4	44.4
10.0–10.49	21.9	23.4	24.9	26.0	27.0	27.9	28.9	29.9	30.9	31.7	33.1	34.3	35.4	36.6	38.0	39.5	41.0	42.6	44.5
10.5–10.99	21.7	23.2	24.5	25.7	26.7	27.7	28.7	29.7	30.8	31.6	33.0	34.1	35.3	36.5	37.8	39.4	40.9	42.4	44.4
11.0–11.49	21.4	22.9	24.2	25.3	26.3	27.3	28.3	29.4	30.4	31.4	32.5	33.7	34.9	36.1	37.4	39.0	40.5	42.1	44.2
11.5–11.99	21.2	22.7	23.9	25.0	26.1	27.1	28.1	29.1	30.1	31.3	32.2	33.3	34.5	35.7	37.0	38.5	40.1	41.7	44.0
12.0–12.49	21.2	22.7	23.9	25.0	26.1	27.1	28.1	29.1	30.1	31.3	32.1	33.2	34.4	35.6	36.8	38.3	39.9	41.6	44.1
12.5–12.99	21.3	22.9	24.2	25.4	26.5	27.5	28.5	29.4	30.4	31.5	32.3	33.4	34.6	35.8	37.0	38.4	40.0	41.7	44.4
13.0–13.49	21.5	23.1	24.5	25.8	26.9	27.9	28.9	29.9	30.8	31.8	32.7	33.8	34.9	36.1	37.3	38.6	40.2	42.0	44.7
13.5–13.99	21.7	23.4	24.8	26.1	27.2	28.2	29.2	30.2	31.1	32.0	33.0	34.1	35.2	36.3	37.5	38.8	40.4	42.2	45.0
14.0–14.49	21.8	23.6	25.1	26.4	27.4	28.4	29.4	30.3	31.3	32.3	33.2	34.2	35.3	36.4	37.6	39.0	40.5	42.4	45.2
14.5–14.99	22.1	23.9	25.5	26.7	27.7	28.7	29.7	30.6	31.5	32.5	33.4	34.4	35.4	36.6	37.7	39.1	40.7	42.6	45.3
15.0–15.49	22.5	24.4	26.0	27.2	28.2	29.2	30.1	31.0	31.9	32.8	33.7	34.7	35.7	36.8	38.0	39.3	41.0	42.9	45.5
15.5–15.99	22.9	25.0	26.5	27.7	28.7	29.7	30.6	31.4	32.3	33.1	34.0	35.0	35.9	37.0	38.2	39.6	41.3	43.2	45.8
16.0–16.49	23.3	25.4	26.9	28.0	29.1	30.0	30.9	31.7	32.5	33.3	34.2	35.2	36.1	37.2	38.3	39.7	41.5	43.5	46.0
16.5–16.99	23.7	25.7	27.1	28.3	29.3	30.2	31.0	31.8	32.6	33.5	34.3	35.3	36.3	37.3	38.4	39.8	41.7	43.7	46.3
17.0–17.49	23.9	25.9	27.3	28.5	29.5	30.3	31.2	31.9	32.7	33.6	34.5	35.4	36.4	37.5	38.6	40.0	41.9	44.1	46.6
17.5–17.99	24.2	26.1	27.5	28.7	29.7	30.5	31.3	32.1	32.9	33.8	34.7	35.7	36.7	37.8	38.9	40.4	42.3	44.5	47.1
18.0–18.49	24.4	26.3	27.7	28.9	29.9	30.7	31.5	32.3	33.1	34.1	35.0	36.0	37.0	38.1	39.4	40.9	42.8	45.0	47.6
18.5–18.99	24.6	26.6	28.0	29.2	30.1	31.0	31.8	32.6	33.4	34.4	35.3	36.4	37.4	38.6	39.9	41.4	43.2	45.4	48.0
19.0–19.49	24.9	26.8	28.3	29.5	30.4	31.3	32.1	32.9	33.8	34.8	35.8	36.8	37.9	39.1	40.3	41.8	43.6	45.7	48.3
19.5–19.99	25.3	27.2	28.8	30.0	30.8	31.7	32.5	33.3	34.2	35.2	36.3	37.4	38.5	39.7	40.8	42.3	44.0	46.0	48.6

SOURCE: CDC/NCHS, National Health and Nutrition Examination Survey, 1999–2004.

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