WAIST CIRCUMFERENCE PERCENTILES IN NATIONALLY REPRESENTATIVE SAMPLES OF AFRICAN-AMERICAN, EUROPEAN-AMERICAN, AND MEXICAN-AMERICAN CHILDREN AND ADOLESCENTS

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Objective To describe and provide estimates of the distribution of waist circumference (WC) according to percentiles in African-, European-, and Mexican-American children, and to test for group differences at different percentiles.

Study design Cross-sectional data from the Third National Health and Nutrition Examination Survey (NHANES III) were examined. The sample evaluated included 9713 nonpregnant persons 2 to 18 years of age with measured values of WCs. Age-, sex-, and ethnicity-specific percentiles were estimated via percentile regression.

Results WC measurements increased in a monotonic fashion across ages but at nonconstant rates and in a manner that varied across age and sex. At higher percentiles of the distribution, estimates of WC differ between Mexican-American (MA) and European-American (EA) and between African-American (AA) and European-American (EA), and, in some cases, exceeded the adult cutoff value for obesity-related disease risk at as early as 13 years of age.

Conclusion Age-, sex-, and ethnicity-specific WC percentiles are available for US children and adolescents and can be used as an assessment tool that could impact public health recommendations. Results suggest concern with respect to high WC values among certain ethnic groups. *(J Pediatr 2004;145:439-44)*

Independent of total adiposity, an upper body, central, or visceral distribution of fat is believed to be a risk factor for poor health in both adults[1] and children.[2] Excess abdominal fat is associated with hyperlipidemia, cardiovascular risk factors, type II diabetes, and other morbidities.[3] Accurate measurement of total and regional body fat is fundamental in order to detect as early as possible whether the population overall or a given child in particular is deviating from normal values or trends. Although waist-to-hip ratio enjoyed widespread use in the past, more recently, a consensus seems to be emerging that waist circumference (WC) alone may be a more useful index in both adults and children.[4-6]

Research has supported that both the trends in WC in the US adult population and the WC cutoff points for identifying risk for comorbidities in adults differ according to race.[7,8] Evaluation of distributions, including percentiles, of measures of upper body adiposity are important in order to assess the extent to which different populations are at risk from excess central adiposity. The evaluation of these distributions is of great importance given the growing concern of obesity among children and the consequences of overweight and obesity for children and adolescents.[9] This study describes the distribution of WC in a nationally representative sample of African-, European-, and Mexican-American children from 2 to 18 years of age. Because the distribution of WC according to age is not normally distributed, the 10th, 25th, 50th, 75th, and 90th percentiles of the WC distribution are examined for each race/ethnic gender classification. A percentile regression approach was used to describe the changes in the percentile estimates as a function of age for every ethnic/gender group.

AA	African-American	NHANES III	Third National Health and Nutrition Examination Survey
EA	European-American	WC	Waist circumference
MA	Mexican-American		

See editorial, p 427 and related article, p 445.

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Table I. Estimated value for percentile regression for European-American children and adolescents, according to sex

	Percentile for boys					Percentile for girls				
	10th	25th	50th	75th	90th	10th	25th	50th	75th	90th
Intercept	39.3	43.2	42.9	43.3	43.8	39.9	41.8	43.6	45.0	46.8
Slope	1.8	1.9	2.1	2.6	3.4	1.6	1.7	1.9	2.3	2.9
Age (y)										
2	42.9	46.9	47.1	48.6	50.6	43.1	45.1	47.4	49.6	52.5
3	44.7	48.8	49.2	51.2	54.0	44.7	46.8	49.3	51.9	55.4
4	46.5	50.6	51.3	53.8	57.4	46.3	48.5	51.2	54.2	58.2
5	48.3	52.5	53.3	56.5	60.8	47.9	50.2	53.1	56.5	61.1
6	50.1	54.3	55.4	59.1	64.2	49.5	51.8	55.0	58.8	64.0
7	51.9	56.2	57.5	61.7	67.6	51.1	53.5	56.9	61.1	66.8
8	53.7	58.1	59.6	64.3	71.0	52.7	55.2	58.8	63.4	69.7
9	55.5	59.9	61.7	67.0	74.3	54.3	56.9	60.7	65.7	72.6
10	57.3	61.8	63.7	69.6	77.7	55.9	58.6	62.5	68.0	75.5
11	59.1	63.6	65.8	72.2	81.1	57.5	60.2	64.4	70.3	78.3
12	60.9	65.5	67.9	74.9	84.5	59.1	61.9	66.3	72.6	81.2
13	62.7	67.4	70.0	77.5	87.9	60.7	63.6	68.2	74.9	84.1
14	64.5	69.2	72.1	80.1	91.3	62.3	65.3	70.1	77.2	86.9
15	66.3	71.1	74.1	82.8	94.7	63.9	67.0	72.0	79.5	89.8
16	68.1	72.9	76.2	85.4	98.1	65.5	68.6	73.9	81.8	92.7
17	69.9	74.8	78.3	88.0	101.5	67.1	70.3	75.8	84.1	95.5
18	71.7	76.7	80.4	90.6	104.9	68.7	72.0	77.7	86.4	98.4

METHODS

Subjects

Data from the Third National Health and Nutrition Examination Survey (NHANES III) were used for the study. A total of 9713 persons were included in the analysis: 3414 were African-American (AA), 2746 were European-American (EA), and 3553 were Mexican-American (MA). WC (cm) was measured by trained technicians using a tape measure at just above the uppermost lateral border of the right ilium, at the end of a normal expiration, and was recorded at the nearest millimeter, as described by the National Center of Health Statistics.[10]

The collection of the NHANES data was reviewed and approved by the National Center for Health Statistics' Institutional Review Board. Information about the brochures and consent form used for the study can be obtained from the National Center for Health Statistics.[11]

Statistical Analysis

Percentile regression was used to model the regression lines of the 10th, 25th, 50th, 75th, and 90th percentiles of the distribution of WC. These estimates were compared across ethnic categories, following the method described by Redden et al.[12] In this method, instead of modeling the mean values, we modeled different percentiles of the distribution by creating an indicator variable (I) to classify the observations within a data set as falling above or below a predicted percentile τ of the distribution of WC. This indicator variable (I) is used as the outcome variable in a logistic regression model to determine if any of the explanatory variables (ethnicity, age, age by ethnicity interaction) significantly explain variability in the log odds of being above the percentile. If the logistic regression indicated these explanatory variables were significant, percentile regression lines were calculated according to the method of Koenker.[13] These methods are easy to apply, are dependent on few statistical assumptions, and are robust to the normality assumption. In this study, the percentile regression lines were modeled as a function of age for each sex, and comparisons between ethnic groups (EAs, AAs, and MAs) were made to determine whether the percentile regression lines differed by ethnicity. Given that the NHANES III survey was a population-based survey with unequal probabilities of participant selection, all statistical analyses incorporated the sampling weights into the calculation methods.

Percentile regression analyses were performed separately for boys (n = 4769) and for girls (n = 4944). All statistical analyses were performed using the Statistical Analysis Systems software, version 8.1 (SAS Inc, Cary, NC) and SUDAAN (Research Triangle Institute, Research Triangle Park, NC).

RESULTS

Tables I, II, and III show the WC estimated value for percentile regression for EA, AA, and MA children and adolescents according to sex, respectively. Percentile regression values were calculated for every group, even when the

Table II. Estimated value for percentile regression for African-American children and adolescents, according to sex

	Percentile for boys					Percentile for girls				
	10th	25th	50th	75th	90th	10th	25th	50th	75th	90th
Intercept	40.1	41.2	42.7	44.1	43.6	39.9	41.2	41.7	42.1	42.8
Slope	1.6	1.7	1.9	2.2	3.2	1.6	1.7	2.1	2.8	3.7
Age (y)										
2	43.2	44.6	46.4	48.5	50.0	43.0	44.6	46.0	47.7	50.1
3	44.8	46.3	48.3	50.7	53.2	44.6	46.3	48.1	50.6	53.8
4	46.3	48.0	50.1	52.9	56.4	46.1	48.0	50.2	53.4	57.5
5	47.9	49.7	52.0	55.1	59.6	47.7	49.7	52.3	56.2	61.1
6	49.4	51.4	53.9	57.3	62.8	49.2	51.4	54.5	59.0	64.8
7	51.0	53.1	55.7	59.5	66.1	50.8	53.2	56.6	61.8	68.5
8	52.5	54.8	57.6	61.7	69.3	52.4	54.9	58.7	64.7	72.2
9	54.1	56.4	59.4	63.9	72.5	53.9	56.6	60.9	67.5	75.8
10	55.6	58.1	61.3	66.1	75.7	55.5	58.3	63.0	70.3	79.5
11	57.2	59.8	63.2	68.3	78.9	57.0	60.0	65.1	73.1	83.2
12	58.7	61.5	65.0	70.5	82.1	58.6	61.7	67.3	75.9	86.9
13	60.3	63.2	66.9	72.7	85.3	60.2	63.4	69.4	78.8	90.5
14	61.8	64.9	68.7	74.9	88.5	61.7	65.1	71.5	81.6	94.2
15	63.4	66.6	70.6	77.1	91.7	63.3	66.8	73.6	84.4	97.9
16	64.9	68.3	72.5	79.3	94.9	64.8	68.5	75.8	87.2	101.6
17	66.5	70.0	74.3	81.5	98.2	66.4	70.3	77.9	90.0	105.2
18	68.0	71.7	76.2	83.7	101.4	68.0	72.0	80.0	92.9	108.9

Table III. Estimated value for percentile regression for Mexican-American children and adolescents, according to sex

	Percentile for boys					Percentile for girls				
	10th	25th	50th	75th	90th	10th	25th	50th	75th	90th
Intercept	41.0	41.8	43.3	44.3	46.2	41.4	42.1	43.9	44.8	47.1
Slope	1.7	1.9	2.2	2.7	3.5	1.5	1.8	2.1	2.6	3.2
Age (y)										
2	44.4	45.6	47.6	49.8	53.2	44.5	45.7	48.0	50.0	53.5
3	46.1	47.5	49.8	52.5	56.7	46.0	47.4	50.1	52.6	56.7
4	47.8	49.4	52.0	55.3	60.2	47.5	49.2	52.2	55.2	59.9
5	49.5	51.3	54.2	58.0	63.6	49.0	51.0	54.2	57.8	63.0
6	51.2	53.2	56.3	60.7	67.1	50.5	52.7	56.3	60.4	66.2
7	52.9	55.1	58.5	63.4	70.6	52.0	54.5	58.4	63.0	69.4
8	54.6	57.0	60.7	66.2	74.1	53.5	56.3	60.4	65.6	72.6
9	56.3	58.9	62.9	68.9	77.6	55.0	58.0	62.5	68.2	75.8
10	58.0	60.8	65.1	71.6	81.0	56.5	59.8	64.6	70.8	78.9
11	59.7	62.7	67.2	74.4	84.5	58.1	61.6	66.6	73.4	82.1
12	61.4	64.6	69.4	77.1	88.0	59.6	63.4	68.7	76.0	85.3
13	63.1	66.5	71.6	79.8	91.5	61.1	65.1	70.8	78.6	88.5
14	64.8	68.4	73.8	82.6	95.0	62.6	66.9	72.9	81.2	91.7
15	66.5	70.3	76.0	85.3	98.4	64.1	68.7	74.9	83.8	94.8
16	68.2	72.2	78.1	88.0	101.9	65.6	70.4	77.0	86.4	98.0
17	69.9	74.1	80.3	90.7	105.4	67.1	72.2	79.1	89.0	101.2
18	71.6	76.0	82.5	93.5	108.9	68.6	74.0	81.1	91.6	104.4

Table IV. Estimated value for percentile regression for all children and adolescents combined, according to sex

	Percentile for boys					Percentile for girls				
	10th	25th	50th	75th	90th	10th	25th	50th	75th	90th
Intercept	39.7	41.3	43.0	43.6	44.0	40.7	41.7	43.2	44.7	46.1
Slope	1.7	1.9	2.0	2.6	3.4	1.6	1.7	2.0	2.4	3.1
Age (y)										
2	43.2	45.0	47.1	48.8	50.8	43.8	45.0	47.1	49.5	52.2
3	44.9	46.9	49.1	51.3	54.2	45.4	46.7	49.1	51.9	55.3
4	46.6	48.7	51.1	53.9	57.6	46.9	48.4	51.1	54.3	58.3
5	48.4	50.6	53.2	56.4	61.0	48.5	50.1	53.0	56.7	61.4
6	50.1	52.4	55.2	59.0	64.4	50.1	51.8	55.0	59.1	64.4
7	51.8	54.3	57.2	61.5	67.8	51.6	53.5	56.9	61.5	67.5
8	53.5	56.1	59.3	64.1	71.2	53.2	55.2	58.9	63.9	70.5
9	55.3	58.0	61.3	66.6	74.6	54.8	56.9	60.8	66.3	73.6
10	57.0	59.8	63.3	69.2	78.0	56.3	58.6	62.8	68.7	76.6
11	58.7	61.7	65.4	71.7	81.4	57.9	60.3	64.8	71.1	79.7
12	60.5	63.5	67.4	74.3	84.8	59.5	62.0	66.7	73.5	82.7
13	62.2	65.4	69.5	76.8	88.2	61.0	63.7	68.7	75.9	85.8
14	63.9	67.2	71.5	79.4	91.6	62.6	65.4	70.6	78.3	88.8
15	65.6	69.1	73.5	81.9	95.0	64.2	67.1	72.6	80.7	91.9
16	67.4	70.9	75.6	84.5	98.4	65.7	68.8	74.6	83.1	94.9
17	69.1	72.8	77.6	87.0	101.8	67.3	70.5	76.5	85.5	98.0
18	70.8	74.6	79.6	89.6	105.2	68.9	72.2	78.5	87.9	101.0

statistical tests indicated lack of differences between certain groups. Table IV shows the WC percentile regression values for males and females of all ethnic groups combined.

For the 10th percentile, WC as a function of age in MA girls was significantly different ($P = .02$) from EA and AA females and was consistently higher than AA girls. After accounting for the differences because of MA females, no significant differences were detected between AA and EA females ($P = .263$) across ages. For males, the line for WC in MA was different from EA and AA ($P = .014$). Further analysis demonstrated that, after controlling for the effect of MA males, WC across ages in AA males differed significantly from WC across ages in EA males ($P < .001$).

Although the regression line of the 25th percentile WC by age for MA females was significantly different ($P = .0197$) from EA and AA females, no differences were observed between AA and EA females ($P = .247$). For males, hypothesis testing also supported differences in the 25th percentile of WC by age for MA when compared with EA and AA (P = .007). WC in MA was greater than AA males in this percentile. Independent of MA, significant differences were detected between the lines of AA and EA males ($P < .001$).

For females, the 50th percentile regression lines differed significantly between MA and the other two ethnic groups ($P < .001$), as well as between EA and AA females ($P < .001$). Overall, MA females had greater WC estimates. Similar results occurred for males, where WC values for MA males were greater ($P < .001$) than EA and AA. In addition, differences between EA and AA were detected after adjusting for the MA contributions ($P < .001$).

For the 75th percentile, regression lines differed significantly among the ethnic groups. Across all ages, MA females and males had higher WC than EA males and females. For girls, MA females differed from EA and AA ($P = .008$), and differences were further qualified between EA and AA females ($P < .001$). Similarly, the regression lines from MA males differed significantly from the other ethnic groups ($P < .001$), and further differences were observed between AA and EA males ($P < .001$).

With regard to modeling the 90th percentile of WC by age, significant evidence was found to support that MA females were different ($P < .001$) from EA and AA females, and that differences persisted between EA and AA females independent of the influences of MA females ($P = .0213$). The cutoff value of 88 cm for at risk of developing obesity-related conditions in women was exceeded at 13 years of age in MA and AA girls, and at 15 years of age in EA girls. Differences were observed also in males, where the 90th percentile of MA significantly differed from the other ethnic groups ($P = .003$). In this percentile, no differences were observed between the regression lines of EA and AA males ($P = .348$). MA boys exceeded the cutoff value for men of 102 cm at 17 years of age and EA males at 18 years of age.

DISCUSSION

The results of this investigation clearly demonstrate that the distribution of WC in a representative sample of US children and adolescents differs according to ethnic classification in boys and girls. In general, MA boys and girls have higher WC at the considered percentiles than AA or EA persons. African-American boys have lower WCs when compared with boys of other ethnic groups.

Our results also show that the rates of increase in WC as children become older differ among AA, EA, and MA of both sexes. AA boys consistently demonstrated a lower rate of increase in WC because of age than any other ethnic group at every percentile of the distribution in this nationally representative sample. On the 75th and 90th percentiles, MA girls evidenced the fastest overall increase of all girls. At any of the percentiles considered, MA persons showed the highest overall WC and the fastest overall rate of WC increase with age. These conclusions were supported also when considering the analysis of the mean value for WC by ethnicity and sex in an OLS regression analyses. The result of these analyses—as quantified by a significant effect of ethnicity, age and their interaction—indicated that the mean WC for the ethnic groups should be modeled by three separate regression lines, that the ethnic groups have different intercepts, and that as children age, mean WC increases at different rates for the ethnic groups (data not shown).

The estimated values in Tables I through IV provide a powerful tool for the interpretation of WC in boys and girls. Based on these values, the careful attention to children and adolescents with WC values that fall on the 75th and 90th percentile, according to their ethnic classification and sex, becomes important in the identification—and prevention—of children at risk for various comorbidities, including cardiovascular disease, hyperinsulinemia, and type II diabetes.[14-16] For example, at the 75th percentile of the distribution, MA and AA girls 16 and 17 years of age, respectively, exceed the WC values of 88 cm identified as the cutoff point for increased risk of obesity-related comorbidities in adult women.[3] Similarly, at age 13, both MA and AA girls in the 90th percentile of the distribution achieve the 88-cm cutoff point. The fact that some persons in the sample exceeded these adult cutoff points presents a concern for healthcare practitioners.

Interpretation of our results requires the understanding that epidemiologic studies rely on the use of measures that, although feasible and accessible, may not be the most informative or accurate. Although WC cannot discriminate between subcutaneous and visceral fat, research has supported that individuals with high WC are more likely to have hypertension, diabetes, dyslipidemia, and metabolic syndrome.[17] In addition, evidence has supported that WC is a better predictor of cardiovascular disease[18] and visceral fat[5] than body mass index. Investigations in which more precise measures of adiposity are used have supported associations between intra-abdominal fat and various metabolic disorders, including cardiovascular disease, hyperinsulinemia, and type 2 diabetes,[14-16] and studies have supported that the relationship between adiposity and risk of disease becomes apparent at early stages of the lifespan.[19,20] In addition, although no relationship has been established between metabolic syndrome and WC in youngsters, it is probable that our results could serve as a diagnostic mechanism for children and adolescents at risk for this condition. Cook and colleagues have recently reported higher incidence of metabolic syndrome in adolescents with body mass index <85th percentile, estimating that approximately 910,000 US adolescents have the condition.[9]

The results of this study describe a nationally representative sample of children and adolescents. Therefore, the estimated WC values at different percentiles describe the existing population and do not establish a standard of what "should be." Our findings demonstrate the importance of considering ethnic and racial groups in clinical research, particularly minority populations who are demonstrated to have higher WC values than EAs in the population. Our study also suggests the possibility of developing ethnic-specific cutoff values for identification of at-risk persons, as previously suggested for the adult US population by Okosun and colleagues.[7] It is important to establish that such ethnic-specific cutoffs require demonstration of differential predictive validity and not simply demonstration of different marginal distributions of the predictor.

Because WC is an easily obtainable and greatly accessible measure, the education of physicians and patients in the use of this tool can serve as a preventive strategy to obesity-related comorbidities.

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50 Years Ago in *The Journal of Pediatrics*

PURULENT MENINGITIS IN INFANTS AND CHILDREN: A REVIEW OF 409 CASES

Smith ES. J Pediatr 1954;45:425-36

For the past 50 years pediatricians have been dealing with the ambitious task of understanding the most relevant epidemiologic, clinical, and experimental issues related to bacterial meningitis. Prognosis of this serious infection improved dramatically after the introduction of antimicrobial therapy, although the quest for improved survival and better outcomes continues to pose a significant challenge.

Smith presents a detailed clinical description of a large series of bacterial meningitis cases over a 10-year period. Of note are the concentration of cases below one year of age; the significant number of cases and deaths observed in neonates; the prevalence of pathogens that have become less common today such as *Haemophilus influenzae*, *Mycobacterium tuberculosis* and *Escherichia coli*; and the significant proportion of cases for whom a pathogen could not be recovered. This last situation was coincident with the widespread use of antimicrobials already observed in the 1950s, leading the authors to quote, "At the present time it is a rare patient who enters the hospital with any illness who has not received a course of antimicrobial therapy." Fifty years later, this problem not only has not improved, but has worsened as a result of widespread use of more sophisticated, broad spectrum antimicrobials. We also learned that subdural effusion during the 1950s was tapped "at the slightest provocation," a procedure questioned by the authors who speculated that it "might not have an iatrogenic factor." Time proved them right and today subdural taps are rarely performed.

Current challenges in further understanding and improving outcome of bacterial meningitis includes comprehension of the integration between bacterial pathogenesis and host response and fine tuning the interventions that can positively modulate this relationship in favor of the patient. Advances in diagnosis through improved clinical awareness and better diagnostic tests, well established consensus on strategies for empiric and pathogen-directed treatment, improved knowledge on pathogenesis and inflammatory response modulation based on experimental models heave been outstanding accomplishments. Success of the *H influenzae* type b vaccines have been a most valuable achievement, and the task is to improve worldwide control of the disease through global access to vaccination.

Improvement in medicine is deriving, among others in an increasing population of persons with chronic illnesses, cancer patients receiving immunosuppressive therapy, and very-low-birth-weight infants, who are more susceptible to severe invasive infections. This new scenario poses future challenges for clinical and basic researchers in the field.

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