Body composition of a young, multiethnic, male population1–4

Kenneth J Ellis

ABSTRACT The study objective was to establish the range of total body-composition values for a young, multiethnic, healthy male population (aged 3–18 y) by using dual-energy X-ray absorptiometry (DXA). Results for 297 males in three ethnic groups [European American (white), n = 145; African American (black), n = 78; and Mexican American (Hispanic), n = 74] are reported. Bone mineral content (BMC), lean tissue mass (LTM), body fat mass, and percentage fat are presented as functions of age. Analysis of variance with age, weight, and height as covariates was used to evaluate differences among the three ethnic groups. BMC and LTM were higher in black than in white males, but no difference in BMC or LTM was evident between the white and Hispanic groups. The relation between total-body BMC and LTM was linear (r = 0.985, P < 0.0001) and independent of age or ethnic classification. The Hispanic males had higher body fat values than the white group, whereas the black males generally had lower values than the white group. When adjusted for body size, the Hispanic males continued to have significantly higher body fat and percentage fat than the white or black males. Ethnic-specific equations for the prediction of body composition as a function of age, weight, and height were derived. The results for the white males in the present study were compared with DXA-derived reference data reported in other countries for young white males. We conclude that reference values of total body composition for young healthy males need to be ethnic specific. Am J Clin Nutr 1997;66:1323–31.

KEY WORDS Body composition, children, young men, bone mineral content, fat, percentage fat, whites, blacks, Hispanics, dual-energy X-ray absorptiometry, lean tissue mass, ethnicity

INTRODUCTION

Dual-energy X-ray absorptiometry (DXA) provides information for a three-compartment model of body composition: bone mineral content (BMC), nonbone lean tissue mass (LTM), and body fat mass. This technique has clear advantages for use in children because the measurement is obtained in only a few minutes, requires minimal cooperation from the subject, and uses a low radiation dose. Furthermore, DXA-derived values for the BMC compartment have been shown to agree with total-body calcium values in children (1) and with body-composition values based on animal carcass chemical analysis at a weight range similar to that of children (2). DXA precision for the measurement of the fat compartment for young children, however, is needed (3). In the present study, DXA was used to measure the composition of the total body in a multiethnic (white, black, and Hispanic) male population from childhood through adolescence. We reported previously similar body-composition findings for young females in the same three ethnic groups (4). The primary aims of the present study were 1) to establish relations for the three-body-composition compartments as functions of age and body size, 2) to determine whether compositional development is different among the three ethnic groups, and 3) to compare our findings for body composition in this age group with similar DXA-derived reference data reported in the literature (5–8).

SUBJECTS AND METHODS

Subjects

A total of 297 males, aged 3–18 y, from three ethnic groups [European American (white), n = 145; African American (black), n = 78; and Mexican American (Hispanic), n = 74] were examined. Subjects were recruited from local public and private schools within the Houston metropolitan area and from responses to notices placed in pediatricians' offices. On the basis of a medical history and physical exam, the subjects participating in this study were considered healthy (without diseases or medications, recent illnesses, or accidents that could alter body composition). For this study, body weight was measured on a beam-balance scale to a precision of 0.1 kg and a stadiometer was used to measure height with a precision of 0.5 cm. Body mass index (BMI) was defined as weight (in kg)/height2 (in m).

Children were classified into ethnic groups according to the ethnicity reported by both parents (self-selected). A full range

1 From the US Department of Agriculture, Agricultural Research Service, Children's Nutrition Research Center, Department of Pediatrics, Baylor College of Medicine, Houston.
2 Supported by the US Department of Agriculture, Agricultural Research Service, under Cooperative Agreement 88-6250-1-003 with Baylor College of Medicine.
3 The contents of this publication do not necessarily reflect the views or policies of the US Department of Agriculture, nor does mention of trade names, commercial products, or organizations imply endorsement.
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Received January 8, 1997.
Accepted for publication June 26, 1997.
of socioeconomic statuses (parents with middle-school education to those with advanced professional degrees) for each of the ethnic groups was represented; minority ethnic groups had a higher percentage of families in the lower socioeconomic groups. Of the subjects participating in this study, 91 males (33 whites, 33 blacks, and 25 Hispanics) had BMIs greater than the 85th percentile of the respective ethnic group as reported in the second National Health and Nutrition Examination Survey (NHANES II) (9) or the Hispanic Health and Nutrition Examination Survey (HHANES I) (10). If these BMI limits are used as a criterion to define obesity in the present study, ∼23%, 42%, and 34% of the subjects in the white, black, and Hispanic groups, respectively, would be classified as obese. There is always a concern about possible selection bias in any study that can sample only a subset of the total population. Until the National Center for Health Statistics publishes their findings for children examined in the 1990s (NHANES III), the representativeness of the present population will not be known. The protocol was reviewed and approved by the Institutional Review Board of Baylor College of Medicine and informed, written consent was obtained for each study participant.

**Dual-energy X-ray absorptiometry**

Body-composition measurements were performed by using a Hologic QDR-2000 instrument (Hologic Inc, Waltham, MA). The whole body was scanned in the single-beam mode and the results analyzed with body-composition software (version 5.56), assuming a fixed hydration constant (0.732 mL/g) for LTM. The DXA analysis also provided an index of body fatness (percentage fat), defined as follows:

\[
\text{Percentage fat} = 100 \times \frac{W_{\text{DXA}} - \text{BMC}}{W_{\text{DXA}}} \tag{1}
\]

where \(W_{\text{DXA}} = \text{BMC} + \text{LTM} + \text{fat mass}\). When \(W_{\text{DXA}}\) was compared with balance-scale weight, the mean difference was \(-0.192 \pm 0.910\) kg (−0.5 ± 2.2%) for the total population of 297 males. There was no trend with fatness (percentage fat) for the differences between the scale weight and DXA weight.

**Statistical analyses**

Anthropometric and body-composition data are presented as means ± SDs. All statistical analyses were performed by using MINITAB (Minitab Inc, State College, PA). The general linear model of analysis of variance (ANOVA) was used to determine differences in body composition among the ethnic groups, with age, weight, and height as covariates. Stepwise-multiple-regression analysis was used to determine which combination of anthropometric variables (age, weight, and height) provided the best estimate for BMC, LTM, and fat mass. In the tables and text, the correlation coefficients (\(R\)) and standard errors of the estimate (SEEs) given are for the results of linear-regression analysis. The changes with age for each of the three DXA-derived values of BMC, LTM, and fat mass for the white males were fitted by using least-squares polynomial regression analysis. In all statistical analyses, \(P \leq 0.05\) were considered significant.

**RESULTS**

Mean (± SD) values for age, weight, height, and BMI are given in Table 1 for each of the three ethnic groups. The corresponding DXA-derived mean (± SD) values for body composition are given in Table 2. For each of these tables, the subjects were grouped into four general age ranges: 3–5, 5–9, 10–14, and 15–18 y. The individual values for BMC, LTM, and fat mass as a function of age are presented in Figure 1 for the white males. The curves included in Figure 1 for BMC (\(r = 0.93, P < 0.0005, \text{SEE} = 0.3\) kg) and LTM (\(r = 0.94, P < 0.0005, \text{SEE} = 5.0\) kg) represent third-order polynomial fits to the data. The scatter in the fat mass versus age data was substantially greater than that observed for BMC or LTM. The curve in Figure 1 for body fat mass is a third-order polynomial (\(r = 0.51, P < 0.001, \text{SEE} = 6.3\) kg).

Body-composition data for the black and Hispanic males are presented in Figure 2. The dashed lines used in Figure 2 are based on the data for the white males and represent the 95%
TABLE 2

Body-composition values for the white, black, and Hispanic males

<table>
<thead>
<tr>
<th>Group and age range</th>
<th>BMC</th>
<th>LTM</th>
<th>Fat mass</th>
<th>Percentage fat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g</td>
<td>kg</td>
<td>kg</td>
<td>%</td>
</tr>
<tr>
<td>White males (n = 145)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3–5 (n = 12)</td>
<td>423 ± 94</td>
<td>13.25 ± 1.29</td>
<td>2.92 ± 0.44</td>
<td>17.6 ± 2.0</td>
</tr>
<tr>
<td>5–9 (n = 51)</td>
<td>793 ± 232</td>
<td>20.42 ± 3.95</td>
<td>4.84 ± 3.83</td>
<td>17.1 ± 6.5</td>
</tr>
<tr>
<td>10–14 (n = 51)</td>
<td>1655 ± 496</td>
<td>37.74 ± 9.49</td>
<td>12.10 ± 8.41</td>
<td>22.2 ± 10.3</td>
</tr>
<tr>
<td>15–18 (n = 31)</td>
<td>2545 ± 430</td>
<td>53.58 ± 7.25</td>
<td>10.26 ± 6.29</td>
<td>14.8 ± 7.0</td>
</tr>
<tr>
<td>Black males (n = 78)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3–5 (n = 8)</td>
<td>456 ± 106</td>
<td>14.70 ± 2.22</td>
<td>2.43 ± 0.71</td>
<td>13.7 ± 3.0</td>
</tr>
<tr>
<td>5–9 (n = 28)</td>
<td>900 ± 195</td>
<td>22.54 ± 3.89</td>
<td>5.20 ± 4.53</td>
<td>16.7 ± 9.4</td>
</tr>
<tr>
<td>10–14 (n = 31)</td>
<td>2038 ± 633</td>
<td>45.73 ± 13.4</td>
<td>12.54 ± 10.57</td>
<td>19.2 ± 9.7</td>
</tr>
<tr>
<td>15–18 (n = 11)</td>
<td>3181 ± 440</td>
<td>65.51 ± 8.04</td>
<td>14.43 ± 10.30</td>
<td>16.7 ± 10.5</td>
</tr>
<tr>
<td>Hispanic males (n = 74)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3–5 (n = 8)</td>
<td>403 ± 63</td>
<td>12.10 ± 1.27</td>
<td>3.28 ± 1.22</td>
<td>20.4 ± 4.8</td>
</tr>
<tr>
<td>5–9 (n = 20)</td>
<td>827 ± 192</td>
<td>21.42 ± 3.71</td>
<td>7.38 ± 3.38</td>
<td>23.9 ± 6.9</td>
</tr>
<tr>
<td>15–18 (n = 15)</td>
<td>2545 ± 334</td>
<td>53.57 ± 5.99</td>
<td>12.06 ± 7.96</td>
<td>16.6 ± 7.2</td>
</tr>
</tbody>
</table>

1 x ± SD. BMC, bone mineral content; LTM, lean tissue mass.
2 Percentage fat = 100 × fat/BMC + LTM + fat mass.

Boundaries for the white population. These limits are provided to illustrate the distribution of the body-composition data for the black and Hispanic males relative to the white males over the full age range.

It is evident from the BMC data presented in Figure 1 for the white males and in Figure 2 for the black and Hispanic males that bone mass increased in a nonlinear fashion with age. In Figure 2 it is also evident that the BMC values for most of the black males were in the upper half of the region defined by the white population or above this region. The BMC data for the Hispanic males, on the other hand, were mainly scattered within the full region defined for the white males. BMC was significantly correlated (P < 0.001) with weight, age, and height for each of the three ethnic groups. Age continued to have a significant effect on BMC among the ethnic groups when body size was controlled for and weight and height were included as covariates in the analysis (P < 0.0005, ANOVA). With age, weight, and height as covariates, significant ethnic differences were detected in BMC (P < 0.001, ANOVA). When comparisons between only two ethnic groups were performed (white compared with black and white compared with Hispanic), there were significant differences in BMC between the black and white males (P < 0.0005, ANOVA), but not between the white and Hispanic populations.

Height has often been used as an index for skeletal size. Although this is not shown, the relation between BMC and height over the full age range of the population studied was nonlinear. Thus, linear regression was performed after a log-transformation of the BMC and height values. The equation was ln[BMC (g)] = 3.42 ln[height (m)] + 5.910 with R = 0.975 and SEE = 0.139. Expressed in exponential form, the relation was BMC = 368 (± 7) × height 13.42 ± 0.045 for the total population of males.

The relation between the LTM compartment and age also changed at a nonlinear rate with increasing age, as seen in Figure 1 for the white males and Figure 2 for the black and Hispanic males. The curve in Figure 1 for LTM represents a polynomial fit to the data. It is evident that the general patterns noted for the BMC relation in the black and Hispanic males were also present for the LTM compartment. That is, the LTM values for the black males tended to be in the upper region of values for the white children or above, whereas the values for the Hispanic group were distributed within the region. ANOVA, with weight and height as covariates, confirmed that there was a significant difference in LTM between the black and white groups (P < 0.0005), but not between the Hispanic and white groups.

The data for total body fat as a function of age are shown in Figure 1 for the white males and in Figure 2 for the black and Hispanic males. Overall, there was a general pattern of increasing fat with increasing age, although the scatter for this data at any age was considerably larger than that observed for the BMC or LTM compartment. It is also clearly evident that there were several males within each ethnic group with substantially higher body fat masses than their age-matched peers. A polynomial fit to the data for the white males has been provided in each figure for comparison among the ethnic groups. It can be seen in Figure 2 that with the exception of a few black males in the 10–15-yr-old age range, most black males had body fat mass values at or below the curve obtained for the white males. The individual data for Hispanic males aged > 15 y were similar to those of the age-matched white males, whereas many of the younger Hispanic boys (aged < 8 y) appeared to have higher fat masses. ANOVA confirmed a significant difference for fat mass among the three ethnic groups as a function of age (P < 0.001). When adjusted for body size by using height and weight as covariates, the ethnic difference remained significant (P < 0.001). However, because fat makes up an increasing proportion of body weight with increasing fatness, these two values are not independent. Thus, ANOVA was repeated by using only height as the covariate; the ethnic differences remained significant (P < 0.01). When the LTM value was used as a covariate, the differences related to height became non-significant (P > 0.6), whereas the ethnic differences remained significant (P < 0.05). The differences in fat mass remained highly significant for Hispanic compared with white males (P < 0.005), whereas the difference between the white and black groups was marginally significant (P < 0.05).
The total-body fat index (percentage fat) as a function of age is presented in Figure 3 for the three ethnic groups. As was evident for absolute fat mass, percentage fat values varied widely as a function of age, independent of ethnicity. At the youngest ages (3–8 y) there was evidence of a consistent decline in percentage fat for the white males. At older ages (> 14 y) there was also the suggestion of a decrease. A broad range of values was seen for the mid range of 8–14 y. For Hispanic males, there was not clear evidence of a reduction in percentage fat at the younger ages (< 8 y) as was observed for the white males, whereas the pattern at the older ages was similar. In general, the black males tended to have lower percentage fat values than did age-matched whites. Several black males in the age range of 8–14 y, however, had significantly higher percentage fat values than did white males in the corresponding age range. ANOVA confirmed that there was an ethnic-dependent difference in percentage fat ($P < 0.0005$). Adjustment for differences in height and LTM did not remove this effect. There was a marginally significant difference in percentage fat when the black males were compared with the...
white group \( P < 0.05 \), whereas there was a highly significant difference between the Hispanic and white males \( P < 0.001 \).

Stepwise-multiple-regression analysis was used to examine the relations between the three DXA-based body-composition compartments and the anthropometric measurements of weight, height, and age. Prediction variables were included in the regression equation only if the \( R^2 \) value was improved by \( \geq 3\% \). With use of this criterion, it was found that use of a third anthropometric variable did not significantly improve the results over those obtained when only two variables were selected. The anthropometric-based equations for the BMC, LTM, and fat mass compartments for each of the ethnic groups are presented in Table 3. In this multiethnic population of young healthy males, \( \approx 93-96\% \) of the variation in the BMC and LTM compartments and \( 75-79\% \) of the variation in body fat mass could be accounted for when age, weight, and height were known. For the anthropometric prediction of BMC, an average uncertainty of 214 g was observed among the three ethnic groups. For the LTM and fat mass compartments, the prediction errors (\( \approx 3.4-3.6 \) kg) were similar for the white and Hispanic groups, whereas the error values for the black males were higher by 0.6 kg. The wide range of body fat values observed at all ages (Figures 1 and 2) significantly reduces the usefulness of these anthropometric-based equations for the prediction of body fat or percentage fat in individuals, although the equations may serve to provide a comparison among the ethnic groups or between the results of the present study and those from other studies.

The equations presented in Table 3 provide a means by which to compare the body composition of different-sized individuals of the same age, of subjects of the same size but different ages, or of subjects from different ethnic groups. For example, if the 50th-percentile values at age 6 y for weight and height from NHANES II are used (9), a white male would have 0.55 kg BMC whereas a black male would have 0.59 kg. By age 15 y, the respective mean BMC values would be 2.14 and

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### Table 3

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>BMC (g)</th>
<th>LTM (kg)</th>
<th>Fat mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>( \text{BMC} = 23.6 \text{ Wt} + 75.5 \text{ age} - 416.5 )</td>
<td>( \text{LTM} = 0.439 \text{ Wt} + 1.52 \text{ age} - 2.76 )</td>
<td>( \text{Fat} = 0.534 \text{ Wt} - 1.59 \text{ age} + 3.03 )</td>
</tr>
<tr>
<td>Black</td>
<td>( \text{BMC} = 21.3 \text{ Wt} + 106.3 \text{ age} - 525.3 )</td>
<td>( \text{LTM} = 0.363 \text{ Ht} + 0.388 \text{ Wt} - 34.2 )</td>
<td>( \text{Fat} = 0.594 \text{ Wt} - 0.381 \text{ Ht} + 36.0 )</td>
</tr>
<tr>
<td>Hispanic</td>
<td>( \text{BMC} = 16.9 \text{ Wt} + 102.3 \text{ age} - 437.2 )</td>
<td>( \text{LTM} = 0.424 \text{ Wt} + 1.56 \text{ age} - 2.98 )</td>
<td>( \text{Fat} = 0.591 \text{ Wt} - 1.82 \text{ age} + 3.36 )</td>
</tr>
</tbody>
</table>

**Note:**
- BMC: Bone mineral content; LTM: Lean tissue mass.
- CV: Coefficient of variation.

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1. Stepwise-multiple-regression analysis. Prediction variables were as follows: age (y), weight (Wt, in kg), and height (Ht, in cm). BMC, bone mineral content; LTM, lean tissue mass.
2. Expressed as a percentage, at age 12 y.
3. The relation between BMC and LTM was independent of race. When LTM was included as a predictor variable, the contributions obtained by adding age, Wt, or Ht to the equation were not significant.
2.36 kg, respectively, a difference of ≈10%. The predicted body fat mass values for a black male at each of these ages would be 3.9 and 6.3 kg, respectively, whereas those of a white male would be 5.2 and 11.4 kg, respectively. By contrast, the average Hispanic male would have higher body fat values at 6 y (5.4 kg) and 15 y (14.2 kg).

ANOVA indicated that the relation between the BMC and LTM compartments was independent of ethnicity. The two regression equations describing this relation for the total population are included in Table 3. BMC increased $\sim 51.3 \pm 1.0$ g/kg LTM. If the LTM compartment is used, then the mean prediction error (144 g) for BMC is reduced by 33% compared with the results for age, weight, and height (214 g). Also, when LTM was selected as the independent prediction variable, the addition of body fat mass as a second variable increased the $R^2$ value by $< 1%$.

DISCUSSION

Most research studies that have used the DXA measurement technique have focused mainly on the assessment of bone of the lumbar spine and femur, primarily for the early detection of osteoporosis in postmenopausal women. Total-body BMC values, especially for young males, are limited. A search of the literature failed to reveal a previous population study that reported total-body BMC values for Hispanic or black males. A few studies reported regional bone BMC data for black and Hispanic males (11, 12). None of these studies, however, reported on the total-body content of LTM or fat mass. This study, therefore, may provide the first direct comparison of the changes in DXA-derived total body composition as a function of age for young males in these three ethnic groups.

Note that for males aged $< 10$ y in each of the three ethnic groups, the variance in the total-body BMC and LTM values (Figures 1 and 2) was substantially less than that observed at older ages. This suggests that in the prepubertal state, growth and body composition are tightly regulated. At these ages, the significant variations in hormone concentrations that occur during sexual maturation have not yet begun. It was also not surprising to find that total-body BMC and LTM were highly correlated because there is a similarly strong association between total-body calcium mass and skeletal muscle mass in adults (13). The fact that this relation was independent of ethnicity and invariant with age in the present study may indicate that those factors that determine the growth of these two compartments, even during sexual maturation, are under common regulation. Inherent physiologic controls, such as the growth hormone and insulin-like growth factor I systems, are the most likely regulators.

The physiologic role, if any, that body fat might contribute to the growth or mineralization of the skeletal mass in children is not known. It has been suggested that BMC may be significantly increased in adults with excess body fat mass (14). A possible mechanism for this increase is that the added weight causes a direct mechanical loading or stress on bones, stimulating increased bone mass. ANOVAs in this study did not detect body fat mass as a significant covariate for predicting BMC, once LTM was used as a prediction parameter. However, because it is known that total nonfat mass (BMC + LTM) can be increased in individuals with excess body fat (15), it is possible that any direct effect of an increased fat mass on bone mass was masked by the high correlation between the BMC and LTM compartments. In this study of young males, after the variations in BMC related to height and LTM were adjusted for, the association between BMC and percentage fat was nonsignificant ($P > 0.3$).

As noted previously, most studies in which bone measurements were performed in healthy children involved mainly the measurement of bone mineral density for selected bone sites (11, 12, 16–18). In some of these studies ethnic differences were reported (12, 17, 18), whereas in others they were not observed (11). Only a few studies reported total-body BMC values at selected age groups for white and black males. Rico et al (19) reported a mean value of $2.92 \pm 0.60$ kg for postpubertal boys and black males. Gree et al et al (20) observed $1.20 \pm 0.20$ kg for a combined group of white and black males aged 9–11 y. Bhudhikanok et al (21) report 1.19 ± 0.29 and 1.93 ± 0.40 kg for total-body BMC at 11 and 15 y of age, respectively, for white males.

Four of the studies listed in Table 4 reported DXA-based total body composition (BMC, LTM, and fat) values for young white males only. The changes in BMC as a function of age for each of these studies are shown in Figure 4 (information used to construct each curve was obtained from tabulated data, figures, or equations published in these studies). Bone mineralization appears to occur in three phases: a gradual increase in the prepubertal years to about age 8–10 y, followed by a rapid increase that continues for $\geq 7$ y and then a slower rate or

<table>
<thead>
<tr>
<th>Country</th>
<th>Age</th>
<th>DXA instrument</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>3-25</td>
<td>Lunar DP4</td>
<td>Geusens et al (7)</td>
</tr>
<tr>
<td>Belgium (n = 45)</td>
<td>3-14</td>
<td>Lunar DP4</td>
<td>Proesmans et al (22)</td>
</tr>
<tr>
<td>Spain (n = 76)</td>
<td>5-18</td>
<td>Norland XR-26</td>
<td>Rico et al (23)</td>
</tr>
<tr>
<td>Argentina (n = 345)</td>
<td>5-18</td>
<td>Norland XR-36</td>
<td>Zanchetta et al (8)</td>
</tr>
<tr>
<td>Australia (n = 137)</td>
<td>4-26</td>
<td>Lunar DPX</td>
<td>Ogle et al (6)</td>
</tr>
<tr>
<td>Ukraine (n = 14)</td>
<td>5-18</td>
<td>Lunar DPX</td>
<td>De Lorenzo et al (24)</td>
</tr>
<tr>
<td>Italy (n = 58)</td>
<td>5-18</td>
<td>Lunar DPX</td>
<td>Manzoni et al (25)</td>
</tr>
<tr>
<td>Canada (n = 116)</td>
<td>8-16</td>
<td>Hologic QDR-2000</td>
<td>Faulkner et al (5)</td>
</tr>
<tr>
<td>United States (GA; n = 21)</td>
<td>9-11</td>
<td>Hologic QDR-2000</td>
<td>Gutin et al (20)</td>
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<tr>
<td>United States (CA; n = 49)</td>
<td>9-26</td>
<td>Hologic QDR-1000</td>
<td>Bhudhikanok et al (21)</td>
</tr>
</tbody>
</table>

* DXA, dual-energy X-ray absorptiometry. Manufacturers are as follows: Lunar Corp, Madison, WI; Norland, Fort Atkinson, WI; Hologic Inc, Waltham, MA.
BODY COMPOSITION OF YOUNG MEN

FIGURE 4. Comparison of total-body bone mineral content (BMC) values as a function of age for white males in the present study with those reported in the literature for similar ethnic populations (5–8).

possibly a gradual plateau region. The differences in BMC at any age among the various studies may appear nonsignificant. However, the average BMC values among the studies can easily be > 150 g different, which would be significant for an individual. For example, an older Australian male (aged > 17 y) appears to have a mean BMC value that is \( \approx 1000 \) g (30%) higher than that observed for an average-sized, age-matched, white male in the present study. Some of these differences are related to stature, but it was not possible to adjust for this effect because height or BMC/height values were not provided in many of these studies. A 17-y-old male from Argentina also appears to have higher bone mass (change in BMC: \( \approx 500 \) g), yet the mean height for an Argentinean male was substantially lower than that observed in the present study.

Some of these differences in the absolute mass for BMC are most likely related to the reference calibration used for each DXA instrument. Unfortunately, it remains unknown which instrument provides the most accurate measure of true bone mineral mass (26–28). Until a common reference material or phantom has been established for total-body BMC measurements in children, it will remain difficult to identify the true biological component of the differences seen in these populations. Even if the BMC data were systematically shifted to account for known differences (8–10%) in calibration among the instruments, this alone would not remove the discrepancies evident in the growth patterns between countries. Although efforts have been made to establish a universal calibration for regional BMC measurements in adults (29, 30), only a few studies have attempted to make these adjustments for body-composition measurements in children (1, 2, 28, 31–34).

A comparison of the total-body LTM compartment as a function of age among countries is shown in Figure 5. There was general agreement among the studies with the exception of the Australian population, who appeared to have substantially lower average LTM values than age-matched males in the other countries. As noted for the BMC measurement, there is no common reference material or phantom presently used among the manufacturers for the calibration of DXA-derived estimates of the LTM compartment.

The most striking difference in body composition among the countries was that of total-body fat mass (Figure 6). The boys from Argentina and Canada had body fat mass values similar to those of the white males in the present study. The body fat pattern as a function of age for Australian males appeared to parallel that for the males in the present study, but was \( \approx 2-3 \) kg lower at ages < 12 y and 5 kg lower at older ages. The values reported for the Spanish children were consistently the lowest among all the studies. Although there were substantial differences in the mean absolute fat mass values among the various studies, the same general pattern was evident in each of the studies. That is, body fat increased from age 5 to 13 y, decreased by \( \approx 3 \) kg over the next 3–4 y, and then started to increase again during the teenage years. The general pattern evident in each of the studies may indicate a common regulatory mechanism for the storage of excess body fat in young males, possibly in support of the high energy requirements for rapid growth of the fat-free mass (combined BMC and LTM compartments) during puberty. This general pattern was also evident in the data for the black and Hispanic males (Figure 2) examined in this study and is supported by observed changes in skinfold thickness (10, 35).

The present study provides DXA-derived total body-composition data for young males in three ethnic groups living in the southwest United States. There were significant differences in body composition among these three groups. The average values for the BMC and LTM compartments for the black

FIGURE 5. Comparison of total-body lean tissue mass (LTM) values as a function of age for white males in the present study with those reported in the literature for similar ethnic populations (5–8).

FIGURE 6. Comparison of total-body fat mass values as a function of age for white males in the present study with those reported in the literature for similar ethnic populations (5–8).
males as a function of age were higher than those observed for age-matched white or Hispanic boys. Even when adjusted for differences in height and weight, the black males continued to have higher BMC and LTM values than the white males, whereas the Hispanic males were not different from the white males. Furthermore, the distribution of the BMC and LTM values within the 95% range observed for the white population indicates that a larger sample size for the Hispanic population would not result in statistical differences for these relations between these two ethnic populations. Thus, reference BMC and LTM values developed for a white male population appear adequate for use with Hispanic males. However, the Hispanic males as a group had higher body fat mass and percentage fat relative to the white males.

Hence, it is proposed that reference values for body composition for young males be ethnic specific. It appears that reference values for the BMC and LTM compartments for white males will not be adequate for black males, but are acceptable for Hispanic males. The substantial scatter in the body fat values for each of the three ethnic groups makes it inappropriate to use the distribution for white males as a standard for Hispanic or black males.

The body-composition findings for the white population in this study are in general agreement with the overall pattern of growth observed in other countries. This was to be expected. However, the substantial differences in the values for the absolute masses of the three body-composition compartments were not fully expected. Currently, an accurate and precise adjustment is not available to account for known differences among the various methods of instrument calibration. Therefore, it is difficult to determine how much of the differences reported among the various countries can be attributed to physiologic or nutritional effects. Unfortunately, there remains no common agreement among the different DXA instrument manufacturers as to a universal reference that will allow for a standardization of body-composition measurements in children. Until this concern is scientifically addressed, it will be difficult to establish the DXA technique as the reference, criterion, or gold standard for body-composition measurements in children or adults, especially for applications in clinical disorders (36). As part of this effort, we have continued to develop pediatric-sized whole-body phantoms (37) as a common reference for the DXA measurement of total body composition.

I acknowledge M Navarrete for subject recruitment; R Shypailo, J Posada, and J Pratt for performing the body-composition measurements; K Fraley for assistance with statistical analyses; and L Loddeke for editorial review of the manuscript.

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