Anthropometry in Body Composition
An Overview

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ABSTRACT: Anthropometry is a simple reliable method for quantifying body size and proportions by measuring body length, width, circumference (C), and skinfold thickness (SF). More than 19 sites for SF, 17 for C, 11 for width, and 9 for length have been included in equations to predict body fat percent with a standard error of estimate (SEE) range of ±3% to ±11% of the mean of the criterion measurement. Recent studies indicate that not only total body fat, but also regional fat and skeletal muscle, can be predicted from anthropometrics. Our Rosetta database supports the thesis that sex, age, ethnicity, and site influence anthropometric predictions; the prediction reliabilities are consistently higher for Whites than for other ethnic groups, and also by axial than by peripheral sites (biceps and calf). The reliability of anthropometrics depends on standardizing the caliper and site of measurement, and upon the measuring skill of the anthropometrist. A reproducibility of ±2% for C and ±10% for SF measurements usually is required to certify the anthropometrist.

INTRODUCTION

More than seven decades ago anthropometry was the only technique available for quantifying body size and proportions. As early as 1921, equations for predicting body fat were developed from measurements of body length, width, circumference, and skinfold thickness. The distinct advantages of this technique are that it is portable, noninvasive, inexpensive, and useful in field studies, and there is a substantial literature available. During the past decade, investigators have emphasized the accuracy of newer techniques, such as dual-energy X-ray absorptiometry (DXA), magnetic resonance imaging (MRI), and computerized tomography (CT), for measuring body composition; nevertheless, anthropometry still is the most widely used method, and recently, it has been used to estimate fat distribution. The newly developed techniques have not decreased the popularity of anthropometry. Instead, studies indicate that several new potential applications have been explored and that the accuracy of estimation has been increased by applying the new techniques as standards. This report presents a brief overview of the methods, instruments, normal values, and applications of anthropometric measurements.

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METHODS

Skinfold Thickness

Skinfold thickness is accepted as a body fatness predictor for two reasons: about 40–60% of total body fat is in the subcutaneous region of the body, and skinfold thickness can be directly measured using a well-calibrated caliper. There are more than 19 sites for measuring skinfold thickness. Figure 1 shows the sites that have been used at our center and at many other laboratories. The site over the triceps has been used more frequently than other sites, because it is easy to access, is reproducible, and can measure wide differences among people. In 50 frequently used prediction equations for fat and fat-free mass in the literature, ten skinfold measurements were used as predictors. The frequency of each in these 50 equations are, in order: triceps (46) > subscapular (38) > abdominal and iliac crest (33) > thigh (27) > biceps, calf (17) > chest (9) > umbilicus (8) > thorax (2). Our studies show consistently higher $r$ values in Whites than in other ethnic groups, and higher $r$ values at axial than at peripheral sites (biceps and calf). To document the development of the “buffalo hump” in the fat distribution of HIV-positive patients receiving protease inhibitors treatment, we added a new skinfold—suprascapular, which is measured at the upper region of the scapular.

According to the literature, four different calipers have been used: Adipometer, Harpenden, Holtain, and Lange. Lange is the most widely used one, whereas
Adipometer is the least expensive one among the four calipers; they have calibrated measuring ranges up to 60 mm and 80 mm, respectively, and both are suitable for measuring obese people. The Harpenden and Holtain calipers have measuring ranges up to 40 mm; therefore, they may not be used on very obese persons. However, they have higher reliabilities than the other two. Lohman found that the Lange caliper gives the highest readings among the four.6 We found, however, that Adipometer gives readings higher than the Lange caliper, and the difference increased with increasing skinfold thickness (unpublished data).

Interobserver error is a major issue in measuring skinfold.6 Standardized methodology, including positioning of the instrument and the subject, a well-trained data collector, and practicing until results are consistent can increase reproducibility. Special attention to locating the site, grasping the skin, and assuring that the caliper is at a 90-degree angle relative to the grasped skinfold are essentials for high reproducibility. At our center, the average reproducibility for a skinfold measured at 10 sites on one person must be ≤10% to qualify as an anthropometrist who can take routine measurements.

Circumferences

More than 17 sites for circumference measurements have been used in equations for predicting body fatness in the past several decades; Figure 1 shows the sites used at our laboratory and at many others. Circumferences measured at midarm, midthigh, waist, and hip are used more frequently than others, because they indicate differences among people in major regions of the body. Recently, many studies have used circumferences for estimating skeletal muscle mass and fat distribution.2–4 Circumferences are more reliable than skinfolds, and they can always be measured regardless of body size and fatness.

Reproducibility can be increased by giving special attention to positioning the subject, using anatomic landmarks to locate measuring sites, taking readings in millimeters with the tape measure directly in contact with the subject’s skin without compression, and keeping the tape at 90 degrees to the long axis of the region of the body under the measured circumference.6 At our center, the average reproducibility for circumferences measured at eight sites on one subject must be ≤2% to qualify as an anthropometrist for routine measurements. A flexible heavy-duty sewing tape made by Dritz suits these purposes better than other types of tapes.

Bone Breadths

Figure 1 shows the sites for measuring bone breadths that have been used at our center and other laboratories. Measurements of bone breadths at wrist, elbow, ankle, and shoulder using specialized calipers are used to assess growth in children. In adults, they provide information on individual frame size. Body frame size was a concern for investigators when the Metropolitan Ideal Weight Table was subdivided according to frame size more than four decades ago. Because the specialized calipers needed for measuring bone breadths are relatively expensive and few studies have used bone breadths in predicting body composition, such measurements are not so popular as measurements of circumferences and skinfold thickness.
ANTHROPOMETRICS BY SEX, AGE, AND ETHNICITY

A substantial number of references suggest that most anthropometric variables vary by age, sex, and ethnicity, as well as by geographical location and year of measurement. Anthropometric measurements have been a major component in the last seven National Health and Nutrition Examination Surveys since 1960. The results from these surveys have been used as references internationally. The Rosetta Project conducted in our laboratory during 1986–1999 is a cross-sectional study using most of the available techniques for measuring body composition in subjects aged 6–111 years, with different ethnic backgrounds from the greater New York City area. In this report, we present anthropometric values in the adult subgroup based on age, sex, and ethnicity. TABLE 1 shows the physical characteristics of these subjects.

FIGURES 2 and 3 show the mean skinfold thicknesses measured at five sites in Asian, Black, and White Rosetta adults matched in age and body mass index (BMI). There is notable homogeneity among the three ethnic groups in the differences between the sexes; females have higher mean values than males for all five sites. There is also notable homogeneity in the relative differences among the five means in the three ethnic female groups; skinfold thickness at the iliac crest has the smallest mean

| TABLE 1. Characteristics of population studied

<table>
<thead>
<tr>
<th>Sex</th>
<th>n</th>
<th>Age</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>BMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>224</td>
<td>53.8 ± 19.1</td>
<td>77.7 ± 12.6</td>
<td>174.5 ± 7.2</td>
<td>25.5 ± 3.5</td>
</tr>
<tr>
<td>Female</td>
<td>228</td>
<td>51.6 ± 18.4</td>
<td>61.1 ± 9.8</td>
<td>162.7 ± 6.7</td>
<td>30.6 ± 3.5</td>
</tr>
</tbody>
</table>

*mean ± SD.
in all three groups. There are striking similarities in mean values among the three male ethnic groups at the five sites. Using data in Whites as an example, Figures 4 and 5 show the four most frequently used skinfold values versus age in females and males. At any age, females have higher values than males, the highest values being in middle-aged people. Males show a similar pattern to females in abdominal skinfold thickness versus age, the highest values being in middle-aged people. The other
three skinfold thicknesses show very little variation in males from ages 22 to 97 years. Figures 6 and 7 show four major body circumferences versus age in White females and males. In general, males have higher values than females for any circumference at any age. Waist and hip circumferences increase with age, thigh circumference decreases with age, and arm circumference changes less with age for both sexes.
Similar data for children are available in the literature and in the Rosetta database. Presenting body composition data in pediatric populations must take into account not only age, sex, and ethnicity, but also Tanner stages.

APPLICATION

As early as 1921, Matiegka developed an equation for predicting body fat from measurements of skinfold thickness. Since then, numerous equations have been developed to predict body density for estimating fat %, fat mass, and fat-free mass. Triceps and upper-midarm circumference frequently have been used over five decades to assess nutritional status in hospitalized patients. In fifty of the most frequently used prediction equations for fat and fat-free mass in the literature, the standard error of estimate (SEE) ranges from ±3% to ±11% of the mean of the criterion measurement; and most prediction equations have an SEE within 3–7%. Jackson and Pollock’s generalized equations for each sex and Durnin and Womersley’s sex- and age-specific equations using the sum of four skinfolds are the ones most often used in the literature. Figures 8 and 9 present body fat % estimated by underwater weighing (UWW) and dual-energy X-ray absorptiometry (DXA), and predicted by three anthropometric models. All three models give similar patterns for fat % versus age as by the other two reliable techniques, UWW and DXA. Because DXA was used as the standard for the equations developed by Wang et al., the good agreement between these two methods in both sexes, as shown by these figures, is expected. However, UWW was used as the standard for both the Jackson-Pollack and Durnin-Womersley models. Both models underestimate fat % when compared with either UWW or DXA, and the differences increase with age for females. The results suggest that these two models require further evaluation.
Now models are available for estimating total and regional fat distribution, skeletal muscle, and bone mass. They use the more reliable methods as standards. Martin et al.\textsuperscript{12} used comprehensive dissection and anthropometric measurements in 12 cadavers to develop a prediction equation for total body skeletal muscle mass:

**FIGURE 8.** Body fat % by anthropometric predictions, DXA, and UWW in adult White females.

**FIGURE 9.** Body fat % by anthropometric predictions, DXA, and UWW in adult White males.
Skeletal muscle mass (kg) = Ht (cm) (0.0553 (thigh circumference corrected for thigh skinfold (cm))^2 + 0.0987 (forearm circumference (cm))^2 + 0.0331 (calf circumference corrected for calf skinfold (cm))^2) − 2445. This equation has $r^2 = 0.97$ and SEE = 1.53 kg. When applying this equation to our Rosetta database in adult males, we found that the average skeletal muscle mass in 50-year-old males is about 11% lower than in 24-year-old males. Similar to the differences reported in the literature, the reduction reflects smaller arm and leg circumferences, but larger skinfold thicknesses in the older group.

The most important contribution of the work of Martin et al. is in demonstrating the additional potential of anthropometry in the body composition field. In the past, anthropometry was only used for predicting fat %, because the only available criterion techniques were two-compartment models for estimating fat %. In the past decade, several reliable new techniques were developed and validated for measuring adipose tissue and skeletal muscle mass in the total body as well in regions.2–4 The spectrum of application of anthropometry was extended by these newer techniques. Goran et al.2 and Rolland-Cachera et al.3 have further demonstrated that anthropometric measurements have strong potential for predicting the values of total body and regional adipose tissue and skeletal muscle mass, as measured by reliable techniques such as MRI and CT. Because these new techniques are expensive and only available at major research centers and because anthropometric technique is available to most investigators in the world, more new prediction equations validated by these reliable techniques are desperately needed.

**SUMMARY**

The distinct advantages of anthropometry are that it is inexpensive, simple, and portable. The disadvantages are lack of standardization in methodology and the need for well-trained anthropometrists. Future studies should emphasize the reliability of measurement and search for new criteria techniques for accurate techniques to measure regional body composition.

**REFERENCES**