Published in final edited form as:
Med Sci Sports Exerc. 2011 March ; 43(3): 542–549. doi:10.1249/MSS.0b013e3181ef3f07.

Predicting Fat Percent by Skinfolds in Racial Groups: Durnin and Womersley Revisited

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Abstract

Purpose—Despite their widespread use in research and fitness settings, Durnin and Womersley's (DW) 1974 prediction equations using skinfold thickness to estimate body fat percent by hydrodensitometry have not been systematically evaluated in racial or ethnic groups using body fat percent measured by dual-energy x-ray absorptiometry ($\%BF_{DXA}$) as the standard.

Methods—This cross-sectional, population-based study examined whether the DW skinfold equations predict $\%BF_{DXA}$ in a large, multiracial sample. Four skinfold measures (biceps, triceps, subscapular, and suprailiac), other clinical anthropometrics, and $\%BF_{DXA}$ were obtained from 1675 healthy adults, age 18–110 yr, who were classified into four racial or ethnic categories: Caucasian, African American, Hispanic, or Asian. Predicted body fat percent using DW equations was compared with $\%BF_{DXA}$ and evaluated within race/ethnicity- and sex-specific groups.

Results—Mean body fat percent predicted by DW equations was significantly different from $\%BF_{DXA}$ in four of eight race/ethnicity- and sex-specific groups, particularly in Asian women and African American men (3.3 and 2.4 percentage point overestimates, respectively, $P < 0.0001$). New linear regression equations were developed estimating $\%BF_{DXA}$ specific to each race/ethnicity and sex group, using the original DW skinfold sites. Body weight, height, and waist circumference independently predicted fat percent and were also included in the new equations.

Conclusions—The 1974 DW equations did not predict $\%BF_{DXA}$ uniformly in all races or ethnicities. Using $\%BF_{DXA}$ as the criterion measure, the original DW skinfold equations have been updated specific to sex and race/ethnicity while maintaining the DW options for a minimalistic model using fewer predictors.

Keywords

DUAL-ENERGY X-RAY ABSORPTIOMETRY; BODY COMPOSITION; ANTHROPOMETRICS; ETHNICITY

With the rampant spread of obesity in the United States (21) and throughout the world (1,9,38), coupled with the recognized impact of obesity on health-related outcomes, the assessment of body fat is becoming an increasingly important clinical measure. Significant technological advances have been made that allow for the estimation of total body fat and fat distribution non-invasively and with relatively good precision in humans (10). The

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None of the authors has any conflicts of interest related to this work.

application of many of these techniques in field settings is limited because of the expense associated with purchase and maintenance of equipment and specially trained and licensed operators required for use of some instruments (28). A pressing need remains for inexpensive and convenient measurement methods that are suitable for application in clinical, research, and field settings or in gyms where the latest equipment is not readily available.

For more than three decades, prediction equations published by Durnin and Womersley (DW) in 1974 (5) have been widely used to estimate percent body fat from caliper-measured skinfold thicknesses. The authors' thorough approach to equation development and provision of easy-to-use tables for estimation of percent body fat with any combination of four commonly used skinfolds (biceps, triceps, subscapular, and suprailiac) made this a seminal contribution to the field of body composition assessment. The equations were developed in a Caucasian population and were based on the linear relationship between the log of skinfolds and the hydrodensitometry-measured body density (5). Since then, several studies have reported that body density, and more specifically the density of fat-free mass, is not constant but varies according to age, sex, and race/ethnicity (3,36). Racial differences in body density (13) and subcutaneous fat patterning (33,40) may partially explain why the DW equations have shown modest differences in their ability to predict percent body fat in some African American (15) and Asian (6) subjects. Thus, a reevaluation of the DW equations is warranted within these and other race/ethnicity groups that have been shown to differ in body composition from Caucasians.

The emergence and now widespread use of dual-energy x-ray absorptiometry (DXA) has added a new dimension to clinical body composition assessment since the development of the DW equations. Having added a third component, bone mineral density, to the two-compartment model used by hydrodensitometry, DXA has expanded clinical use (in addition to its original purpose in osteoporosis screening and bone mineral density assessment) and is increasingly used as a criterion measurement for body composition assessment in clinics and research facilities (24). The DW equations have recently been shown to underestimate percent body fat in a Caucasian sample using a four-compartment model (23), but as yet, no study has systematically evaluated whether these equations apply across race or ethnic groups to predict DXA-measured percent body fat.

The primary aim of this study was to apply the 1974 DW equations, using the sum of four skinfolds to predict percentage body fat using DXA as the criterion method in a large multiracial adult sample. A secondary aim of this study was to develop sex- and race/ethnicity-specific equations for the prediction of DXA-measured percent fat using standard clinical anthropometric measures and any combination of the set of four skinfolds originally proposed by DW.

MATERIALS AND METHODS

Subjects

Data for this study were gathered from a total of 1675 subjects who participated in one of nine studies conducted at New York Obesity Nutrition Research Center's Body Composition Unit between 1986 and 2005. All studies obtained written informed consent and were approved by the Radiation Safety Committee and Institutional Review Board of St. Luke's-Roosevelt Hospital. Subjects were classified as having no known or diagnosed diabetes, cancer, heart disease, or any health conditions that would affect body composition or fat distribution; they were ambulatory, weight stable (less than 2 kg weight change in previous 6 months) adults who underwent testing that included skinfolds and a total body DXA scan to determine fat percent. Excluded from analysis were subjects who had any skinfold measurement that approached the maximum capacity of the Lange skinfold calipers (capacity = 65 mm, excluded if >62 mm; 10 subjects). Race/ethnicity was determined by self-report and included declaration of race/ethnicity for parents and grandparents. Four race/ethnicity categories were created: Caucasian (C), African American (AA), Hispanic (H), and Asian (A). Those who reported mixed race/ethnicity within three generations or who fell into another racial category were excluded (49 subjects). Nearly 75% of the H group reported family origins in Puerto Rico and/or the Dominican Republic. The A group was predominantly of Japanese, Chinese, or Korean descent.

Body Composition

Anthropometrics—

Three trained laboratory technicians obtained all anthropometric data. Body weight was measured to the nearest 0.1 kg using a balance beam scale (Weight Tronix, New York, NY) with the subject wearing a hospital gown. A wall-mounted stadiometer (Holtain, Crosswell, Wales) was used to measure standing height to the nearest 0.1 cm. Waist circumference was obtained using a heavy-duty inelastic plastic fiber tape measure (Prym-Dritz USA, Spartanburg, SC) at the level of the iliac crest, with intertester error of less than 2% (35). Height, weight, and circumferences were originally examined in DW's development of prediction equations and were reevaluated as ancillary predictors in the current analyses. Skinfold thickness to the nearest 1 mm was obtained at four sites (biceps, triceps, subscapular, and suprailiac) on the subject's right side using a Lange caliper (Beta Technology, Inc., Cambridge, MD) and in accordance with standard procedures (11). Each technician was trained and cross-validated (able to obtain skinfold values that differed from an experienced trainer by less than 10%) on at least 50 subjects before qualifying to obtain routine measurements (35).

Whole-body DXA—

The DXA-measured body fat percent ($\%BF_{DXA}$) was obtained using one of three Lunar (now GE Lunar, Madison, WI) scanners: DPA (Lunar DP4, software version 5E), DPX (Lunar DPX, software version 3.1), and DPX-L (Lunar DPX-L, software version 4.7e). The technology used by each of these models has been validated for measurement of fat mass, lean mass, and bone mineral content using the four-compartment model as a criterion (8,12,26). Standard procedures were followed for the acquisition of a whole-body scan and for subsequent soft tissue analysis using the scanner-specific software with manual correction. On the morning before testing each subject, quality control tests were performed using an anthropomorphic spine phantom. The phantom was also scanned thrice weekly and before and after manufacturer maintenance, regardless of subject testing schedules. Calculated phantom spine bone mineral density remained stable throughout the study periods for DPA (January 1986 to December 1989), DPX (January 1993 to December 2001), and DPX-L (December 1995 to November 2005). For DPX and DPX-L machines, quality control for fat and fat-free mass measurement was assessed using soft tissue phantoms of water (coefficient of variation = 1.5%–1.6%) and alcohol (coefficient of variation = 0.6%–1.3%). Percent body fat was calculated using the total fat value obtained by the scanner and dividing it by total body mass as measured by DXA.

Some studies have reported significant differences in outcome between densitometer models, especially when the scanners vary in technology (25). To adjust for these differences, two cross-validation studies were conducted. In the first study, data were used from a separate sample of 113 healthy volunteers (86 of whom were included in a similar analysis published previously [29]) who had whole-body scans performed with DPA and DPX densitometers on the same day. The R^2 between DPA and DPX body fat percent was 0.96 ($P < 0.0001$). The following equation was created to convert percent fat from DPA to DPX: $\%BF_{DPX} = -2.1379 + (0.9494\ \%BF_{DPA})$. In another sample of 78 volunteers (from a cross-calibration study also published previously (31)), whole-body DPX and DPX-L scans were performed on the same day. The R^2 between DPX and DPX-L body fat percent was 0.99, $P < 0.0001$, and the following conversion equation was created: $\%BF_{DPX\text{-}L} = -0.5532 + (0.9813\ \%BF_{DPX})$. Applying these conversions, the percent fat from DPA and DPX models is presented as DPX-L values.

Statistical Analyses

Descriptive statistics were calculated and expressed as mean ± SD. Paired *t*-tests were used to compare the DW age-specific and all-age equations (coupled with Siri's equation for conversion from density to percent body fat [30]) versus $\%BF_{DXA}$. Ordinary least products regression methods (20) were used to test the hypothesis that the relationship between $\%BF_{DXA}$ and percent body fat estimated by the DW sex-specific sum of four skinfold equations was consistent with the line of identity. Because there were statistically significant differences between the mean $\%BF_{DXA}$ and the mean percent fat values by both DW equations, the effects of race and sex on the comparisons were explored by repeating the paired *t*-tests for each combination of race and sex. Linear regression was used to evaluate the agreement between fat percent using the DW sum of skinfold equations and $\%BF_{DXA}$ while testing for race, sex, and their interactions. Dummy variables were used to model the effects of the two categorical variables, race and sex. One dummy variable was required for sex, $m = 1$ for men and $m = 0$ for women; three dummy variables were used to model race: $b = 1$ for African Americans (otherwise, $b = 0$), $h = 1$ for Hispanic (otherwise, $h = 0$), and $a = 1$ for Asian (otherwise, $a = 0$), which made our reference group Caucasian women. Interactions between race, sex, and other variables were formed by calculating products among the appropriate variables. A global *F*-test was used to test for the effect of race. Sex and race/ethnicity-specific regression analyses were used in the development of new percent body fat equations. Variables included in development of the models were the sum of four skinfolds, the logarithm ($\log_{10}$) of the sum of four skinfolds, sex, race/ethnicity, age, height, weight, waist circumference, and interaction terms: log of the sum of four skinfolds × sex and log of the sum of four skinfolds × race/ethnicity. PRESS statistics, SEE_{PRESS}, and R^2_{PRESS} are provided to give an assessment of the validity of the equations (14). For all analyses, alpha was set at 0.05. Analyses were performed with SAS version 9.1 (SAS Institute Inc., Cary, NC).

RESULTS

A significant difference was found between the mean percent body fat estimated by the DW sex-specific sum of four skinfold equations and the mean $\%BF_{DXA}$ ($P < 0.0001$). The relationship between $\%BF_{DXA}$ and percent body fat estimated by the DW sex-specific sum of four skinfold equations was derived using ordinary least product regression. The intercept was −3.70 with a 95% confidence interval equal to (−4.35 to −3.05). Therefore, the intercept was significantly different from zero ($P < 0.0001$), which indicates that a fixed bias was present. The slope was equal to 1.09 with a 95% confidence interval equal to (1.06, 1.11). The slope was significantly different from unity ($P < 0.0001$), indicating that a proportional bias was also present. These differences were found to be both race and sex dependent. Thus, the physical characteristics of the sample are presented in Table 1, divided by sex and racial or ethnic group. All groups were well represented, and each was characterized by a wide range of age and adiposity. Table 2 compares $\%BF_{DXA}$ to that predicted by the DW age-specific and all-age equations on the basis of the sum of four skinfolds in four race/ethnicity groups. Percent body fat derived from the DW age-specific equations significantly overestimated $\%BF_{DXA}$ in all groups ($P < 0.0001$). The DW all-age equations predicted $\%BF_{DXA}$ within 1 percentage point in Caucasian men and African American women but significantly overestimated it in all other groups.

Because sex- and race-dependent differences were found between body fat predicted by the DW skinfold equations and actual $\%BF_{DXA}$, new sex-specific prediction equations were developed within each race/ethnicity group. The original analytical framework evaluating the original four DW skinfolds and the ancillary anthropometric predictors were revisited, except that $\%BF_{DXA}$ was directly predicted as the outcome measure. Similar to the DW observation of the relationship between skinfold thickness and body density (5), a curvilinear relationship was found between skinfold thickness and $\%BF_{DXA}$, as illustrated in Figure 1 in both men and women. The logarithmic transformation of skinfold values provided a linear relationship with $\%BF_{DXA}$ (Fig. 2) that decreased the SE nearly uniformly across all groups and all combinations of skinfolds (data not shown). In all sex and ethnic groups, the logarithm of the sum of four skinfolds was the primary predictor in the model. Age, height, weight, and waist circumference were independent predictors of $\%BF_{DXA}$ but never explained more than 5% of the variance after the log of skinfolds was included. Waist circumference was correlated (50% shared variance) with weight such that in some race- and sex-specific models, one rendered the other coefficient not significantly different from zero. For example, waist was not beneficial when weight was included in the sum of four skinfold model for Caucasians and for Asian women; waist rendered weight nonsignificant in Hispanics and in Asian men. However, because weight and waist each significantly improved the SE of most models, were distinctly beneficial to some subgroups, and are commonly acquired clinical measures, both were included as predictors in the new equations.

Table 3 presents new sex- and race/ethnicity-specific prediction equations for $\%BF_{DXA}$ using the original sum of four skinfolds used by DW. Because age, body weight, height, and waist circumference contributed significantly to our models, these variables are included in the equations to improve the prediction of $\%BF_{DXA}$. Estimates of $\%BF_{DXA}$ can be calculated from Table 3 in the following manner, using as an example values from the equation for Caucasian women: $\%BF_{DXA} = 22.044(\log SF) + 0.053(\text{age}) + 0.179(\text{weight}) -0.155(\text{height}) + 0.156(\text{waist}) -13.093$, where logSF is the logarithm ($\log_{10}$) of an individual skin-fold thickness or sum of skinfold thicknesses in millimeters, age is the subject’s age in years, height is the subject’s height in centimeters, weight is the subject’s body weight in kilograms, and waist is abdominal circumference in centimeters at the level of the iliac crest.

As a modern solution to the useful tables by which DW presented their original equations, providing users with options to estimate percent fat with any combination of the four skinfolds, we created an easy-to-use body fat prediction calculator (see Supplemental Digital Content 1, Body Fat Calculator, http://links.lww.com/MSS/A47), which automates the computation of the full equations from Table 3. In addition, the program accesses prediction equations produced from our data set for any combination of the four skinfolds, weight, height, or waist circumference.

DISCUSSION

This study evaluated the ability of the 1974 DW equations to predict DXA-measured percent body fat in a large sample of healthy adults and found that the DW equations over-estimated $\%BF_{DXA}$ in all but Caucasian men and African American women. These findings underscore the need for race/ethnicity-specific equations when predicting percent body fat from skinfold thickness. New DXA-based prediction equations were developed, incorporating the original DW skinfolds and also providing options for deriving a percent fat estimate from any combination of the skinfolds. Prediction accuracy is improved by including three easily obtained field test outcomes, body height, weight, and waist circumference, thus supporting the use of the equations in research, clinical, or fitness settings.

The use of body density estimates in previous studies to predict body fat percent, especially when primarily on the basis of male Caucasian cadaver data (30), may be problematic when applied to subjects of different racial backgrounds. Although some studies report negligible racial differences in body density (7,32), other studies dispute these findings with reports of greater body density in African American (22) or Asian subjects (37) in comparison with Caucasians. As a portion of the fat-free mass component in a two-compartment model, bone plays a significant role in race/ethnicity-dependent body density differences. Bone mineral density in African Americans has been shown to be greater than that in Caucasians, which in turn is greater than that in Hispanics (19). The density differences attributable to bone, while seemingly minor, profoundly influence fat-free mass and, by extension, predictions of percent body fat by body density. Theoretically, a 2% difference in bone mineral content alone could result in an 8% error in body density-based estimations of percent body fat (18). The results from the present study confirm the need for a race-specific approach, particularly in African Americans and Asians. The known age-, sex-, and race-dependent variability in bone mineral density and fat-free mass is taken into account when equations are developed on the basis of percent body fat by DXA, which measures bone mineral density in addition to fat-free mass.

The original DW equations (5) first predicted body density and then converted that value to percent body fat using Siri's formula (30). Similar to DW skinfold density data in Caucasians, scatterplots of the sum of skinfolds with $\%BF_{DXA}$ in the current study yielded a consistent curvilinear pattern across each sex and race/ethnicity group. The logarithmic transformation of the sum of skinfolds also provided a linear relationship with $\%BF_{DXA}$ and reduced SE in the prediction model. Another similarity was a uniformly significant age effect. Noting the significant loss of predictive power that occurred when DW divided their group by age (made evident in the results of age-specific equations presented in Table 2), age was included as a continuous prediction variable in each equation rather than creating age-specific groups.

The results of this study differ from those of DW in that body weight and height remained in the model as significant predictors of $\%BF_{DXA}$ independent of skinfold thickness. Peterson et al. (23) compared the DW equations with the four-compartment model in a sample of Caucasian adults and also found that height and weight had a significant but not dramatic contribution to the prediction of body fat. We chose to include these easily obtainable anthropometric measures in the equations to improve prediction accuracy. Although various limb circumferences were measured in the original DW analyses, the only body circumference was a maximal hip or buttocks measure, obtained on only a portion of the subjects. In recent decades, waist circumference has become an increasingly useful clinical tool for assessment of health risk as a surrogate of intra-abdominal fat mass: a depot wholly undetectable by skinfold thicknesses. As a slight deviation from the DW protocol, we chose to test waist circumference as a potential predictor of fat percentage. When included, waist added significantly to the prediction model, particularly in non-Caucasian subjects, and was thus included in the new equations. These ancillary predictors help to improve prediction accuracy, resulting in SEE that range from 3.4 to 4.0: a full percentage lower than those presented by DW (4.6 for men and 5.4 for women—using density SEE values converted to fat percentage SEE by a first-order approximation of the Taylor expansion of Siri's equation).

The finding that a skinfold prediction equation developed in a purely Caucasian population does not apply equally to other races or ethnicities is not without precedent. A few studies support the use of Caucasian-based equations in Asian (39) or African American (15) subjects, but most agree that total fat prediction by skinfold thickness must be accomplished using race-specific formulas (2–4,6,16,40). In support of this notion, Jackson et al. (16) recently provided a similar update of another set of skinfold prediction equations using DXA as an outcome to replace body density by hydrostatic weighing in a large sample of younger (18–35 yr old) Caucasian, African American, and Hispanic adults. Race effects by skinfold thickness were observed, and new race-specific prediction equations were published (16). Subcutaneous fat distribution may be responsible for the variation between races in skinfold prediction (3). The race-dependent differences in “fat patterning” observed by Zillikens and Conway (40) were also observed in the current sample (data not shown), reiterating the need for race-specific equations in the estimation of percent body fat by skinfold thickness.

Although these new race/ethnicity-specific equations now replace the original Caucasian-based DW equations, further research on the influence of race or ethnicity on the prediction of body fat by skinfold thickness is needed. Even within each of the four racial categories identified, various ethnic group and locale-related differences exist. Since the current study’s sample is composed of and represents the ethnic admixture of New York City residents (34), validation studies are recommended to examine the application of these equations to other ethnicities.

A strength of this study is the large, multiracial sample that encompasses nearly the entire adult age range (18–110 yr) and includes an obesity range limited only by weight limits of the DXA tables (113 kg) and the skinfold caliper capacity (62 mm). Thus, although the equations may not apply to some severely obese phenotypes, a majority of the world’s population falls within the ranges of the prediction parameters used in this study. The assessment of the final model’s fit to the data, which included residual and influence analyses, indicated that predicted values were in agreement with the DXA percent body fat across the range of the independent variables for this sample. Interestingly, in most cases, using fewer than four skinfolds did not increase the SE dramatically. Thus, the researcher or clinician may evaluate special cases when there are missing or suspect data and choose an equation using the body fat calculator (Supplemental Digital Content 1, http://links.lww.com/MSS/A47) that fits the available data and minimizes error for optimal prediction accuracy. However, if all skinfolds and anthropometrics are available, the use of the most comprehensive equation (sum of four skinfolds, presented in Table 3) is encouraged for best results.

Several limitations of this study are that while DXA is increasingly considered the gold standard for body composition research, some may argue that several factors such as body thickness and hydration contribute to erroneous results in the estimation of soft tissue (17). The study also included data obtained using the Lunar DPA densitometer, which has now been replaced by later Lunar DXA models. Conversion of DPA to DPX may have introduced some error. Finally, race or ethnic group was determined by self-report, which is reported to be a suitable proxy for genetic ancestry, especially when assessing disease risk (27), but does not take into account degrees of admixture.

In summary, this study evaluated the ability of the original DW skinfold equations to predict DXA-measured fat percent within both sexes in four racial or ethnic groups. The results demonstrate that the DW equations do not estimate fat percent uniformly in all racial or ethnic groups. Provided are new skinfold prediction equations for total body fat percentage within race/ethnicity- and sex-specific groups using a large sample with a wide age and adiposity range. In revisiting the combinations of four skinfolds used by DW, body height, weight, and waist circumference were added to improve prediction accuracy. These data support the continued use of commonly used skinfold sites originally proposed by DW and present updated equations that recognize race-related body composition differences and predict DXA-measured body fat percent.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Funding for this project was obtained through the following grants: NIH T32-DK007559, PO1-DK42618, RO1-DK37352 and R29-AG14715, P30-DK26687, and RR024157.

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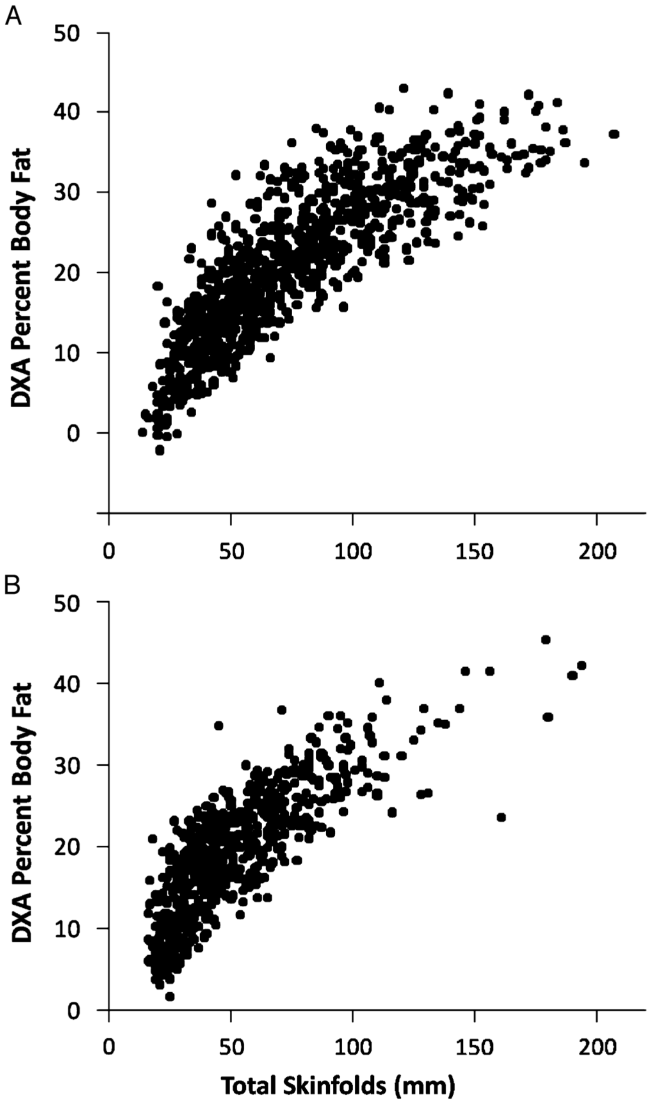

FIGURE 1.

Scatterplots demonstrating the curvilinear relationship between sum of biceps, triceps, subscapular, and suprailiac skinfolds and DXA-measured percent body fat in 1002 women (A) and 673 men (B).

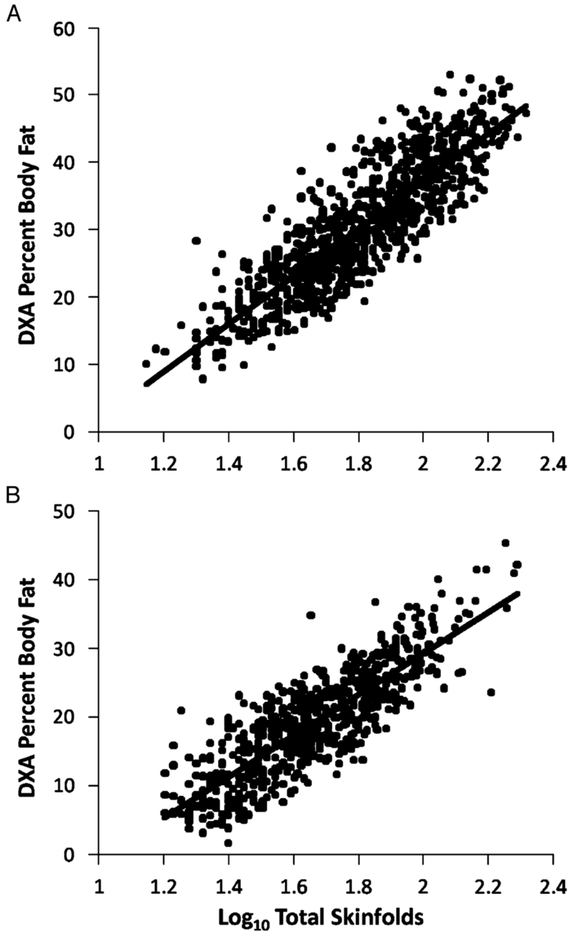

FIGURE 2.

Linear relationship between logarithm of sum of skinfolds and percent fat in 1002 women (A) and 673 men (B). Individual values for DXA-measured percent body fat and the logarithm of the sum of four skinfolds with best-fit regression lines are as follows: DXA percent body fat in all women = 35.884 logSF −33.709, $R^2 = 0.749$, SEE = 4.561; DXA percent body fat in all men = 30.729 logSF −31.122, $R^2 = 0.714$, SEE = 4.123.

TABLE 1

Descriptive characteristics of sample across race/ethnicity and sex groups.

	Caucasian	African American	Hispanic	Asian
Women (*n*)	469	202	164	167
Age (yr)	48.8 (20.0)	56.0 (20.2)	50.9 (16.5)	47.2 (19.7)
Height (cm)	162.6 (7.0)	161.3 (7.4)	155.4 (6.6)	157.2 (6.3)
Body weight (kg)	61.3 (10.7)	71.2 (14.3)	67.0 (12.1)	54.2 (8.4)
BMI ($kg \cdot m^{-2}$)	23.2 (4.0)	27.3 (4.9)	27.8 (5.1)	21.9 (3.1)
Waist (cm)	93.5 (11.0)	100.5 (11.9)	99.2 (10.7)	89.4 (7.4)
Body fat by DXA (%)	27.9 (8.2)	34.6 (8.8)	36.8 (7.0)	28.2 (6.6)
Biceps skinfold (mm)	9.1 (6.4)	15.0 (9.7)	20.1 (9.0)	8.6 (4.7)
Triceps skinfold (mm)	20.8 (7.7)	27.3 (10.7)	28.4 (8.6)	21.4 (6.8)
Subscapular skinfold (mm)	14.9 (9.0)	24.0 (11.3)	31.5 (13.1)	19.2 (8.1)
suprailiac skinfold (mm)	14.2 (9.1)	22.0 (11.3)	25.5 (9.2)	17.3 (8.4)
Men (*n*)	282	122	142	127
Age (yr)	48.8 (19.3)	45.9 (21.5)	47.6 (15.5)	48.6 (19.0)
Height (cm)	175.6 (7.4)	176.5 (7.7)	169.1 (7.5)	170.8 (6.3)
Body weight (kg)	77.9 (12.0)	81.0 (15.3)	77.9 (14.9)	67.9 (8.0)
BMI ($kg \cdot m^{-2}$)	25.2 (3.4)	26.0 (4.4)	27.1 (4.4)	23.3 (2.5)
Waist (cm)	95.1 (9.4)	94.9 (10.4)	97.1 (11.3)	90.3 (6.6)
Body fat by DXA (%)	18.1 (7.4)	18.3 (8.6)	22.7 (7.7)	18.8 (5.7)
Biceps skinfold (mm)	5.4 (4.8)	6.8 (5.2)	8.1 (5.8)	5.4 (2.9)
Triceps skinfold (mm)	12.6 (6.5)	14.1 (8.7)	13.7 (6.4)	12.6 (4.5)
Subscapular skinfold (mm)	15.0 (7.6)	18.4 (9.9)	22.7 (10.7)	16.5 (5.8)
suprailiac skinfold (mm)	12.2 (8.6)	15.8 (11.3)	21.2 (10.6)	12.9 (6.9)

Values are expressed as group mean (SD); *n*, number of subjects.

TABLE 2

DXA percent fat versus DW's sum of four skinfolds percent fat equations.

	DXA	DW Age-Specific Equation			DW All-Age Equation		
	%BF	**%BF**	**Error**	***P***	**%BF**	**Error**	***P***
Women							
Caucasian (*n* = 469)	27.9 (8.8)	31.4 (7.6)	3.6 (4.6)	<0.0001	29.2 (6.7)	1.4 (4.7)	<0.0001
African American (*n* = 202)	34.6 (8.8)	37.5 (7.8)	2.9 (4.7)	<0.0001	35.1 (7.4)	0.5 (4.6)	0.134
Hispanic (*n* = 164)	36.8 (7.0)	40.5 (6.2)	3.7 (4.3)	<0.0001	38.4 (5.5)	1.7 (4.2)	<0.0001
Asian (*n* = 167)	28.2 (6.6)	33.4 (6.6)	5.4 (4.2)	<0.0001	31.5 (5.4)	3.3 (3.8)	<0.0001
Men							
Caucasian (*n* = 282)	18.0 (7.3)	20.8 (7.6)	2.8 (4.1)	<0.0001	18.2 (6.9)	0.2 (4.0)	0.347
African American (*n* = 122)	18.3 (8.6)	22.4 (8.4)	4.1 (4.8)	<0.0001	20.8 (7.8)	2.4 (4.3)	<0.0001
Hispanic (*n* = 142)	22.7 (7.7)	26.5 (6.9)	3.9 (4.7)	<0.0001	24.1 (6.4)	1.4 (4.0)	<0.0001
Asian (*n* = 127)	18.8 (5.7)	22.4 (6.5)	3.6 (4.5)	<0.0001	19.7 (5.4)	1.0 (4.0)	0.008

Values are presented as mean (SD).

%BF, percent body fat; Error, bias (systematic variation) of DW estimate and SD of the errors represents imprecision from using the DW equation to predict DXA %BF; *n*, number of subjects.

TABLE 3

Linear regression equations and PRESS statistics to estimate DXA-measured percent fat by sex and race using the logarithm of the sum of four skinfolds, age, height, weight, and waist circumference.

	Log of Sum of Four[a] Skinfolds	Age (yr)	Weight (kg)	Height (cm)	Waist (cm)	Constant	R^2	SEE	PRESS	
									R^2	SEE
Women										
C	22.044	0.053	0.179	−0.155	0.156	−13.093	0.800	3.944	0.795	3.968
AA	20.867	0.052	0.140	−0.152	0.149	−8.227	0.800	3.982	0.784	4.083
H	23.871	0.019	−0.022	−0.118	0.249	−16.782	0.731	3.710	0.707	3.799
A	21.430	0.036	0.241	−0.149	0.067	−7.525	0.734	3.437	0.715	3.494
Men										
C	23.317	0.064	0.097	−0.126	0.081	−15.596	0.772	3.537	0.760	3.587
AA	22.702	0.065	0.043	−0.080	0.156	−26.806	0.790	4.008	0.765	4.131
H	23.660	0.040	−0.036	−0.109	0.272	−26.410	0.808	3.431	0.785	3.550
A	13.832	0.020	0.081	−0.210	0.289	−0.650	0.649	3.450	0.612	3.543

[a] Log_{10} (biceps + triceps + subscapular + suprailiac skinfolds (in mm)).

C, Caucasian; AA, African American; H, Hispanic; A, Asian.