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Body Composition

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**A COMPARISON OF METHODS TO DETERMINE BODY FAT IN INDIVIDUALS WITH CYSTIC FIBROSIS: A PILOT STUDY**

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**ABSTRACT**

A COMPARISON OF METHODS TO DETERMINE BODY FAT IN INDIVIDUALS WITH CYSTIC FIBROSIS: A PILOT STUDY. **Anne K. Swisher, Rachel Yeater, Kathryn Moffett, Linda Baer, Bonita Stanton.** *JEPonline* 2003;6(2):105-114. Malnutrition is known to contribute to poor clinical outcome in persons with Cystic Fibrosis (CF). There is a need for accurate, reliable and clinically applicable methods to assess nutritional status. This study compared BOD POD air plethysmography, near-infrared interactance (NIR) and skinfold equations for determining body fat in persons with CF and lean controls. Ten CF subjects (5 males, 5 females) and 10 age- and sex-matched controls had body fat determined by each of the methods in a random order during a single session. Percent fat by BOD POD was  $19.4 \pm 4.7$  in CF females,  $9.7 \pm 6.1$  in CF males,  $14.2 \pm 3.3$  in control females and  $15.5 \pm 3.7$  in control males. Percent fat by NIR was  $24.6 \pm 4.4$  for CF females,  $15.5 \pm 5.5$  for CF males,  $23.3 \pm 3.9$  for control females, and  $23.3 \pm 3.9$  for control males. Percent fat by skinfolds ranged from 15-21% for CF females, 6-8% for CF males, 19-20% for control females, and 14-16% for control males, depending on the number of sites used. Analysis of variance and Pearson product moment correlations were determined for both sexes in CF and control groups. Body fat by NIR was significantly higher than BOD POD and skinfold equations in both sexes in each group. Skinfold equations using 7-sites, 4-sites and 3-sites significantly correlated to BOD POD in CF males ( $r=0.95-0.96$ ). No skinfold equation was found to correlate significantly with BOD POD in CF females. NIR cannot be recommended, due to its consistent overestimation of body fat levels in lean subjects. The use of skinfold equations to determine body composition in CF can be supported for males only.

Key Words: Body composition, BOD POD, near infrared interactance

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## INTRODUCTION

Cystic Fibrosis (CF) is the most common genetically inherited lethal disease in Caucasians (1). Persons with CF may have several manifestations of the disease, which affects their ability to absorb and utilize nutrients in the diet (2,3,4) leading to low body fat percentage. In addition, persons with CF have frequent respiratory infections, which increases metabolic demand and may cause anorexia due to impaired taste sense or profuse coughing (4).

Studies have documented that the nutritional status of persons with CF has a direct effect on both morbidity and mortality (1,5). In addition, decreased fat-free mass has been associated with bone loss (6) and decreased inspiratory muscle strength (7). Thus, there is a need to accurately assess patients' nutritional status, including the tissue composition of body weight (8).

Hydrostatic or underwater weighing (HW) is generally considered the "gold standard" in determining body density and fat composition. However, this method has several problems, especially for persons with CF. In order to perform the test accurately, a subject must be completely submerged in water and perform a complete exhalation of air. This test often requires many trials to get an accurate value. For persons with CF, total immersion in water can be an uncomfortable and frightening experience. These patients also have large residual lung volumes due to their disease and find it difficult to perform complete exhalation (3). Since the standard measures of body density are based on a normal residual volume, these values may not be valid for CF patients. The time it may take to get an accurate weight with the subject underwater may exceed the time that individuals with CF could hold their breath (3).

Newby et al. (3) found that the calculated body composition values from HW were not significantly correlated with bioelectrical impedance, total-body electrical conductivity, and skinfold measurements in subjects with CF. These authors concluded that HW was not a valid test for persons with CF.

In order to address concerns about HW, a new form of body plethysmography, called the BOD POD, has been developed. This device uses body mass and air displacement in an enclosed chamber to calculate body density (9). It does not require immersion in water or full exhalation as in HW and can easily be performed by a trained person in a few minutes. The BOD POD was found to have excellent test-retest reliability (coefficient of variability of 1.7%) and differ from HW in estimation of percent body fat by only 0.3% in a group of 68 healthy adults of varying age and fatness (10). Percent body fat measurements by BOD POD have been found to highly correlate with HW in healthy women ( $r = 0.94$ ) (11), and in 10- to 18-year-old children ( $r=0.94$ )(12). Koda found percent body fat determined by BOD POD to correlate highly with dual x-ray absorptiometry (DEXA) in middle-aged and elderly Japanese men ( $r=0.89$ ) and women ( $r=0.90$ ) (13). Collins et al (14) found the BOD POD to have excellent test-retest reliability ( $r=0.99$ ), and percent body fat measurements correlated highly with those determined by both HW ( $r=0.89$ ) and DEXA ( $r=0.89$ ) in a group of collegiate football players. Lockner et al (12) found BOD POD to have less bias in estimating total body fat mass than DEXA in healthy children. Most importantly, Fields and Goran (11) compared the accuracy, precision, and bias of fat mass as assessed by DEXA, HW, total body water and BOD POD in children (11) and adult women (15). They found that the only technique that could accurately, precisely, and without bias estimate fat mass in nine- to 14-year-old children was the BOD POD (11) and that the BOD POD was an unbiased estimate of HW in adult women (15). They also found no difference in body density as measured by BOD POD and HW (15). Millard-Stafford et al have also shown that the BOD POD can be an acceptable substitute for HW in lean young adults of both sexes (16). Clearly, the preponderance of the evidence in the literature indicates that the BOD POD is a valid and reliable method for determining body composition in children and young adults. This system is an excellent choice for determining body composition in CF patients since it does not require any difficult breathing maneuvers, it requires little time to complete, and it correlates highly with HW in measures of percent body fat and fat mass

One expert panel has recommended using triceps skinfold thickness measures to track nutritional status in persons with CF (4). In addition, McNaughton et al. (17) recommended triceps skinfold measurement in CF as the most accurate clinical measure when more precise measures, such as total body potassium content, are not feasible. The use of a single measurement site allows for greater error, as it does not correct for differences in individual fat deposition patterns (18,19). This method also does not allow the user any way to assess fat deposits in areas other than subcutaneous tissues, such as visceral fat deposits. The use of multiple sites to measure skinfolds is believed to increase the ability to predict whole body fat content. Prediction equations have been developed for 3-site to 7-site measurements. However, it is unknown whether persons with CF have similar patterns of fat distribution as healthy individuals and which skinfold equations might allow the best prediction of whole body fat content. Skinfolds have not been compared to a criterion method such as the BOD POD, whose accuracy is independent of fat location.

The use of near-infrared interactance (NIR) has become a popular way to assess body composition in settings such as health clubs or health screenings. The device requires little training to use, is portable and can give a measurement in as little as one minute. One such device, the Futrex-5000, uses a single-site measurement of tissue composition to determine whole body percent fat. However, its validity when compared to HW has been found to be problematic (20-22). McClean and Skinner (21) found that NIR was an acceptable measure of body fat in average weight persons, but was less accurate for individuals of low body fat. Broeder et al. (20) also found the NIR method to lack sensitivity to changes in body fat due to training. Rubiano et al (23) found a poor correlation between Futrex NIR and DEXA ( $r=0.77$ ) and a significant underestimation of total body fat in healthy, middle-aged subjects with a mean body fat of 35-37%. NIR would be a quick and easy method to use in the clinic, however, NIR has not been studied in persons with CF.

Since the accuracy of the BOD POD is independent of site specific fat depots, and subjective evaluations of fitness, and it is highly correlated with HW, this method was used as the criterion for determining body composition in this pilot study. Although it is currently unknown if the 2 compartment model (fat, fat-free) is appropriate for persons with CF due to potential effects of the disease on bone density, total body water and tissue density, there is a great need to compare current clinical measures to a more precise standard. Therefore, the purpose of this study was to compare skinfold, and NIR measurements of body composition to BOD POD measurements in subjects with CF and matched controls to determine whether these methods produce similar values.

## **METHODS**

### **Subjects**

Ten subjects with CF (5 male, 5 female) were recruited from the Mountain State Cystic Fibrosis Center at West Virginia University. All patients aged 14 and older with CF who were not oxygen dependent at rest were eligible to participate. Control subjects of similar age (5 males, 5 females) who were within 20% of ideal body weight were also recruited from a local college student population. Informed consent was received from all subjects prior to testing and all procedures were approved by the Institutional Review Board for the Protection of Human Subjects at West Virginia University.

### **Measurements**

All subjects reported to the Human Performance Laboratory at West Virginia University for testing. Upon arrival, height (to the nearest 1.0 cm) and weight (to the nearest 0.01 kg) were measured using standard hospital scales to allow calculation of body mass index (BMI). Subjects were weighed without shoes, dressed in swimsuits or lightweight shirts and shorts. Body fat analyses were performed in a random order during a single testing session for all subjects.

### **Body Plethresmography**

Subjects were tested using the BOD POD (Life Measurement Instruments, Concord, CA). They were instructed to wear either a swimsuit or lightweight shirt and shorts for testing. All male subjects wore lightweight swim shorts for testing and leg openings were taped to fit as snugly as possible. Female CF subjects did not feel comfortable wearing swimsuits for testing, so were tested in lightweight t-shirts and shorts. Sleeves and pant legs were taped to fit snugly. Control females were dressed similarly to CF females. All subjects wore a swim cap for the measurements in order to minimize air displacement due to hair.

After initial calibration of the scale and chamber, the subjects were weighed. Next, subjects were seated in the chamber and measurements of body volume were taken. A minimum of two tests was performed until the BOD POD's standards for consistency were achieved. The subject then placed a mouthpiece in his or her mouth and breathed normally. At a given signal directed by the investigator, the subject performed a huffing maneuver. This huffing allowed measurement of thoracic volume. Measured thoracic gas volume has been shown to have less error than predicted volumes (24). These procedures were repeated as necessary to produce results within the BOD POD's standards for consistency in lung volume and expired air velocity. Once an acceptable test was performed, body density was calculated and automatically converted to percent body fat using the Siri equation (25).

### **NIR**

Subjects were assessed standing with the dominant arm relaxed at the side. After calibration of the Futrex-5000Ai (Futrex, Inc. Gaithersburg, MD), the subject's height, weight, and body frame size were entered into the machine. Next, a correction factor based on self-reported exercise frequency, intensity and duration was entered as per the device's instructions. The optical density wand was then placed on the mid-point of the subject's biceps muscle belly and two measurements were taken, in accordance with the manufacturer's directions. Following the second measurement, the device calculated percent body fat for each subject.

### **Skinfold Measurement**

Subjects stood in a relaxed posture while seven sites for skinfold measurement were marked on the right side of their bodies. The sites were marked according to the ACSM guidelines (26) for triceps, chest, mid-axillary, subscapular, abdominal, suprailiac and thigh skinfolds. Skinfold thickness measurements were made by a single investigator using a Lange caliper (Beta Technology Incorporated, Cambridge, MD). Three measurements to the nearest 1.0 mm were taken at each site. If the measurements were not within 2 mm of each other, additional measurements were taken until all three measurements were within 2 mm of each other. The mean of the three measurements was entered in 7-site, 4-site, 3-site and 2-site equations to calculate percent body fat (see Appendix A).

### **Statistical Analyses**

Descriptive data are expressed as means  $\pm$  standard deviations. Pearson product moment correlation coefficients were obtained for percent body fat determined by each method. One-way ANOVA tests were conducted to determine significant differences between methods within groups (CF male, CF female, control male, control female). Differences in skinfold thickness at each measured site among groups were also analyzed by two-way ANOVA. Tukey post-hoc analyses was performed to locate specific mean differences. Significance was set at a level of  $p < 0.05$ .

## **RESULTS**

Subject characteristics are presented in Table 1. Male CF subjects weighed significantly less and had lower BMI than male controls. There were no significant differences between female CF subjects and control female subjects in age, height, weight, or BMI. Pulmonary function tests indicated moderate to severe obstructive lung disease in the CF subjects but disease severity did not differ between male and female CF subjects.

All subjects were able to perform BOD POD breathing techniques comfortably and consistently enough to get results in less than 3 trials. The mean percent body fat by BOD POD in each group was 19.4±4.7 in CF females, 9.7±6.1 in CF males, 14.2±3.3 in control females and 15.5±3.7 in control males.

**Table 1. Subject Characteristics.**

Group	N	Age (yr)	Height (cm)	Weight (kg)	BMI (kg/m <sup>2</sup> )	FEV1 % predicted	FVC % predicted
CF males	5	26.4±8.0	173.0±7.9	55.0±12.8	17.8±2.5	42±5.9	55±7.0
CF males	5	22.2±3.3	182.0±4.6	83.6±8.1*	24.6±1.2*	-----	-----
Control males	5	18.0±9.9	158.5±5.3	45.5±5.6	17.8±1.8	57±16.6	78±19.5
CF females	5	20.8±0.8	168.0±2.0	55.3±4.1	19.2±1.2	-----	-----

Mean±SD; \* = significantly greater than CF males (p < 0.0001)  
 FEV1%= forced expiratory volume in 1 second percentage of predicted value  
 FVC%=forced vital capacity percentage of predicted value

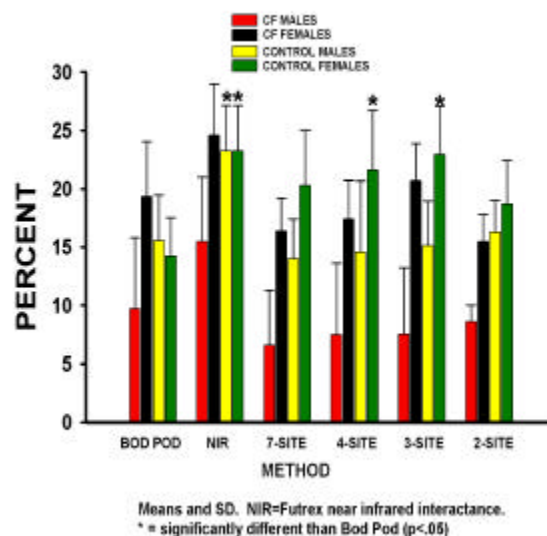
In assessing the accuracy of clinical measures compared to BOD POD in lean, young subjects, we first analyzed differences between methods in the entire group of 20 subjects. NIR was significantly different than BOD POD (p=0.003) and to overestimate body fat by 5-7%. Skinfold measurements were not found to differ from BOD POD in the combined group.

Since percent body fat should be different in males and females, the next comparison was made by gender. For control and CF males combined, NIR was different from 3-site, 4-site and 7-site skinfolds (p=0.01) and overestimated body fat by 7-8%. In the combined group of females, NIR was higher than BOD POD and 2-site skinfold (p=0.01) and overestimated body fat by 6-7%.

To examine the effect of disease on these relationships, we compared the combined CF subjects to combined control subjects. For the combined CF group, NIR gave a mean value that was 6-9% higher than BOD POD and skinfolds, but this difference was not significant due to low statistical power in this patient group. The combined control subject group's NIR values differed significantly (p=0.004) from the other methods and again overestimated body fat by 6-9%.

Analyses were then performed by gender and disease state. The results of the analysis on the four groups, CF males, CF females, control males and control females, are presented in Figure 1. In the male CF group, there was no significant difference between methods. However, the mean percent fat by NIR was 6-8% higher than by the BOD POD or skinfolds. This difference may not have reached significance due to low power (56%) and large variability in this group. There was no significant difference between percent body fat determined by any method in the female CF subjects, although body fat by NIR was 6-8% higher than the other methods. Again, variability in this subject group led to insufficient power to detect a difference (46%).

**Figure 1- Body Fat as measured by each method**



In male control subjects, NIR was significantly different than BOD POD and skinfolds ( $p=0.007$ ) and overestimated body fat by 8-9%. NIR was also found to be different than the other measures in the control females ( $p=0.007$ ) and overestimated body fat by 7-9%. Three-site and 4-site skinfolds were also higher than BOD POD in this group ( $p=0.007$ ).

In order to examine the relationship between BOD POD and the other measures Pearson product moment correlations were determined. The results are shown in Table 2.

**Table 2. Correlations Between Body Fat Percentage Determined by BOD POD and Other Methods.**

	<i>NIR</i>	<i>7-site skinfold</i>	<i>4-site skinfold</i>	<i>3-site skinfold</i>	<i>2-site skinfold</i>
<i>CF males</i>	0.44	0.95*	0.96*	0.95*	0.35
<i>Control males</i>	0.90*	0.70	0.76	0.58	0.75
<i>CF females</i>	0.48	0.75	0.77	0.79	0.89*
<i>Control females</i>	-0.33	-0.27	-0.33	-0.58	-0.47

\*= $p<0.01$ ; NIR=near infrared interactance

In the CF males, BOD POD significantly correlated to 7-site, 4-site and 3-site skinfolds. In CF females, there were no significant correlations between BOD POD and any skinfold equation. There were no significant correlations in control males between BOD POD and any skinfold equation. In control females, BOD POD significantly correlated with 2-site skinfolds ( $r=0.89$ ).

Analysis of variance on each individual skinfold site among groups revealed that CF males had significantly lower skinfolds at the biceps ( $p=0.03$ ), chest ( $p=0.002$ ), midaxillary ( $p=0.003$ ), and subscapular sites ( $p=0.005$ ) than control males. There were no significant differences in skinfold thickness at any site for the CF female subjects compared to control females (Table 3).

**Table 3. Skinfold Thicknesses (Mean $\pm$ SD).**

<i>Site Thickness (mm)</i>	<i>CF Males</i>	<i>Control Males</i>	<i>CF Females</i>	<i>Control Females</i>
<i>Biceps</i>	3.5 $\pm$ 0.8*	10.4 $\pm$ 4.8	4.7 $\pm$ 1.4	8.1 $\pm$ 4.9
<i>Abdomen</i>	11.3 $\pm$ 11.8	21.0 $\pm$ 2.0	13.2 $\pm$ 7.1	16.7 $\pm$ 7.3
<i>Triceps</i>	7.2 $\pm$ 1.6	15.0 $\pm$ 8.4	11.6 $\pm$ 3.0	16.2 $\pm$ 5.2
<i>Chest</i>	4.9 $\pm$ 3.2*	12.2 $\pm$ 3.7	5.3 $\pm$ 0	5.4 $\pm$ 8
<i>Midaxillary</i>	4.9 $\pm$ 1.4*	11.3 $\pm$ 2.4	6.6 $\pm$ 1.7	10.5 $\pm$ 4.0
<i>Subscapular</i>	7.0 $\pm$ 1.4*	14.5 $\pm$ 3.2	9.6 $\pm$ 2.6	11.8 $\pm$ 3.6
<i>Suprailiac</i>	5.3 $\pm$ 2.8	13.8 $\pm$ 10.2	8.1 $\pm$ 3.3	13.8 $\pm$ 5.9
<i>Thigh</i>	9.9 $\pm$ 6.5	15.2 $\pm$ 10.7	24.2 $\pm$ 6.0	28.0 $\pm$ 5.2

\*=significantly different from control male group ( $p<0.05$ )

## DISCUSSION

This study showed that persons with CF can comfortably complete body composition assessment in the BOD POD. This is an important finding, as the BOD POD can measure whole body fat in this population, without exposure to radiation, as in DEXA or labeled water techniques.

Body composition determined by NIR appears to overestimate body fat by 6-9% in all groups examined. McClean and Skinner (21) also found NIR to overestimate percent body fat in lean healthy individuals compared to HW. They similarly found closer agreement between skinfolds and HW than with NIR. One theory these authors cited for the large error was that use of self-reported activity level used by the NIR to determine percent body fat at a single testing session may not accurately reflect overall activity level. Broeder et al. (20) also found NIR to be unable to detect changes in body composition due to training. They found a low correlation between NIR and HW and cited as possible sources of error the need for activity reporting and the use of a single body site to predict whole body composition. The overestimation of body fat found in our study

is particularly troubling in CF subjects as it may mask malnutrition which is associated with higher mortality and morbidity.

Regarding the use of skinfold equations to predict total body fat in CF subjects, our findings indicate that their use can be supported only in male CF subjects. This finding supports other research that has used skinfold equations to monitor body fat in CF patients. De Meer et al (27) used 4-site skinfold measurement of body fat before and after an exercise program in children with CF and found this measurement to be reliable and sensitive to changes in body composition due to the exercise program. Similarly, Stettler et al (8,28) used 4-site skinfold measurements to track nutritional patterns over four years in a sample of Australian CF boys. Both groups of researchers have recommended skinfold measurement as the best clinical tool to assess body composition in CF patients. Based on our findings of significant correlations of 0.95-0.96 between 7-site, 4-site and 3-site skinfold equations and the BOD POD in male CF subjects, any of these equations could be used for clinical measurements.

There were no significant correlations found between BOD POD and skinfolds in the CF females. In addition, the correlation coefficients, even though not significant, were all negative (see Table 2). This is not easily explained, but may reflect one of three possible differences in this group. Females with CF may differ more from healthy females in their patterns of fat distribution than males with CF differ from healthy males. Some evidence for this can be seen in our study, as there was a greater discrepancy between CF females and control females in mean skinfold thicknesses at the abdominal, subscapular and suprailiac sites than in the extremity sites (see Table 3). None of these differences reached significance, probably due to larger variability in the female subjects. Perhaps the stresses of the disease cause a mobilization of the abdominal and trunk fat earlier than limb fat deposits. It is well known that women with CF die sooner than men with this disease (29). Perhaps differences in fat utilization by women account for part of this early mortality and may explain why males with CF in this study had correlations similar to healthy subjects. Finally, the effect of clothing worn by female subjects cannot be entirely discounted. Fields et al (30) found that the BOD POD's validity in measuring body composition was affected by the amount of clothing worn during the measurements. Our females with CF wore t-shirts and shorts, rather than swimsuits for the measurement, as these thin young women did not feel comfortable in revealing clothing. Our control females were dressed in similar clothing to CF females, but there may have been more trapped air in the clothing worn by the thinner CF females.

Skinfold measurements are now being used in the clinic to assess the nutritional status of females with CF. The lack of agreement we found between methods clearly indicates that further studies are warranted with larger numbers of CF females wearing tight fitting clothing or swimsuits during the BOD POD measurement, and including another criterion method such as DEXA.

### **Conclusions**

We found that CF patients could comfortably perform the breathing techniques required for the BOD POD and recommend its use for patients with CF. We cannot recommend the use of NIR in any lean subjects, with or without CF, as it systematically overestimates body fat. It appears that 3-site, 4-site or 7-site skinfold equations are all valid for estimating body composition in males with CF and may be acceptable when access to BOD POD or other whole-body measures is not possible.

Our results indicate that none of the skinfold equations agree with BOD POD in females with CF, in some cases correlating negatively. Since females with CF have a more rapid decline and earlier mortality than males (29), relying on skinfold measurements to assess nutritional status in these patients may lead to undetected malnutrition. Future studies need to be performed to determine if our findings hold true for larger groups of CF females. In addition, comparisons of skinfold measures to a different standard, such as DEXA may determine the validity of these measures in females.

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## APPENDIX A—SKINFOLD EQUATIONS USED

### Men

**7-site equation** (chest, mid-axillary, triceps, subscapular, abdomen, suprailiac, and thigh)

Body Density =  $1.112 - 0.00043499 (\text{sum of seven skinfolds}) + 0.00000055 (\text{sum of seven skinfolds})^2 - 0.00028826 (\text{age})$

**4-site equation** (abdomen, suprailiac, triceps, and thigh)

Percent Body Fat =  $0.29288 (\text{sum of four skinfolds}) - 0.0005 (\text{sum of four skinfolds})^2 + 0.15845 (\text{age}) - 5.76377$

**3-site equation** (abdomen, suprailiac, and triceps)

Percent Body Fat =  $0.39287 (\text{sum of three skinfolds}) - 0.00105 (\text{sum of three skinfolds})^2 + 0.15772 (\text{age}) - 5.18845$

**2-site equation** (triceps and subscapular)

Percent Body Fat =  $0.43 (\text{triceps}) + 0.58 (\text{subscapular}) + 1.47$

### Women

**7-site equation** (chest, mid-axillary, triceps, subscapular, abdomen, suprailiac, and thigh)

Body Density =  $1.097 - 0.00046971 (\text{sum of seven skinfolds}) + 0.00000056 (\text{sum of seven skinfolds})^2 - 0.00012828 (\text{age})$

**4-site equation** (abdomen, suprailiac, triceps, and thigh)

Percent Body Fat =  $0.29669 (\text{sum of four skinfolds}) - 0.00043 (\text{sum of four skinfolds})^2 + 0.02963 (\text{age}) + 1.4072$

**3-site equation** (triceps, suprailiac, and thigh)

Percent Body Fat =  $0.41563 (\text{sum of three skinfolds}) - 0.00112 (\text{sum of three skinfolds})^2 + 0.3661 (\text{age}) + 4.03653$

**2-site equation** (triceps and subscapular)

Percent Body Fat =  $0.55 (\text{triceps}) + 0.31 (\text{subscapular}) + 6.13$

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