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Practical Assessment of Body Composition

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In brief: The assessment of body composition has become an important method for determining a desirable body weight of adults and athletes. Hydrostatic weighing is a popular and valid method, but it is often not feasible for the clinical setting or for mass testing; thus, anthropometry has become the preferred method. This article reviews the scientific basis for generalized body composition prediction equations and provides methods for evaluating body composition. The authors recommend using a sum of three skinfolds (triceps, chest, and subscapula for men and triceps, abdomen, and suprailium for women) and give detailed instructions for securing accurate measurements of body fat.

With the growing body of literature supporting the value of regular physical activity for health and fitness, the evaluation of body composition has become an important aspect of adult fitness and medically supervised rehabilitation programs. A major goal of adult fitness and rehabilitation programs is to control body weight and fat with regular exercise and proper nutrition, so accurate measurements of body composition are needed to develop sound weight reduction and preventive health programs. Suitable body composition is important not only for health but also for athletes interested in maximizing their performance. Being overweight has been shown to be associated with medical problems such

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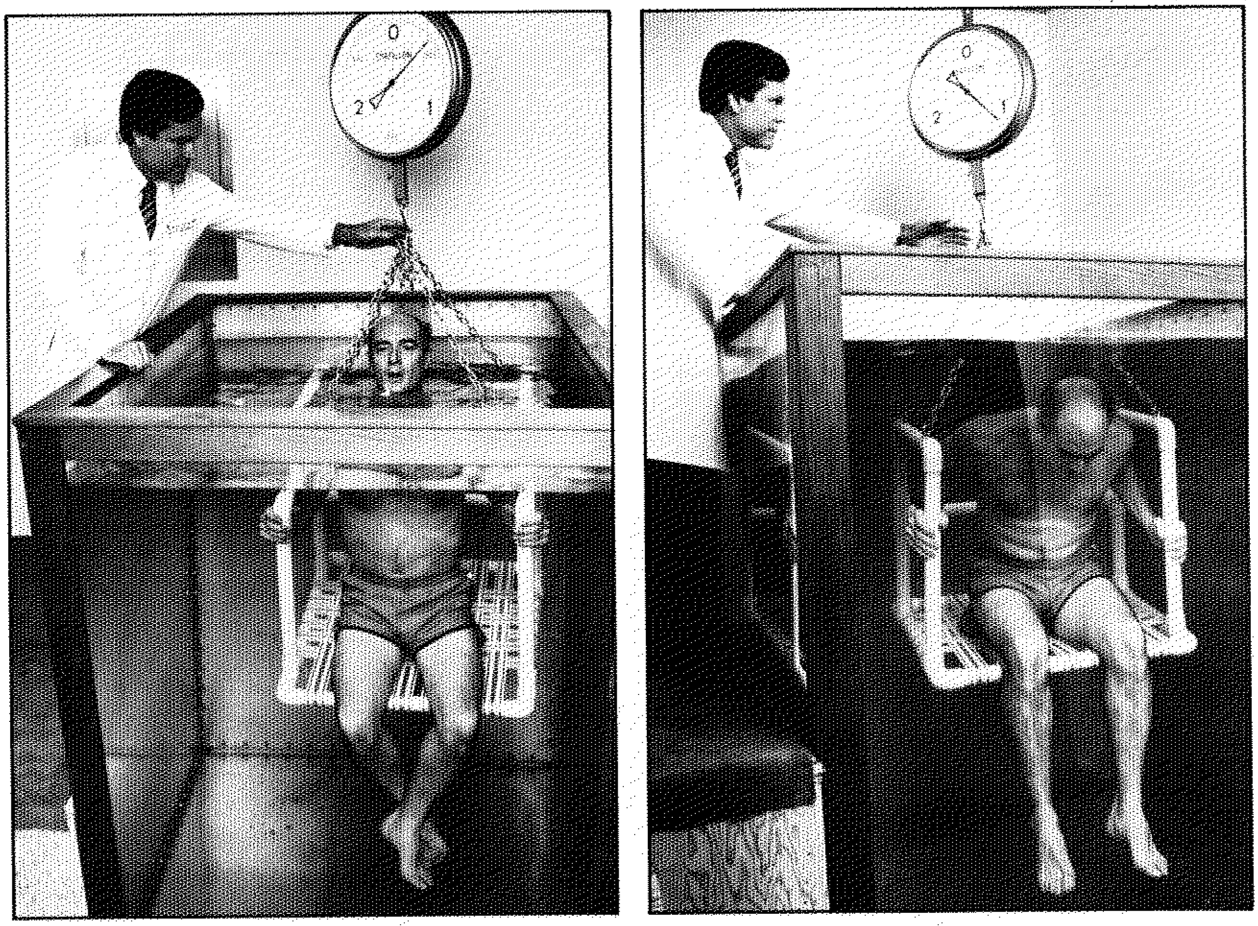

Figure 1. Dr. Pollock is shown using an underwater weighing tank to determine body composition.

Table 1. Linear Correlations Between Body Density and Anthropometric Variables for Adults

Variables	Men[7] (n = 402)	Women[8] (n = 283)
Height	−0.03	−0.06
Weight	−0.63	−0.63
Body mass index*	−0.69	−0.70
Skinfolds		
Chest	−0.85	−0.64
Axilla	−0.82	−0.73
Triceps	−0.79	−0.77
Subscapula	−0.77	−0.67
Abdomen	−0.83	−0.75
Suprailium	−0.76	−0.76
Thigh	−0.78	−0.74
Sum of seven	−0.88	−0.83
Circumferences		
Waist	−0.80	−0.71
Gluteal	−0.69	−0.74
Thigh	−0.64	−0.68
Biceps	−0.51	−0.63
Forearm	−0.35	−0.41

*wt/ht^2, where weight is in kg and height is in meters

as hypertension, diabetes mellitus, and heart disease.[1] Athletes must move their body mass quickly and efficiently in most sports. Excessive accumulation of body fat decreases jumping ability, reduces running speed, and lowers the endurance of athletes. There is a growing body of data supporting desirable body composition levels for various groups of athletes.[2]

Several methods are available for measuring body composition.[3] The methods most often used are laboratory techniques, of which hydrostatic weighing is the most popular (figure 1), and anthropometric techniques, which include height-weight indexes, skinfold fat, body circumferences, and bone diameters. The laboratory methods are accurate but expensive in terms of time, equipment, and trained technicians. For these reasons, the hydrostatic methods are usually not used in the clinical setting or for mass testing. Various height-weight ratios have been used most often to evaluate body fatness. However, research has shown that skinfold variables provide more accurate estimates of hydrostatically measured

Table 2. Descriptive Statistics and Statistical Differences for Men[7] and Women[8]

Variables	Men (n = 402) Mean	SD	Range	Women (n = 283) Mean	SD	Range	t-ratio
General characteristics							
Age (yr)	32.8	11.0	18-61	31.8	11.5	18-55	1.15
Height (cm)	179.0	6.4	163-201	168.6	5.8	152-185	21.76*
Weight (kg)	78.2	11.7	53-123	57.5	7.4	36-88	26.27*
Body mass index (wt/ht²)	24.4	3.2	17-37	20.2	2.2	14-31	19.17*
Laboratory determined							
Body density (gm/ml)	1.058	0.018	1.016-1.100	1.044	0.016	1.022-1.091	10.45*
Percent fat (%)	17.9	8.0	1-37	24.4	7.2	8-44	− 10.91*
Lean weight (kg)	63.5	7.3	47-100	43.1	4.2	30-54	42.32*
Fat weight (kg)	14.6	7.9	1-42	14.3	5.7	2-35	0.55
Skinfolds (mm)							
Chest	15.2	8.0	3-41	12.6	4.8	3-26	4.89*
Axilla	17.3	8.7	4-39	13.0	6.1	3-33	7.17*
Triceps	14.2	6.1	3-31	18.2	5.9	5-41	− 8.57*
Subscapula	16.0	7.0	5-45	14.2	6.4	5-41	1.90
Abdomen	25.1	10.8	5-56	24.2	9.6	4-36	1.12
Suprailium	16.2	8.9	3-53	14.0	7.1	3-40	3.45*
Thigh	18.9	7.7	4-48	29.5	8.0	7-53	− 17.46*
Sum of skinfolds (mm)							
All seven	122.9	52.0	31-272	125.6	42.0	35-266	− 0.72
Chest, abdomen, thigh	59.2	24.5	10-118				
Triceps, chest, subscapula	45.3	19.6	11-105				
Triceps, suprailium, thigh				61.6	19.0	16-126	
Triceps, suprailium, abdomen				56.3	21.0	13-131	

*$p < .01$.

body density than height-weight ratios.[4,5] A popular method is to use a regression equation and predict body density from various combinations of anthropometric variables. Lohman[4] discussed the practical application and accuracy of body composition prediction equations. The purpose of this paper is to present valid and practical field methods to use with adults who vary considerably in age and body fatness.

Prediction of Body Density

Many researchers have published regression equations with functions to predict hydrostatically measured body density from various combinations of anthropometric variables, and more than 100 equations appear in the literature. Early researchers developed equations for relatively homogeneous populations. In 1951 Brozek and Keys[6] published the first valid equations for young and middle-aged men. Thirty years of research on estimating body density from anthropometric variables has shown that skinfold measurements are more accurate predictors of body density than other anthropometric variables. Table 1 shows the linear correlations between body density and selected variables using data from a large sample of men[7] and women.[8] As these data show, the poorest predictors of body density are with height-weight variables. The highest correlations are between skinfolds and body density, with the sum of all seven skinfolds yielding the highest correlations. Selected body circumference measurements are substantially correlated with body density. This is especially true for gluteal and waist circumference for women and waist circumference for men.

Three major research trends have emerged in the prediction of body density from anthropometric variables. First, skinfold fat is distributed differently in men and women.[9] Table 2 gives the descriptive statistics for men[7] and women.[8] There was no sex difference for the sum of all seven skinfolds, but the skinfolds for women were larger in the limbs, while the men had more skinfold fat at the chest, axilla, and suprailium sites. These data show that to-

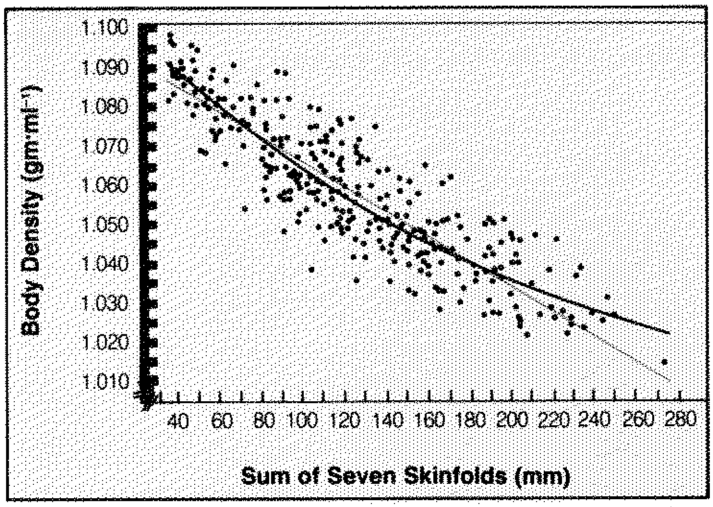

Figure 2. Bivariate distribution of hydrostatically determined body density and sum of seven skinfolds with the linear and quadratic regression lines of adult men aged 18 to 61 years. Reprinted with permission from Jackson AS, Pollock ML: Generalized equations for predicting body density of men. Br J Nutr 1978;40:497-504.

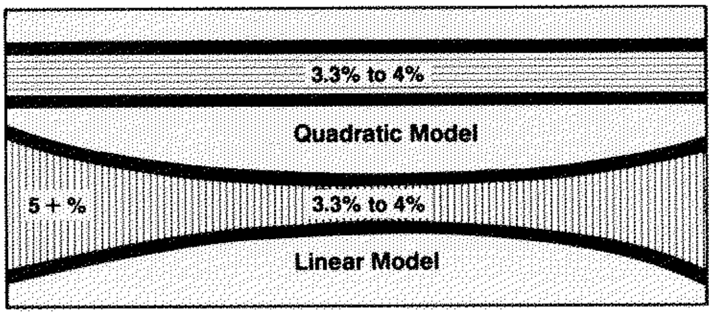

Figure 3. The figure diagrammatically illustrates the differences of the standard error of measurement for predicting percent body fat (body density) using the linear and quadratic regression models. Note that the standard errors of the mean are similar at the population means but vary significantly away from the mean for the linear model. The linear model tends to underestimate body density in lean subjects and overestimate it in fatter-than-average subjects (see figure 1). Reprinted with permission from Jackson AS, Pollock ML: Steps toward the development of generalized equations for predicting body composition of adults. Can J Appl Sports Sci 1982;7(September):187-196.

Table 3. Three Generalized Body Density Equations for Men*

Regression Equation	R	SE
$BD(M\text{-}1) = 1.11200000 - 0.00043499\,(X_1) + 0.00000055\,(X_1)^2 - 0.00028826\,(X_4)$	0.90	0.008
$BD(M\text{-}2) = 1.1093800 - 0.0008267\,(X_2) + 0.0000016\,(X_2)^2 - 0.0002574\,(X_4)$	0.91	0.008
$BD(M\text{-}3) = 1.1125025 - 0.0013125\,(X_3) + 0.0000055\,(X_3)^2 - 0.0002440\,(X_4)$	0.89	0.008

*X_1 = sum of seven skinfolds. X_2 = sum of chest, abdomen, and thigh skinfolds. X_3 = sum of chest, triceps, and subscapular skinfolds. X_4 = age in years.

tal skinfold thicknesses of men and women are similar, but individual site distributions are different. Even though the sum of seven skinfolds of men and women were nearly identical, hydrostatically determined percent body fat is substantially different and can be traced to differences in sex-specific essential fat.[5] Second, as shown in figure 2, the relationship between body density and skinfold fat is nonlinear.[7,8,10] A linear regression equation provides accurate predictions for the middle of the bivariate distribution, but the prediction errors are larger at the extremes. With a nonlinear regression model, consistent prediction accuracy is maintained through the varying range of body fatness (figure 3). Third, age has been shown to be independently related to body composition.[7,8,10] To illustrate, for a sum of seven skinfolds of 130 mm, the average body density of 20-year-old men is 1.059 gm·ml⁻¹ (17.4% fat), but for 50-year-old men it is 1.050 (21.3% fat).[7]

Body composition prediction equations are termed either population specific or generalized. Population-specific equations were developed from relatively small, homogeneous samples, and their application is limited to that subsample. The more recent approach has been to develop generalized equations that can be used with samples varying greatly in age and body fatness. The generalized equations[7,8,10] were developed on large heterogeneous samples using regression models that account for age and the nonlinear relationship between skinfold fat and body density (figure 2). The main advantage of the generalized approach is that one equation replaces several without a loss in prediction accuracy. A detailed discussion of population-specific and generalized equations can be found in other sources.[4,11]

Tables 3 and 4 show three generalized body density prediction equations.[7,8] Separate equations are provided for men and women to account for sex differences. A quadratic component is used to adjust for the nonlinearity, and age is an independent variable to account for aging. The sum of three and seven skinfolds are highly correlated ($r \geq 0.97$), which demonstrates that different combinations of the sum of skinfolds can be used with minimal loss of accuracy. The use of the sum of three instead of the sum of seven enhances feasibility. We found that adding body circumference measurement[8] to age and the quadratic form of skinfold fat produced statistically significant

Table 4. Three Generalized Body Density Equations for Women*

Regression Equation	R	SE
$BD(F\text{-}1) = 1.0970 - 0.00046971 (X_1) + 0.00000056 (X_1)^2 - 0.00012828 (X_4)$	0.85	0.008
$BD(F\text{-}2) = 1.099421 - 0.0009929 (X_2) + 0.0000023 (X_2)^2 - 0.0001392 (X_4)$	0.84	0.009
$BD(F\text{-}3) = 1.089733 - 0.0009245 (X_3) + 0.0000025 (X_3)^2 - 0.0000979 (X_4)$	0.83	0.009

*X_1 = sum of seven skinfolds. X_2 = sum of triceps, thigh, and suprailium skinfolds. X_3 = sum of triceps, suprailium, and abdominal skinfolds. X_4 = age in years.

higher multiple correlations. The increase in the multiple correlations was from 0.90 to 0.92 for men and from 8.85 to 8.87 for women.[7,8]

In our experience abdominal skinfold in men and thigh skinfold for women are difficult for some technicians to measure. Additionally, the best sum of three skinfold equations, shown as BD(M-2) and BD(F-2) in tables 3 and 4, requires the removal of clothing, which can be awkward in some testing situations. For these reasons, equations BD(M-3) and BD(F-3) (tables 3 and 4) were developed. The multiple correlations for these equations are slightly lower, but the standard errors of prediction, rounded to the nearest 0.001 $gm \cdot ml^{-1}$, are identical to the best sum of three equations.

The multiple correlations and standard errors of measurement for the generalized equations are well within the range reported for equations developed on homogeneous samples. These findings demonstrate that generalized equations can be used to replace several different population-specific equations and are valid for adults varying greatly in age and body fatness. However, an important caution should be raised when using the generalized equations: The equations were developed on men and women who ranged from 18 to 61 years of age, so the accuracy of the equations beyond this age range is not known. For this reason, the equations should be used cautiously with subjects outside this age range. For these extreme age-groups, body water and bone density vary, which could affect an equation's accuracy.[12] Another concern should be raised with extremely obese individuals. Percent body fat estimates for persons with sums of skinfold fat exceeding the ranges provided in table 2 must be interpreted with caution. Prediction errors larger than normal can be expected with this type of person; the more the sum exceeds the upper value listed in table 2, the larger prediction errors will become.

The accuracy of the generalized equations with adults similar to the descriptive statistics presented in table 2 has been cross-validated.[7,8] The accuracy of the generalized equations with unique populations (eg, professional football players) has not been adequately defined. Thorland et al[13] cross-validated the generalized equations on samples of adolescent male and female athletes and found the generalized equations could be accurately used with these populations. More cross-validation research is needed.

Suggested Methods

Just weight, age, and the sum of three skinfolds are needed to evaluate an adult's body composition. We recommend two different sums of three skinfolds for men and women. For men it is the sum of chest, abdomen, and thigh skinfolds, and for women it is the sum of triceps, suprailium, and thigh skinfolds. These two sums of three skinfolds were selected because they provided a good representation of the total body and were highly correlated with the sum of seven. The memory jogger[12,14,15] (figures 4 through 10) gives detailed instructions for measuring body fat.

We think that it is more practical to use the

memory jogger

Measuring Skinfold Fat

The accuracy of body density estimates from regression equations depends on securing accurate measures of skinfold fat. Accuracy is enhanced by using a suitable caliper and having a trained technician measure skinfold fat at the proper locations. Improper site selection is probably the most common reason for error in measuring skinfold fat.[12,14,15]

A Lange caliper (Cambridge Scientific Industries, Cambridge, Maryland) was used to measure skinfold fat of the subjects who were used to develop the generalized equations. Several companies have produced inexpensive plastic calipers that correlate highly with the more expensive caliper, but a recent study[15] showed that other calipers yielded somewhat higher readings than the Lange caliper. This suggests that the inexpensive calipers will yield somewhat lower estimates of true body fatness, but the ranking of individuals within the tested group will be consistent with the ranking using the Lange caliper. A Lange caliper will give the most accurate estimate of true body density with the generalized equations. If another caliper is used, it should be demonstrated to yield results consistent with the Lange caliper.

The skinfold sites and methods are listed below. All measurements were taken on the right side of the body. Figures 4 through 10 illustrate the measurement methods.

1. Chest: a diagonal fold taken half of the distance between the anterior axillary line and nipple for men and one third of the distance from the anterior axillary line to the nipple for women (figure 4).

2. Axilla: a vertical fold on the midaxillary line at the level of the xiphoid process of the sternum (figure 5).

continued

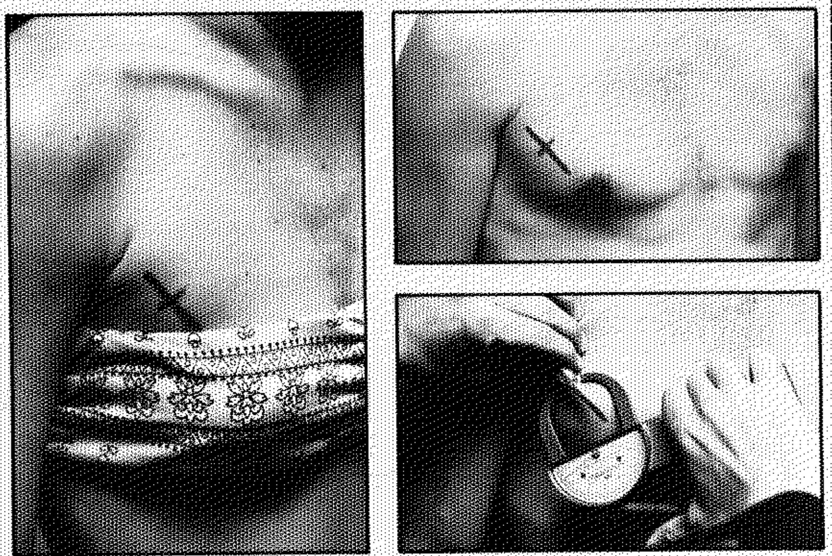

***Figure 4.** Test site for men and women and placement of calipers for chest skinfold.*

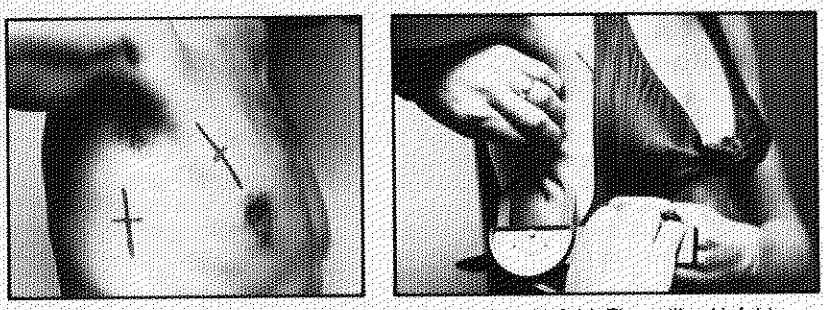

***Figure 5.** Test site and placement of calipers for axilla skinfold. The axilla skinfold site is shown in relation to the men's chest site.*

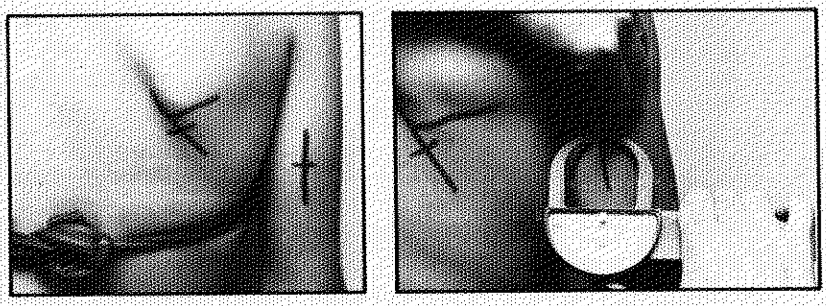

***Figure 6.** Test site and placement of calipers for triceps skinfold. The triceps skinfold site is shown in relation to the subscapular skinfold site.*

Clip and copy for a useful guide.

3. Triceps: a vertical fold on the posterior midline of the upper arm (over the triceps muscle), halfway between the acromion and olecranon processes; the elbow should be extended and relaxed (figure 6).

4. Subscapular: a fold taken on a diagonal line coming from the vertebral border to 1 to 2 cm from the inferior angle of the scapula (figure 7).

5. Abdominal: a vertical fold taken at a lateral distance of approximately 2 cm from the umbilicus (figure 8).

6. Suprailium: a diagonal fold above the crest of the ilium at the spot where an imaginary line would come down from the anterior axillary line (figure 9). Many recommend that the measure be taken more laterally at the anterior axillary line.

7. Thigh: a vertical fold on the anterior aspect of the thigh midway between hip and knee joints (figure 10).

Grasp the skinfold firmly by the thumb and index finger. The caliper is perpendicular to the fold at approximately 1 cm (1/4 in.) from the thumb and forefinger. Then release the caliper grip so that full tension is exerted on the skinfold. Use the pads at the tip of thumb and finger to grasp the skinfold. Testers may need to trim their nails. Read the dial to the nearest 0.5 mm approximately one to two seconds after the grip has been released. A minimum of two measurements should be taken at each site. If the repeated measurements vary by more than 1 mm, a third should be taken.

If consecutive fat measurements become smaller and smaller, the fat is being compressed; this occurs mainly with 'fleshy' people. The tester should go on to the next site and return to the trouble spot after finishing the other measurements; the final value will be the average of the two that seem to best represent the skinfold fat site. Typically, the tester should complete a measurement at one site before moving to another. It is better to make measurements when the skin is dry, because when the skin is moist or wet the tester may grasp extra skin (fat) and get larger values. Measurements should not be taken immediately after exercise or when a subject is overheated, because the shift of body fluid to the skin will increase skinfold size. Practice is necessary to grasp the same size of skinfold consistently at the same location every time. Consistency can be ensured by having several technicians take the same measurements and comparing results. Proficiency in measuring skinfolds may take practice sessions with up to 50 to 100 subjects.

Figure 7. *Placement of calipers for subscapular skinfold. The proper site location is shown in figure 6.*

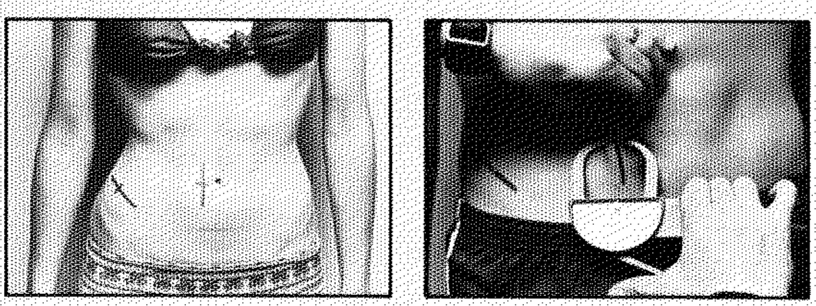

Figure 8. *Test site and placement of calipers for abdominal skinfold. The abdominal site is shown in relation to the suprailium site.*

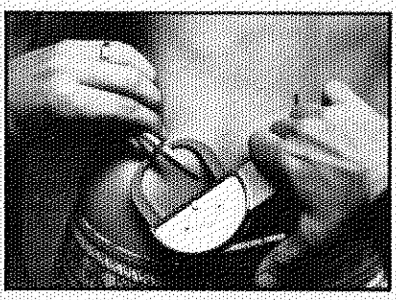

Figure 9. *Caliper placement for suprailium skinfold. The proper site location is shown in figure 8.*

Figure 10. *Caliper placement for thigh skinfold.*

Table 5. Percent Fat Estimate for Men: Sum of Chest, Abdomen, and Thigh Skinfolds

Sum of Skinfolds (mm)	Age to Last Year: Under 22	23-27	28-32	33-37	38-42	43-47	48-52	53-57	Over 57
8-10	1.3	1.8	2.3	2.9	3.4	3.9	4.5	5.0	5.5
11-13	2.2	2.8	3.3	3.9	4.4	4.9	5.5	6.0	6.5
14-16	3.2	3.8	4.3	4.8	5.4	5.9	6.4	7.0	7.5
17-19	4.2	4.7	5.3	5.8	6.3	6.9	7.4	8.0	8.5
20-22	5.1	5.7	6.2	6.8	7.3	7.9	8.4	8.9	9.5
23-25	6.1	6.6	7.2	7.7	8.3	8.8	9.4	9.9	10.5
26-28	7.0	7.6	8.1	8.7	9.2	9.8	10.3	10.9	11.4
29-31	8.0	8.5	9.1	9.6	10.2	10.7	11.3	11.8	12.4
32-34	8.9	9.4	10.0	10.5	11.1	11.6	12.2	12.8	13.3
35-37	9.8	10.4	10.9	11.5	12.0	12.6	13.1	13.7	14.3
38-40	10.7	11.3	11.8	12.4	12.9	13.5	14.1	14.6	15.2
41-43	11.6	12.2	12.7	13.3	13.8	14.4	15.0	15.5	16.1
44-46	12.5	13.1	13.6	14.2	14.7	15.3	15.9	16.4	17.0
47-49	13.4	13.9	14.5	15.1	15.6	16.2	16.8	17.3	17.9
50-52	14.3	14.8	15.4	15.9	16.5	17.1	17.6	18.2	18.8
53-55	15.1	15.7	16.2	16.8	17.4	17.9	18.5	19.1	19.7
56-58	16.0	16.5	17.1	17.7	18.2	18.8	19.4	20.0	20.5
59-61	16.9	17.4	17.9	18.5	19.1	19.7	20.2	20.8	21.4
62-64	17.6	18.2	18.8	19.4	19.9	20.5	21.1	21.7	22.2
65-67	18.5	19.0	19.6	20.2	20.8	21.3	21.9	22.5	23.1
68-70	19.3	19.9	20.4	21.0	21.6	22.2	22.7	23.3	23.9
71-73	20.1	20.7	21.2	21.8	22.4	23.0	23.6	24.1	24.7
74-76	20.9	21.5	22.0	22.6	23.2	23.8	24.4	25.0	25.5
77-79	21.7	22.2	22.8	23.4	24.0	24.6	25.2	25.8	26.3
80-82	22.4	23.0	23.6	24.2	24.8	25.4	25.9	26.5	27.1
83-85	23.2	23.8	24.4	25.0	25.5	26.1	26.7	27.3	27.9
86-88	24.0	24.5	25.1	25.7	26.3	26.9	27.5	28.1	28.7
89-91	24.7	25.3	25.9	26.5	27.1	27.6	28.2	28.8	29.4
92-94	25.4	26.0	26.6	27.2	27.8	28.4	29.0	29.6	30.2
92-97	26.1	26.7	27.3	27.9	28.5	29.1	29.7	30.3	30.9
98-100	26.9	27.4	28.0	28.6	29.2	29.8	30.4	31.0	31.6
101-103	27.5	28.1	28.7	29.3	29.9	30.5	31.1	31.7	32.3
104-106	28.2	28.8	29.4	30.0	30.6	31.2	31.8	32.4	33.0
107-109	28.9	29.5	30.1	30.7	31.3	31.9	32.5	33.1	33.7
110-112	29.6	30.2	30.8	31.4	32.0	32.6	33.2	33.8	34.4
113-115	30.2	30.8	31.4	32.0	32.6	33.2	33.8	34.5	35.1
116-118	30.9	31.5	32.1	32.7	33.3	33.9	34.5	35.1	35.7
119-121	31.5	32.1	32.7	33.3	33.9	34.5	35.1	35.7	36.4
122-124	32.1	32.7	33.3	33.9	34.5	35.1	35.8	36.4	37.0
125-127	32.7	33.3	33.9	34.5	35.1	35.8	36.4	37.0	37.6

sum of triceps, chest, and subscapula for men and triceps, abdomen, and suprailium for women. The accuracy of the two sums of three skinfolds is similar, which provides the option of using either combination. All equations are provided in tables 3 and 4. Tables 5 through 8 are provided to expedite the calculation of percent body fat from the sum of three skinfolds and age. The tables were computer-generated using the regression equations, and body density was transformed to percent body fat using the Siri formula.[16] Similar equations and tables using different combinations of skinfolds may be found in the revision of *The Y's Way to Physical Fitness.*[17]

If computer facilities are available, the body

Table 5. Percent Fat Estimate for Men: Sum of Chest, Abdomen, and Thigh Skinfolds

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11-13	2.2	2.8	3.3	3.9	4.4	4.9	5.5	6.0	6.5
14-16	3.2	3.8	4.3	4.8	5.4	5.9	6.4	7.0	7.5
17-19	4.2	4.7	5.3	5.8	6.3	6.9	7.4	8.0	8.5
20-22	5.1	5.7	6.2	6.8	7.3	7.9	8.4	8.9	9.5
23-25	6.1	6.6	7.2	7.7	8.3	8.8	9.4	9.9	10.5
26-28	7.0	7.6	8.1	8.7	9.2	9.8	10.3	10.9	11.4
29-31	8.0	8.5	9.1	9.6	10.2	10.7	11.3	11.8	12.4
32-34	8.9	9.4	10.0	10.5	11.1	11.6	12.2	12.8	13.3
35-37	9.8	10.4	10.9	11.5	12.0	12.6	13.1	13.7	14.3
38-40	10.7	11.3	11.8	12.4	12.9	13.5	14.1	14.6	15.2
41-43	11.6	12.2	12.7	13.3	13.8	14.4	15.0	15.5	16.1
44-46	12.5	13.1	13.6	14.2	14.7	15.3	15.9	16.4	17.0
47-49	13.4	13.9	14.5	15.1	15.6	16.2	16.8	17.3	17.9
50-52	14.3	14.8	15.4	15.9	16.5	17.1	17.6	18.2	18.8
53-55	15.1	15.7	16.2	16.8	17.4	17.9	18.5	19.1	19.7
56-58	16.0	16.5	17.1	17.7	18.2	18.8	19.4	20.0	20.5
59-61	16.9	17.4	17.9	18.5	19.1	19.7	20.2	20.8	21.4
62-64	17.6	18.2	18.8	19.4	19.9	20.5	21.1	21.7	22.2
65-67	18.5	19.0	19.6	20.2	20.8	21.3	21.9	22.5	23.1
68-70	19.3	19.9	20.4	21.0	21.6	22.2	22.7	23.3	23.9
71-73	20.1	20.7	21.2	21.8	22.4	23.0	23.6	24.1	24.7
74-76	20.9	21.5	22.0	22.6	23.2	23.8	24.4	25.0	25.5
77-79	21.7	22.2	22.8	23.4	24.0	24.6	25.2	25.8	26.3
80-82	22.4	23.0	23.6	24.2	24.8	25.4	25.9	26.5	27.1
83-85	23.2	23.8	24.4	25.0	25.5	26.1	26.7	27.3	27.9
86-88	24.0	24.5	25.1	25.7	26.3	26.9	27.5	28.1	28.7
89-91	24.7	25.3	25.9	26.5	27.1	27.6	28.2	28.8	29.4
92-94	25.4	26.0	26.6	27.2	27.8	28.4	29.0	29.6	30.2
92-97	26.1	26.7	27.3	27.9	28.5	29.1	29.7	30.3	30.9
98-100	26.9	27.4	28.0	28.6	29.2	29.8	30.4	31.0	31.6
101-103	27.5	28.1	28.7	29.3	29.9	30.5	31.1	31.7	32.3
104-106	28.2	28.8	29.4	30.0	30.6	31.2	31.8	32.4	33.0
107-109	28.9	29.5	30.1	30.7	31.3	31.9	32.5	33.1	33.7
110-112	29.6	30.2	30.8	31.4	32.0	32.6	33.2	33.8	34.4
113-115	30.2	30.8	31.4	32.0	32.6	33.2	33.8	34.5	35.1
116-118	30.9	31.5	32.1	32.7	33.3	33.9	34.5	35.1	35.7
119-121	31.5	32.1	32.7	33.3	33.9	34.5	35.1	35.7	36.4
122-124	32.1	32.7	33.3	33.9	34.5	35.1	35.8	36.4	37.0
125-127	32.7	33.3	33.9	34.5	35.1	35.8	36.4	37.0	37.6

sum of triceps, chest, and subscapula for men and triceps, abdomen, and suprailium for women. The accuracy of the two sums of three skinfolds is similar, which provides the option of using either combination. All equations are provided in tables 3 and 4. Tables 5 through 8 are provided to expedite the calculation of percent body fat from the sum of three skinfolds and age. The tables were computer-generated using the regression equations, and body density was transformed to percent body fat using the Siri formula.[16] Similar equations and tables using different combinations of skinfolds may be found in the revision of *The Y's Way to Physical Fitness*.[17]

If computer facilities are available, the body

Table 6. Percent Fat Estimate for Women: Sum of Triceps, Suprailium, and Thigh Skinfolds

	Age to Last Year								
Sum of Skinfolds (mm)	Under 22	23-27	28-32	33-37	38-42	43-47	48-52	53-57	Over 57
23-25	9.7	9.9	10.2	10.4	10.7	10.9	11.2	11.4	11.7
26-28	11.0	11.2	11.5	11.7	12.0	12.3	12.5	12.7	13.0
29-31	12.3	12.5	12.8	13.0	13.3	13.5	13.8	14.0	14.3
32-34	13.6	13.8	14.0	14.3	14.5	14.8	15.0	15.3	15.5
35-37	14.8	15.0	15.3	15.5	15.8	16.0	16.3	16.5	16.8
38-40	16.0	16.3	16.5	16.7	17.0	17.2	17.5	17.7	18.0
41-43	17.2	17.4	17.7	17.9	18.2	18.4	18.7	18.9	19.2
44-46	18.3	18.6	18.8	19.1	19.3	19.6	19.8	20.1	20.3
47-49	19.5	19.7	20.0	20.2	20.5	20.7	21.0	21.2	21.5
50-52	20.6	20.8	21.1	21.3	21.6	21.8	22.1	22.3	22.6
53-55	21.7	21.9	22.1	22.4	22.6	22.9	23.1	23.4	23.6
56-58	22.7	23.0	23.2	23.4	23.7	23.9	24.2	24.4	24.7
59-61	23.7	24.0	24.2	24.5	24.7	25.0	25.2	25.5	25.7
62-64	24.7	25.0	25.2	25.5	25.7	26.0	26.7	26.4	26.7
65-67	25.7	25.9	26.2	26.4	26.7	26.9	27.2	27.4	27.7
68-70	26.6	26.9	27.1	27.4	27.6	27.9	28.1	28.4	28.6
71-73	27.5	27.8	28.0	28.3	28.5	28.8	29.0	29.3	29.5
74-76	28.4	28.7	28.9	29.2	29.4	29.7	29.9	30.2	30.4
77-79	29.3	29.5	29.8	30.0	30.3	30.5	30.8	31.0	31.3
80-82	30.1	30.4	30.6	30.9	31.1	31.4	31.6	31.9	32.1
83-85	30.9	31.2	31.4	31.7	31.9	32.2	32.4	32.7	32.9
86-88	31.7	32.0	32.2	32.5	32.7	32.9	33.2	33.4	33.7
89-91	32.5	32.7	33.0	33.2	33.5	33.7	33.9	34.2	34.4
92-94	33.2	33.4	33.7	33.9	34.2	34.4	34.7	34.9	35.2
95-97	33.9	34.1	34.4	34.6	34.9	35.1	35.4	35.6	35.9
98-100	34.6	34.8	35.1	35.3	35.5	35.8	36.0	36.3	36.5
101-103	35.3	35.4	35.7	35.9	36.2	36.4	36.7	36.9	37.2
104-106	35.8	36.1	36.3	36.6	36.8	37.1	37.3	37.5	37.8
107-109	36.4	36.7	36.9	37.1	37.4	37.6	37.9	38.1	38.4
110-112	37.0	37.2	37.5	37.7	38.0	38.2	38.5	38.7	38.9
113-115	37.5	37.8	38.0	38.2	38.5	38.7	39.0	39.2	39.5
116-118	38.0	38.3	38.5	38.8	39.0	39.3	39.5	39.7	40.0
119-121	38.5	38.7	39.0	39.2	39.5	39.7	40.0	40.2	40.5
122-124	39.0	39.2	39.4	39.7	39.9	40.2	40.4	40.7	40.9
125-127	39.4	39.6	39.9	40.1	40.4	40.6	40.9	41.1	41.4
128-130	39.8	40.0	40.3	40.5	40.8	41.0	41.3	41.5	41.8

composition values can be easily calculated. An example of a simple program using the transformation capabilities of a standard statistical package (Statistical Package of Social Sciences) is shown in another source.[18] A second method is with microcomputers. Using the equations provided in tables 4 and 5, we have developed a program[19] for the Apple microcomputer.

Calculation of Desirable Weight

What is a desirable level of body fatness? This is difficult to determine with certainty, but normative data have provided some guidelines. Although some have suggested more stringent guidelines for general health, Lohman[4] considered that levels of 10% to 22% fat content in men and 20% to 32% fat content in women were suitable. Whatever the stan-

Table 7. Percent Fat Estimate for Men: Sum of Triceps, Chest, and Subscapula Skinfolds

	Age to Last Year								
Sum of Skinfolds (mm)	Under 22	23-27	28-32	33-37	38-42	43-47	48-52	53-57	Over 57
8-10	1.5	2.0	2.5	3.1	3.6	4.1	4.6	5.1	5.6
11-13	3.0	3.5	4.0	4.5	5.1	5.6	6.1	6.6	7.1
14-16	4.5	5.0	5.5	6.0	6.5	7.0	7.6	8.1	8.6
17-19	5.9	6.4	6.9	7.4	8.0	8.5	9.0	9.5	10.0
20-22	7.3	7.8	8.3	8.8	9.4	9.9	10.4	10.9	11.4
23-25	8.6	9.2	9.7	10.2	10.7	11.2	11.8	12.3	12.8
26-28	10.0	10.5	11.0	11.5	12.1	12.6	13.1	13.6	14.2
29-31	11.2	11.8	12.3	12.8	13.4	13.9	14.4	14.9	15.5
32-34	12.5	13.0	13.5	14.1	14.6	15.1	15.7	16.2	16.7
35-37	13.7	14.2	14.8	15.3	15.8	16.4	16.9	17.4	18.0
38-40	14.9	15.4	15.9	16.5	17.0	17.6	18.1	18.6	19.2
41-43	16.0	16.6	17.1	17.6	18.2	18.7	19.3	19.8	20.3
44-46	17.1	17.7	18.2	18.7	19.3	19.8	20.4	20.9	21.5
47-49	18.2	18.7	19.3	19.8	20.4	20.9	21.4	22.0	22.5
50-52	19.2	19.7	20.3	20.8	21.4	21.9	22.5	23.0	23.6
53-55	20.2	20.7	21.3	21.8	22.4	22.9	23.5	24.0	24.6
56-58	21.1	21.7	22.2	22.8	23.3	23.9	24.4	25.0	25.5
59-61	22.0	22.6	23.1	23.7	24.2	24.8	25.3	25.9	26.5
62-64	22.9	23.4	24.0	24.5	25.1	25.7	26.2	26.8	27.3
65-67	23.7	24.3	24.8	25.4	25.9	26.5	27.1	27.6	28.2
68-70	24.5	25.0	25.6	26.2	26.7	27.3	27.8	28.4	29.0
71-73	25.2	25.8	26.3	26.9	27.5	28.0	28.6	29.1	29.7
74-76	25.9	26.5	27.0	27.6	28.2	28.7	29.3	29.9	30.4
77-79	26.6	27.1	27.7	28.2	28.8	29.4	29.9	30.5	31.1
80-82	27.2	27.7	28.3	28.9	29.4	30.0	30.6	31.1	31.7
83-85	27.7	28.3	28.8	29.4	30.0	30.5	31.1	31.7	32.3
86-88	28.2	28.8	29.4	29.9	30.5	31.1	31.6	32.2	32.8
89-91	28.7	29.3	29.8	30.4	31.0	31.5	32.1	32.7	33.3
92-94	29.1	29.7	30.3	30.8	31.4	32.0	32.6	33.1	33.4
95-97	29.5	30.1	30.6	31.2	31.8	32.4	32.9	33.5	34.1
98-100	29.8	30.4	31.0	31.6	32.1	32.7	33.3	33.9	34.4
101-103	30.1	30.7	31.3	31.8	32.4	33.0	33.6	34.1	34.7
104-106	30.4	30.9	31.5	32.1	32.7	33.2	33.8	34.4	35.0
107-109	30.6	31.1	31.7	32.3	32.9	33.4	34.0	34.6	35.2
110-112	30.7	31.3	31.9	32.4	33.0	33.6	34.2	34.7	35.3
113-115	30.8	31.4	32.0	32.5	33.1	33.7	34.3	34.9	35.4
116-118	30.9	31.5	32.0	32.6	33.2	33.8	34.3	34.9	35.5

dard used, recent data from the Framingham heart study[1] show that increased weight after age 25 years increased the risk of coronary heart disease for both men and women. Losing excess weight reduced risk. The body fat values for average adults would be too high for athletes. Wilmore[2] has published a comprehensive summary of data of athletes. The average levels are about 12% for men and 18% for women. For events that emphasize efficient body movement (distance running, football, gymnastics, etc), the body fat levels tend to range from 4% to 10% for men and 13% to 18% for women. These ranges can be used as guidelines, and people doing extensive work with athletes should examine the data summarized by Wilmore.[2] More research is needed to accurately determine desirable body fat val-

Table 8. Percent Fat Estimate for Women: Sum of Triceps, Abdomen, and Suprailium Skinfolds

Sum of Skinfolds (mm)	Age to Last Year 18-22	23-27	28-32	33-37	38-42	43-47	48-52	53-57	Over 57
8-12	8.8	9.0	9.2	9.4	9.5	9.7	9.9	10.1	10.3
13-17	10.8	10.9	11.1	11.3	11.5	11.7	11.8	12.0	12.2
18-22	12.6	12.8	13.0	13.2	13.4	13.5	13.7	13.9	14.1
23-27	14.5	14.6	14.8	15.0	15.2	15.4	15.6	15.7	15.9
28-32	16.2	16.4	16.6	16.8	17.0	17.1	17.3	17.5	17.7
33-37	17.9	18.1	18.3	18.5	18.7	18.9	19.0	19.2	19.4
38-42	19.6	19.8	20.0	20.2	20.3	20.5	20.7	20.9	21.1
43-47	21.2	21.4	21.6	21.8	21.9	22.1	22.3	22.5	22.7
48-52	22.8	22.9	23.1	23.3	23.5	23.7	23.8	24.0	24.2
53-57	24.2	24.4	24.6	24.8	25.0	25.2	25.3	25.5	25.7
58-62	25.7	25.9	26.0	26.2	26.4	26.6	26.8	27.0	27.1
63-67	27.1	27.2	27.4	27.6	27.8	28.0	28.2	28.3	28.5
68-72	28.4	28.6	28.7	28.9	29.1	29.3	29.5	29.7	29.8
73-77	29.6	29.8	30.0	30.2	30.4	30.6	30.7	30.9	31.1
78-82	30.9	31.0	31.2	31.4	31.6	31.8	31.9	32.1	32.3
83-87	32.0	32.2	32.4	32.6	32.7	32.9	33.1	33.3	33.5
88-92	33.1	33.3	33.5	33.7	33.8	34.0	34.2	34.4	34.6
93-97	34.1	34.3	34.5	34.7	34.9	35.1	35.2	35.4	35.6
98-102	35.1	35.3	35.5	35.7	35.9	36.0	36.2	36.4	36.6
103-107	36.1	36.2	36.4	36.6	36.8	37.0	37.2	37.3	37.5
108-112	36.9	37.1	37.3	37.5	37.7	37.9	38.0	38.2	38.4
113-117	37.8	37.9	38.1	38.3	39.2	39.4	39.6	39.8	39.2
118-122	38.5	38.7	38.9	39.1	39.4	39.6	39.8	40.0	40.0
123-127	39.2	39.4	39.6	39.8	40.0	40.1	40.3	40.5	40.7
128-132	39.9	40.1	40.2	40.4	40.6	40.8	41.0	41.2	41.3
133-137	40.5	40.7	40.8	41.0	41.2	41.4	41.6	41.7	41.9
138-142	41.0	41.2	41.4	41.6	41.7	41.9	42.1	42.3	42.5
143-147	41.5	41.7	41.9	42.0	42.2	42.4	42.6	42.8	43.0
148-152	41.9	42.1	42.3	42.8	42.6	42.8	43.0	43.2	43.4
153-157	42.3	42.5	42.6	42.8	43.0	43.2	43.4	43.6	43.7
158-162	42.6	42.8	43.0	43.1	43.3	43.5	43.7	43.9	44.1
163-167	42.9	43.0	43.2	43.4	43.6	43.8	44.0	44.1	44.3
168-172	43.1	43.2	43.4	43.6	43.8	44.0	44.2	44.3	44.5
173-177	43.2	43.4	43.6	43.8	43.9	44.1	44.3	44.5	44.7
178-182	43.3	43.5	43.7	43.8	44.0	44.2	44.4	44.6	44.8

ues for proper health and optimal athletic performance.

Once percent fat is known, the weight of an individual for desired percent body fat level can be calculated. This can help an individual establish a weight reduction goal or a suitable competitive weight. Desired weight is calculated by: [weight x (% fat/100)]/1 − X, where X is the desired percent body fat level in decimal form. We recommend using a range of desirable weights to account for the measurement error associated with estimating body

$$\text{Desired Weight} = \frac{\text{Weight}-[\text{weight} \times (\%\ \text{fat}/100)]}{1-x}$$

For example the calculations for a desired weight for 15% and 20% fat are:

$$\text{DW } 15\% = \frac{200 \times [200 - (28/100)]}{1-.15}$$

$$\text{DW } 20\% = \frac{200 \times [200 - (28/100)]}{1-.20}$$

Figure 11. Formula and examples of determining desirable weight.

density. For adult fitness, we recommend that 15% to 20% for men and 22% to 28% for women be used for weight reduction goals. To illustrate, assume a 200-lb man was found to be 28% fat. The desired weight range (15% to 20%) would be 169 to 180 lb (figure 11). For use with athletes, lower desired percent body fat levels would be used and the levels would depend on an athlete's sex and event.

Conclusion

Body composition evaluation by the skinfold method described in this paper is valid and feasible for mass testing. The skinfold method is not as accurate as the laboratory method of hydrostatic weighing but considerably more accurate than the traditional method of using height and weight. The multiple regression equations used to predict body density from the quadratic function of the sum of skinfold fat and age provide accurate estimates of body density that can be used for a varied population. The provided tables and use of microcomputers simplify the calculations and enhance the feasibility of evaluating body composition in the field setting.

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References

1. Hubert HB, Feinleib M, McNamara PM, et al: Obesity as an independent risk factor for cardiovascular disease: a 26-year follow-up of participants in the Framingham heart study. Circulation 1983;67(May):968-977
2. Wilmore JH: Training for Sport and Activity: The Physiological Basis of the Conditioning Process, ed 2. Boston, Allyn and Bacon, 1982
3. Behnke AR, Wilmore JH: Evaluation and Regulation of Body Build and Composition. Englewood Cliffs, NJ, Prentice-Hall, 1974
4. Lohman TG: Body composition methodology in sports medicine. Phys Sportsmed 1982;10(December):46-58
5. Pollock ML, Schmidt DH, Jackson AS: Measurement of cardiorespiratory fitness and body composition in the clinical setting. Com Ther 1080;6(September):12-27
6. Brozek J, Keys A: The evaluation of leanness-fatness in man: norms and intercorrelations. Br J Nutr 1951; 5:194-205
7. Jackson AS, Pollock ML: Generalized equations for predicting body density of men. Br J Nutr 1978; 40(November):497-504
8. Jackson AS, Pollock ML, Ward A: Generalized equations for predicting body density of women. Med Sci Sports Exerc 1980;12(3):175-182
9. Edwards DAW: Differences in the distributions of subcutaneous fat with sex and maturity. Clin Sci 1951;10:305-315
10. Durnin JV, Womersley J: Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged 16 to 72 years. Br J Nutr 1974;32(July):77-97
11. Jackson AS, Pollock ML: Steps toward the development of generalized equations for predicting body composition of adults. Can J Appl Sports Sci 1982; 7(September):187-196
12. Lohman TG: Skinfolds and body density and their relation to body fatness: a review. Hum Biol 1981; 53(May):181-225
13. Thorland WG, Johnson GO, Tharp GD, et al: Validity of anthropometric equations for the estimation of body density in adolescent athletes. Med Sci Sports Exerc 1984;16(1):77-81
14. Lohman TG, Pollock ML: Which caliper? How much training? JOPER 1981;52(January):27-29
15. Lohman TG, Pollock ML, Slaughter MH, et al: Methodological factors and the prediction of body fat in female athletes. Med Sci Sports Exerc 1984;16(1):92-96
16. Siri WE: Body Composition From Fluid Spaces and Density: Analysis of Methods in Techniques for Measuring Body Composition. Washington, DC, National Academy of Science, National Research Council, 1961, pp 223-244
17. Golding LA, Meyers CR, Sinning WE: The Y's Way to Physical Fitness, revised. Chicago, National Board of YMCA, 1982
18. Baumgartner TA, Jackson AS: Measurement for Evaluation in Physical Education, ed 2. Dubuque, IA, Wm D Brown Co, 1982, pp 298-299
19. Wendt J, Morrow J, Jackson AS: Program for calculating body composition values from Jackson-Pollock generalized equations. Program for Apple microcomputer. Houston, University of Houston, October 1983