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Effects of Skin Thickness and Skinfold Compressibility on Skinfold Thickness Measurement

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ABSTRACT Variability in both skin thickness and skinfold compressibility affects the relationship between the skinfold caliper reading at a particular site on the body and the actual adipose thickness at that site, thus inducing error in the estimation of body fatness. To investigate this variability, skinfold thickness by caliper and incised depth of subcutaneous adipose tissue were measured at 13 skinfold sites in 6 male and 7 female unembalmed cadavers aged 55 to 94 years. All skin was then removed and its thickness measured at the exact sites of skinfold measurement. The regional patterns for skin thickness were similar in men and women, though women had significantly ($P < .05$) thinner skin than men at the biceps, chest, supraspinale, and abdominal sites. Mean (SD) skin thickness for each cadaver over all sites ranged from 0.76 mm (0.28 mm) to 1.47 mm (0.43 mm), with an overall mean for men of 1.22 mm (0.36 mm) and for women of 0.98 mm (0.36 mm). The thickness of a double layer of skin expressed as a percentage of skinfold thickness for all cadavers over all 13 sites ranged from 7.1% to 33.4%. Because of their leanness and thicker skin, the mean for men, 22.7% (10.1%), was significantly greater than that for women, 10.8% (6.2%) ($P < .0001$). Mean skinfold compressibility over all sites was 53.5% (16.4%) in men and 51.9% (16.5%) in women (not significant). Such marked variability in skinfold compressibility and in the relative contribution of skin thickness to skinfold thickness suggests the need for caution in comparing estimates of fatness by skinfold caliper between different subjects.

The use of skinfold calipers to predict body fat is widespread (Lohman, 1981), though the limitations of the technique are not well understood. Many assumptions underlie the estimation of the percentage of fat in the body (%fat) by skinfold caliper. These include 1) choice of the number and location of skinfold sites, 2) the relationship between internal and subcutaneous adipose tissue masses, 3)assumptions in calibrating the technique against densitometry, and 4) variability in the fraction of fat in adipose tissue (Martin et al., 1985). Before these issues are resolved, there is a more fundamental question concerning the use of skinfold calipers: do they accurately measure subcutaneous adipose tissue thickness at the selected site? The two important factors affecting this accuracy are the contribution of skin thickness to skinfold thickness, and the amount and variability of the compressibility of the skinfold. We report the variability in skin thickness and skinfold compressibility in 13 unembalmed cadavers dissected as part of the Brussels Cadaver Study.

MATERIALS AND METHODS

As part of a comprehensive cadaver study of body composition, 13 unembalmed cadavers ages 55 to 94 years (6 male and 7 female)

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were subjected to extensive anthropometry prior to complete separation by dissection of adipose tissue, muscle, bone, and organs. No cadavers showing emaciation or signs of compositional changes due to chronic illness were selected. Skinfold thicknesses were measured with a Harpenden caliper at 13 common skinfold sites: triceps (TR), biceps (BI), forearm (FO) (on the anterior surface at maximum girth), subscapular (SS), chest (C) (on the anterior axillary line at the level of the xiphoid process), waist (W) (on the anterior axillary line at the level of the waist narrowing), supraspinale (S) (5–7 cm above ilio-spinale on a line to the acromiale), abdominal (A) (2 cm below and lateral to the umbilicus), front thigh (FT) (on the anterior surface midway between the inguinal fold and the mid-patella), medial thigh (MT), rear thigh (RT), patella (P) (2 cm above the superior edge of the patella), and the medial calf (MC) (at maximum girth). After skinfold caliper readings were taken, incisions were made at all sites, using a scalpel, to the depth of the muscle fascia. A small metal rule was inserted into the incision and the thickness of the adipose tissue plus skin layer was measured with a precision of 0.5 mm.

The cadavers were then dissected and all skin was completely removed in a number of pieces. Any adipose tissue adhering to the skin was removed by gentle scraping. It was possible to locate all skinfold sites precisely because of the incisions that had been made. Skin thickness at each site was measured by folding the skin in two at the incision and applying Harpenden skinfold calipers to the double layer. Skin thickness at each site was taken as the mean of five measurements, measured to a precision of 0.05 mm. Skinfold compressibility (%) was defined as

$$\frac{100\,(\text{incised depth} - \frac{1}{2}\,\text{caliper reading})}{\text{incised depth}},$$

such that application of the skinfold caliper causing no compression of the tissue gives a value of zero.

Data analysis consisted of descriptive and inferential statistics; tests for sex differences were conducted utilizing independent *t*-tests (two-tailed). Pearson's product-moment correlation coefficient was used to assess the association between percentage skinfold compressibility and percentage adipose tissue. Statistical significance was set at the .05 level of probability.

RESULTS

Descriptive data for each cadaver and the entire sample have been reported previously (Clarys et al., 1984), and a separate study demonstrated that the anthropometric dimensions of the cadavers did not differ significantly from those taken on a group of living Belgians of similar mean age (Mertens, 1981). Skin thicknesses at the 13 right side sites for each subject are shown in Table 1. Skin thickness for each subject, averaged over all sites, ranged from a mean (±SD) of 0.76 mm (±0.28 mm) to 1.47 mm (±0.43 mm) with an overall mean of 1.09 mm (±0.46 mm). For the entire sample, the site with the thinnest skin was the biceps, 0.62 mm (±0.21 mm) and the thickest was the subscapular, 1.88 mm (±0.38 mm). Although women had thinner skin than men at all sites, the differences were significant only at the biceps ($P < .02$), chest ($P < .002$), supraspinale ($P < .05$), and abdominal ($P < .02$) sites; trends to thinner skin in women were observed at the forearm and wrist sites ($P < .10$). Mean skin thickness for all women over all sites was 0.98 mm (±0.36 mm) compared to 1.22 mm (±0.36 mm) for the men, but this difference was of borderline significance ($P = .06$). The regional pattern for skin thickness was similar in men and women (Fig. 1).

The contribution of skin thickness to skinfold thickness was evaluated by expressing the thickness of a double layer of skin as a percentage of the skinfold thickness at the corresponding site (Table 2). The mean percentage skin thickness over all 13 sites ranged from 7.1% to 13.5% in the women and from 13.5% to 33.4% in the men. The mean for men (22.7%) was significantly greater than that for women (10.8%) ($P < .0001$). By site, mean percentage skin thickness was significantly greater in the men than in the women at the triceps ($P < .001$), biceps ($P < .0005$), forearm ($P < .0005$), subscapular ($P < .05$), chest ($P < .02$), supraspinale ($P < .001$), abdominal ($P < .02$), front thigh ($P < .05$), medial thigh ($P < .01$), rear thigh ($P < .005$), and medial calf ($P < .05$) sites; there were no sig-

TABLE 1. Skin thickness (mm) by sex and site in 6 male and 7 female cadavers[1,2]

														All sites	
Sex	TR	BI	FO	SS	C	W	S	A	FT	MT	RT	P	MC	Mean	SD
M	1.40	0.90	1.05	2.55	1.60	1.80	1.75	1.55	1.40	1.25	1.55	1.25	1.00	1.47	0.43
M	1.95	0.85	1.00	—*	1.65	1.85	1.45	1.80	1.65	0.75	1.20	1.70	0.80	1.39	0.44
M	0.65	0.50	0.45	1.55	1.15	1.30	0.70	—*	0.70	0.70	0.70	0.75	0.50	0.80	0.34
M	1.30	0.55	0.70	2.15	1.05	1.25	1.15	1.15	1.05	0.75	1.05	0.80	0.85	1.06	0.40
M	1.10	0.80	0.65	1.85	1.40	1.45	1.15	1.20	1.10	0.95	1.40	1.35	0.95	1.18	0.32
M	1.25	1.00	0.75	2.25	1.50	1.85	1.40	1.75	1.35	1.05	1.35	1.45	1.25	1.40	0.39
Mean	1.28	0.77	0.77	2.07	1.39	1.58	1.27	1.49	1.21	0.91	1.21	1.22	0.89	1.22	
SD	0.42	0.20	0.23	0.38	0.24	0.28	0.36	0.30	0.33	0.22	0.30	0.37	0.25		0.36
F	1.05	0.55	0.55	1.50	0.85	1.45	0.90	0.95	1.00	0.75	0.95	1.05	0.70	0.94	0.29
F	1.20	0.45	0.55	2.10	0.75	1.50	0.90	0.95	1.10	0.95	1.45	1.25	0.95	1.08	0.43
F	0.45	0.35	0.50	1.25	—*	1.05	1.00	0.75	1.00	0.55	0.60	0.90	0.75	0.76	0.28
F	1.45	0.65	0.75	1.70	1.20	1.65	1.00	1.25	1.10	0.95	1.05	1.15	0.90	1.14	0.32
F	1.20	0.35	0.55	1.70	0.60	1.00	1.05	—*	0.85	0.85	0.90	0.85	0.70	0.88	0.35
F	0.95	0.50	0.65	1.70	0.75	1.30	0.95	1.05	1.10	0.70	1.30	0.65	0.85	0.96	0.33
F	1.40	0.60	0.65	2.20	0.75	1.30	0.90	1.30	1.00	0.75	1.00	1.10	0.70	1.05	0.43
Mean	1.10	0.49	0.60	1.74	0.82	1.32	0.96	1.04	1.02	0.79	1.04	0.99	0.79	0.98	
SD	0.34	0.12	0.09	0.33	0.20	0.24	0.06	0.21	0.09	0.14	0.28	0.20	0.11		0.36
All subjects															
Mean	1.18	0.62	0.68	1.88	1.10	1.44	1.10	1.25	1.11	0.84	1.12	1.10	0.84	1.09	
SD	0.37	0.21	0.18	0.38	0.37	0.28	0.28	0.34	0.24	0.18	0.29	0.30	0.18		0.46

[1]Means and standard deviations (SD) for each subject, each site, all men, all women, and all subjects.
[2]TR = triceps, BI = biceps, FO = forearm, SS = subscapular, C = chest, W = waist, S = supraspinale, A = abdominal, FT = front thigh, MT = medial thigh, RT = rear thigh, P = patellar, MC = medial calf.
*Denotes missing data.

nificant differences at the waist and patellar sites. In men and women, the greatest mean contribution of skin to skinfold thickness was at the subscapular site (34.0% and 23.9%, respectively), while the medial thigh was the site least affected by skin (11.6% and 5.2%, respectively) (Fig. 2).

Skinfold compressibility (%) showed wide variation by site and subject (Table 3). Mean compressibility over all sites was not significantly different between the sexes, but ranged from 38.2% to 68.6% for the men and from 47.0% to 60.6% for the women. There was considerable overlap in skinfold compressibility by site between men and women (Fig. 3), and no significant differences were observed. For men and women combined, and for men alone, there were no significant associations of percentage total adiposity with percentage skinfold compressibility at any specific site or with the mean compressibility value of all sites combined. However, for women alone, there was a significant correlation between percentage skinfold compressibility at the triceps site and percentage total adiposity ($r = .97$, $P < .0005$); there were no other significant correlations with percentage total adiposity in women.

DISCUSSION

Skin thickness and skin thickness relative to skinfolds

All skinfold measurements include a double layer of skin whose thickness is unknown and, in lean subjects, variability in skin thickness poses a potential concern, because skin thickness accounts for a greater fraction of the skinfold. However, data on skin thickness are sparse. In an autopsy study on 35 Chinese subjects (Lee, 1957), forearm skin thickness ranged from 0.82 mm to 1.82 mm. At the same site, Sheppard and Meema (1967), using radiography, reported a mean thickness of 1.43 mm in male and 1.34 mm in female Caucasians. A third study (Bliznak and Staple, 1975) using a similar procedure, found that 1) for a given age and weight, males had a thicker skin than females and 2) for each sex, skin thickness decreased with age; however, these findings were based only on radiographs of

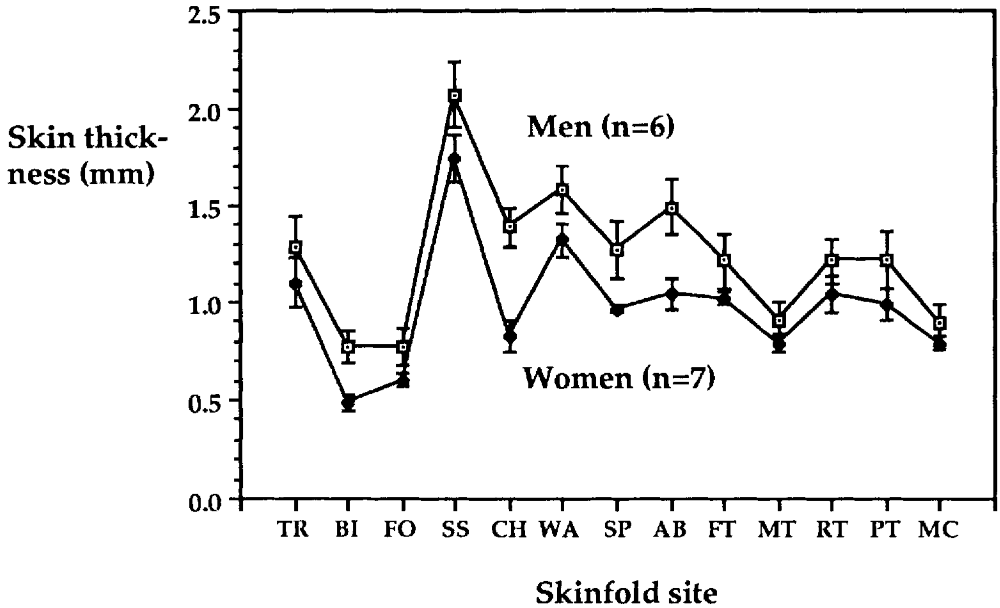

Fig. 1. Skin thicknesses in 6 men and 7 women, showing means ± standard errors at 13 sites. (Skinfold sites as defined in text.)

the forearm site. In a more comprehensive study (Lee and Ng, 1965), skin thickness was measured directly at nine skinfold sites in 35 adult Chinese cadavers. The mean values at each site ranged from 0.96 mm (biceps) to 3.41 mm (subscapular) with somewhat smaller values in females. However the measurement technique, which utilized a plastic ruler inserted in an incision in the skin, only gave readings to the nearest 0.5 mm, a value larger than some of the thicknesses being measured.

The effect of the variability of skin thickness on skinfold values and fat prediction has never been seriously assessed. The same caliper reading on two people may correspond to different thicknesses of subcutaneous adipose tissue because of differences in skin thickness. For example, since skin thickness is generally of the order of a few millimetres, the effect of skin on skinfold caliper readings may be negligible when skin thickness is small in relation to skinfold thickness, but the effect of skin could be most marked at those sites and in those subjects with little adipose tissue (i.e., where the relative contribution of skin to the caliper reading is high). Athletes are considerably leaner than the general population, and elite gymnasts and distance runners typically have skinfolds at some sites of 2 mm to 5 mm (Pollock et al., 1977). While there are no data on skin thickness in athletes there is little reason to believe that it differs markedly from non-athletes. Thus, in such cases, the contribution of skin thickness to the caliper reading may be 50% or more and intersubject differences may induce large errors in predictions of percent body fat.

The data reported here demonstrate considerable variability in skin thickness both from site to site within a single subject as well as between subjects. For example, in the six males, skin thickness at the triceps ranged from 0.65 mm to 1.95 mm (Table 1). The corresponding range in the seven females was 0.45 mm to 1.45 mm. The site where the effect of skin was most marked was the subscapular, where skin thickness accounted for 34.0% of the caliper reading in males. When skinfold thicknesses at all 13 sites were totaled for the leanest male subject, skin thickness constituted fully one-third of this amount. This subject had 18% of his body weight made up of adipose tissue (weighed after complete dissection), and

TABLE 2. Double skin thickness as a percentage of skinfold thickness by sex and site in 6 male and 7 female cadavers[1,2]

Sex	TR	BI	FO	SS	C	W	S	A	FT	MT	RT	P	MC	All sites Mean	All sites SD
M	24.0	41.6	29.5	40.7	32.7	33.0	45.5	19.5	35.8	18.7	40.3	32.5	40.9	33.4	8.6
M	15.5	17.3	26.6	27.9	17.9	16.1	28.8	15.9	13.7	9.0	21.0	22.7	11.5	18.8	6.2
M	12.0	29.4	25.4	38.3	27.5	40.3	28.3	—*	13.8	16.2	28.3	19.5	12.2	24.3	9.6
M	16.7	29.1	18.2	—*	13.3	18.0	20.1	17.6	14.8	8.1	35.3	27.9	15.8	19.6	7.6
M	15.7	17.2	13.7	24.0	10.1	14.0	21.5	8.0	8.4	5.6	13.0	13.6	10.2	13.5	5.3
M	22.6	38.8	24.6	39.1	27.3	35.2	40.9	27.2	14.6	12.2	20.7	17.3	25.0	26.6	9.5
Mean	17.8	28.9	23.0	34.0	21.5	26.1	30.9	17.6	16.9	11.6	26.4	22.3	19.3	22.7	
SD	4.6	10.3	5.9	7.5	9.0	11.3	10.3	6.9	9.6	5.0	10.2	7.0	11.9		10.1
F	10.3	7.6	13.1	27.1	14.1	19.5	7.6	7.9	10.2	5.9	—*	30.9	8.1	13.5	8.2
F	6.8	5.4	8.5	16	—*	11.3	8.4	6.6	4.9	2.4	3.9	6.3	4.2	7.1	3.7
F	10.3	8.2	13.6	34.5	8.1	8.1	13.1	—*	7.3	5.6	15.7	15.1	8.1	12.3	7.7
F	12.5	9.6	10.0	20.3	9.8	18.6	13.9	10.3	4.6	4.7	8.7	—*	8.6	11.0	4.8
F	6.7	7.7	9.8	19.1	9.7	20.1	14.9	7.7	7.4	4.5	9.1	7.3	7.2	10.1	4.9
F	9.3	9.9	10.1	32.4	6.8	13.0	7.7	8.3	7.6	6.0	8.1	—*	6.4	10.5	7.2
F	9.0	11.5	10.6	18.1	9.6	25.3	14.2	—*	6.9	7.5	10.4	8.5	7.5	11.6	5.4
Mean	9.3	8.6	10.8	23.9	9.7	16.6	11.4	8.2	7.0	5.2	9.3	13.6	7.2	10.8	
SD	2.1	2.0	1.9	7.4	2.5	6.0	3.3	1.4	1.9	1.6	3.8	10.3	1.5		6.2
All subjects															
Mean	13.2	17.9	16.4	28.1	15.6	21.0	20.4	12.9	11.5	8.2	17.9	18.3	12.7	16.4	
SD	5.5	12.6	7.5	8.8	8.8	9.8	12.3	6.9	8.1	4.8	11.6	9.3	9.9		10.4

[1]Means and standard deviations (SD) for each subject, each site, all men, all women, and all subjects.
[2]TR = triceps, BI = biceps, FO = forearm, SS = subscapular, C = chest, W = waist, S = supraspinale, A = abdominal, FT = front thigh, MT = medial thigh, RT = rear thigh, P = patellar, MC = medial calf.
*Denotes missing data.

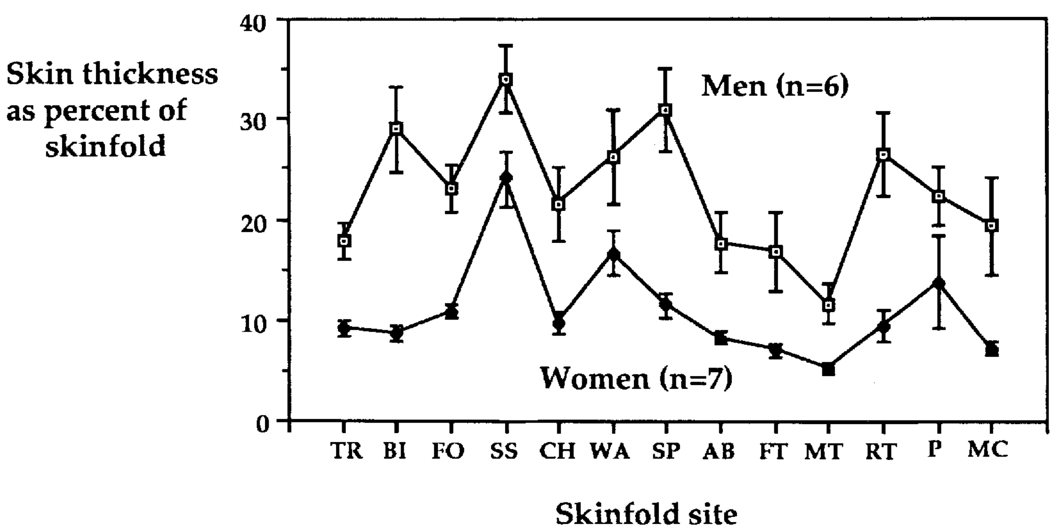

Fig. 2. Skin as percentage of skinfold thickness, showing means ± standard errors at 13 sites. (Skinfold sites as defined in text.)

therefore could not be considered lean in comparison to athletes, suggesting that the contribution of skin to skinfold thickness and therefore the potential error in the estimation of %fat would be even greater in athletes.

Compressibility

A phenomenon familiar to all users of skinfold calipers is a decline in caliper reading after the initial application of the caliper to the skinfold. This dynamic aspect of cali-

TABLE 3. Percentage skinfold compressibility by sex and site in 6 male and 7 female cadavers[1,2]

Sex	TR	BI	FO	SS	C	W	S	A	FT	MT	RT	P	MC	All sites Mean	All sites SD
M	60.2	67.9	56.0	60.4	67.1	70.7	73.4	50.8	56.1	59.4	46.5	53.9	48.3	59.3	8.5
M	35.4	50.5	34.2	39.2	25.4	14.0	59.5	61.1	18.2	44.5	38.5	63.3	12.8	38.2	17.4
M	64.0	71.7	72.7	68.8	72.2	73.1	64.6	69.2	61.0	76.6	69.1	70.4	59.0	68.6	5.1
M	40.3	78.3	45.0	46.7	59.3	48.8	64.8	71.3	39.6	62.8	54.7	60.6	32.3	54.2	13.5
M	65.4	69.5	46.1	61.1	56.6	57.6	79.0	61.7	30.8	55.5	40.0	67.2	46.5	56.7	13.1
M	35.0	63.2	56.4	55.8	62.1	59.6	57.2	48.6	2.4	31.2	23.2	44.2	33.3	44.0	18.1
Mean	50.1	66.9	51.7	55.3	57.1	54.0	66.4	60.5	34.7	55.0	45.3	59.9	38.7	53.5	
SD	14.6	9.4	13.1	10.7	16.5	21.5	8.3	9.3	22.4	15.6	15.6	9.6	16.2		16.4
F	27.8	51.3	56.0	62.0	70.6	39.5	53.1	54.8	30.2	38.6	—*	76.0	22.9	48.6	16.9
F	75.1	64.7	53.0	57.7	—*	61.1	73.7	77.2	37.7	35.6	54.4	33.7	28.4	54.4	17.1
F	36.8	39.3	57.4	55.2	75.7	45.2	59.0	—*	31.2	39.3	42.5	48.9	33.7	47.0	12.9
F	42.7	68.6	41.1	39.7	69.9	65.0	78.8	52.2	17.5	51.1	65.0	—*	32.1	52.0	18.1
F	48.5	60.8	56.0	73.4	77.9	64.0	52.8	48.6	19.2	49.4	7.7	47.4	32.6	49.1	19.8
F	60.3	79.0	69.7	69.9	54.7	59.5	67.6	73.2	53.5	51.7	54.1	—*	34.4	60.6	12.1
F	41.9	64.6	58.4	68.2	68.8	68.2	60.5	66.4	40.0	63.8	53.2	27.6	30.6	54.8	14.8
Mean	47.6	61.2	55.9	60.9	69.6	57.5	63.6	62.1	32.8	47.1	46.2	46.7	30.7	51.9	
SD	15.7	12.7	8.4	11.4	8.1	10.8	10.1	11.9	12.5	9.9	20.1	18.7	4.0		16.5
All subjects															
Mean	48.7	63.8	54.0	58.3	63.4	55.9	64.9	61.3	33.6	50.7	45.7	53.9	34.4	52.7	
SD	14.6	11.3	10.6	11.0	14.0	16.0	9.0	10.2	17.0	13.0	17.2	15.3	11.6		16.4

[1]Means and standard deviations (SD) for each subject, each site, all men, all women, and all subjects.
[2]TR = triceps, BI = biceps, FO = forearm, SS = subscapular, C = chest, W = waist, S = supraspinale, A = abdominal, FT = front thigh, MT = medial thigh, RT = rear thigh, P = patellar, MC = medial calf.
*Denotes missing data.

per use has been reported in the literature, but given little attention (Booth et al., 1966; Fletcher, 1962; Orpin and Scott, 1964). Brans et al. (1974) quantified the dynamic compressibility of subcutaneous adipose tissue in neonates, showing an exponential decline in caliper reading over the 1st minute. They suggested that the main cause of variation in this decline was the varying proportion of interstitial water in the adipose tissue, but provided only indirect evidence for this. Most workers adopt some technique to standardize the reading despite its dynamic characteristics. Some wait "for all needle movements to cease before taking the reading" (Booth et al., 1966), while others record after "an initial rapid phase of the movement" (Orpin and Scott, 1964), or "approximately 2 seconds after application, when the needle slows" (Ross and Marfell-Jones, 1982).

There is also a static compressibility in addition to the dynamic one. Even when timing of the caliper reading has been standardized, similar thicknesses of adipose tissue may yield different caliper readings due to different degrees of tissue compressibility. Various workers have studied the extent to which skinfold calipers compress tissue in relation to some uncompressed standard such as that obtained by radiography and ultrasound (Brožek and Mori, 1958; Edwards, 1951; Garn and Gorman, 1956; Hammond, 1955; Jones, 1970; Ward, 1979). Mean compressibilities for different samples ranged from 16% to 51%, with the variability being attributed to sex, age, site, and level of tissue hydration (Brožek and Mori, 1958). Significant additional variability will also be introduced by the use of different methods for obtaining the reference value.

It seems probable that variations due to sex, age, and site are the result of changes in skin and adipose tissue composition associated with these factors. For example, Brožek and Kinsey (1960) studied age-related changes in compressibility and suggested that the observed differences were due in part to changed elastic properties of the skin and adipose tissue, and to differing degrees of tissue hydration. Clegg and Kent (1960) concluded that female adipose tissue was more compressible than that of males, whereas Jones (1970) found the opposite. The greater muscularity (and resulting increased skin tension) of Jones's female subjects may account for some of the difference, but Clegg and Kent (1960) did not take skinfold thickness into account. If thicker skinfolds (i.e., the adipose tissue of more obese subjects) are more compressible than thinner ones, these contradictory findings can be

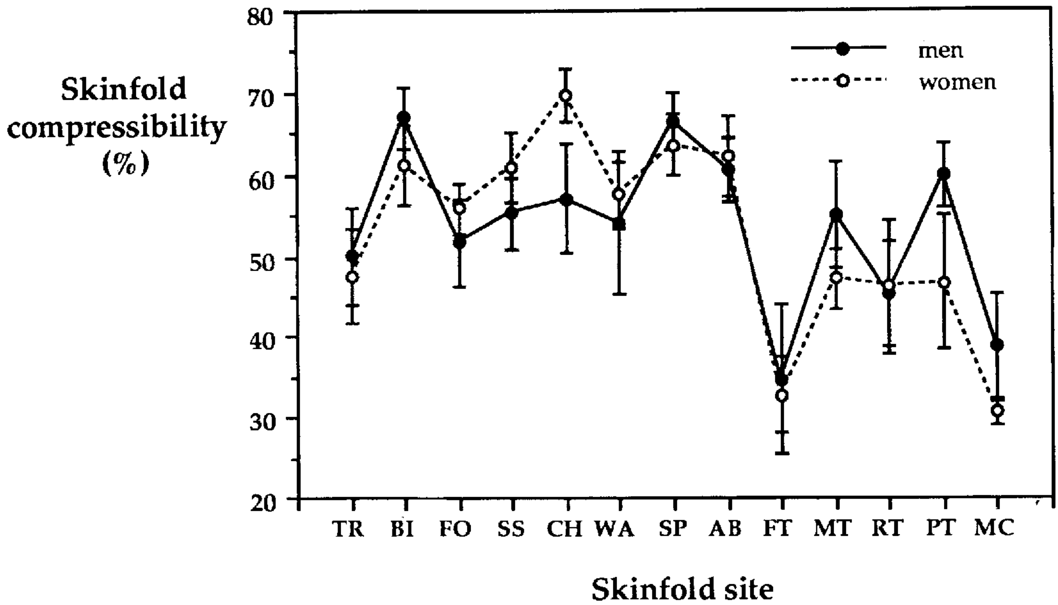

Fig. 3. Skinfold compressibility (%), showing means ± standard errors at 13 sites. (Skinfold sites as defined in text.)

easily resolved. Ward (1979) stressed the importance of the effect of skinfold thickness on skinfold compressibility and, having allowed for this, found no sex differences in his subjects.

The minimum (38.2%) and maximum (68.6%) values for compressibility in the six males are of particular interest, since the two subjects in which these values were observed had almost identical values for percentage total adiposity (27.1% and 27.8%, respectively). However, fatness expressed as the sum of 13 skinfold thicknesses was very different in the two men (217.6 mm and 98.5 mm, respectively). This discrepancy reveals a problem with the use of skinfold calipers to assess fatness. In the absence of information other than the 13 skinfold thicknesses, it might reasonably be concluded that the former subject was more than twice as fat as the latter since his sum of skinfolds was 121% greater. Only when the incised adipose tissue thicknesses are examined can this be resolved. The sum of 13 thicknesses obtained in this way was 185 mm for the former, which was only 16% greater than for the latter, 159 mm. The problem was less evident in women who showed a narrower range of compressibility (47.0% to 60.6%) than men.

Compressibility varied considerably by site, though the variation in men and women showed a similar pattern (Fig. 3). In men, the front thigh and medial calf had the lowest compressibilities, 34.7% and 38.7%, respectively. In women the lower limb sites were less compressible than upper limb and trunk. We found no significant relationship between overall fatness and compressibility at any site (except the triceps in women, perhaps an artifact of the small sample size).

Skinfold compressibility averaged over all 13 sites and all 13 subjects (Table 3) was 52.7% (16.4%). There was no significant difference between the mean for men, 53.5% (16.4%), and the mean for women, 51.9% (16.5%). However, when considering the mean of 13 sites for each individual, it can be seen that the range for women (47.0%–60.6%) was less than that for the men (38.2%–68.6%). This raises the questions of how variability is assessed. A second approach is to calculate variability using only the mean values (over all sites) for each subject. For the 7 female subjects this gives 4.7%, but ignores inter-site variability. A third approach is to simply take the mean of the 7 standard deviations, as a measure of the variability of the mean compressibility over the 7 women. This gives 16.0%. However, in practice, the importance of this variability is in its effect on %fat estimation, and this will vary with the skinfold sites selected. To examine this, we used one of the generalized equations of Jackson and Pollock (1978) to estimate body density from the sum of three skinfolds: the chest, abdomen, and thigh. Mean (SD) compressibilities at these sites were 57.1% (16.5), 60.5% (9.3), 34.7% (22.4) for the men and 69.6% (8.1), 62.1% (11.9), 32.8% (12.5) for the women. The mean of the three SD's was taken as the SD of the sum: 16.1% for men and 10.8% for women. Then %fat from Siri's equation was calculated from body density. For men, the values of ±1 SD of 16.5% in skinfold thicknesses translated into a %fat estimation of 16.9 to 21.7, i.e., a mean %fat of 19.3 with a SD of 2.4% fat. For women the values of ±1SD of 10.8% in skinfold thicknesses translated into a %fat estimation of 24.9 to 29.7, i.e., a mean %fat of 27.3 with a SD of 2.4% fat. Thus, despite the different equations and compressibilities, the error due to skinfold compressibility appears to be similar in men and women.

In summary, though little information on skin thickness is available, the variability reported in this sample of 13 subjects is large, with a coefficient of variation of 42%. One implication is that, while the contribution of skin to total skinfold thickness is not large in the general population, it may lead to significant error in lean subjects such as athletes, both males and females, where estimation of fatness on an individual basis is common. A second problem is the variability in skinfold compressibility reported here. It is difficult to be certain that equal caliper readings observed in two different subjects (or even at different sites in the same subject) do, in fact, correspond to the same adipose tissue thickness. Since compressibility is difficult to measure in vivo, it remains an unknown in most studies of body composition, and results in an uncertainty in %fat estimates. With the use of the 3-skinfold Jackson and Pollock equations, a standard deviation in compressibility of 16.1% for men and 10.8% for the women resulted in the same deviation of 2.4% fat in both men and women.

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