A Comparison of Skinfold Measurements with Three Standard Calipers

By A. W. Sloan and M. Shapiro

ABSTRACT

The body density of 28 young men was determined by underwater weighing. Skinfold measurements were made at each of 4 sites by each of two trained observers, using each of three types of skinfold caliper (MNL, Harpenden, and Lange). The best agreement between observers was obtained with the Harpenden caliper. There was no systematic difference between measurements with the different calipers at any site. Multiple correlations of skinfold measurements with body density were of the same order with the different calipers. Formulae are presented for the prediction of body density from arm and abdominal or from arm and scapular sites.

The most satisfactory method at present available for determining total human body fat is from the measurement of body density by the method of underwater weighing, allowance being made for the volume of air in the lungs and air passages at the time of weighing under water. From the density the proportion by weight of fat in the body can be calculated. Since this method requires laboratory facilities, including a large tank of warm water, methods have been developed to predict body density from simpler procedures.

In any particular age-group of men or of women the thickness of the layer of subcutaneous fat is related to the percentage by weight of fat in the body (Allen et al. 1956, Edwards 1956, Mayer 1959). This thickness may be measured at selected sites by an ultrasonic echo-sounding technique (Whittingham 1962, Booth et al. 1966, Sloan 1967), from soft-tissue X-rays (Garn 1961), or by picking up a fold of skin and subcutaneous tissue with thumb and index finger and measuring its thickness with a caliper. Several satisfactory types of caliper for this purpose are available but only a few attempts have been made to ascertain whether readings obtained with different instruments are comparable (Insull et al. 1954, Edwards et al. 1955, Le Bideau 1959).

1 Department of Physiology and Medical Biochemistry, University of Cape Town, Cape Town, South Africa.

© Wayne State University Press, 1972
In the present investigation three standard calipers are compared in order to ascertain which gives the closest agreement between readings at selected sites by two trained observers. The same calipers are used to ascertain the correlation between skinfold thickness at each site and body density and to derive equations for prediction of body density from skinfold measurements.

**SUBJECTS AND METHODS**

The subjects of the investigation were 28 healthy young white men, students of physiology at the University of Cape Town. Their ages ranged from 17 to 25 years, their mean height was 175.8 cm. (S.D. ± 6.31), and their mean weight 69.2 kg (S.D. ± 7.85).

To determine body density each subject was weighed in air, wearing light bathing shorts, and weighed again completely submerged in water at a known temperature of about 35°C. For the underwater weighing the subject expired maximally under water and the pulmonary residual volume was measured as soon as he came to the surface by closed-circuit nitrogen dilution with oxygen (Lundsgaard and van Slyke 1918, Sloan and Bredell 1971). Several practice runs were performed until the subject became used to the procedure and a reasonably constant level of expiration was achieved. Body fat was then calculated from body density by Brozek’s revised formula (Brozek et al. 1963).

\[
F = 100 \left( \frac{4.570}{D} - 4.142 \right)
\]

where
- \(F\) equals fat (per cent of body mass)
- \(D\) equals density (g/ml)

Skinfold measurements were performed with 3 standard calipers, the MNL (Best 1954), the Harpenden (Tanner and Whitehouse 1955), and the Lange (Lange and Brozek 1961) at 4 selected sites. Each site was located visually (not by measurement) and marked so that the two observers measured the identical site. Measurements were made on the right side of the body with the subject standing erect with his arms by his sides. The sites selected were those which were found in a previous investigation (Sloan 1967) to give the highest correlation with body density in young men, viz.:
Skinfold Measurement

(1) **Thigh**—vertical skinfold in the mid-line of the front of the thigh half-way between the inguinal ligament and the top of the patella.

(2) **Abdomen**—horizontal skinfold on the anterior abdominal wall half-way between the umbilicus and the mid-axillary line.

(3) **Scapula**—oblique skinfold on a line running downward and laterally, at an angle of about 30° from vertical, from the inferior angle of the scapula.

(4) **Arm**—vertical skinfold in the mid-line of the back of the arm half-way between acromion and olecranon processes.

Each observer measured and recorded the skinfolds without reference to the findings of the other observer, each measurement being repeated until successive readings differed by not more than 1 mm.

The reliability of the three calipers was compared by comparing the differences between readings by the two observers with each caliper at each site. The mean of the measurements by the two observers with the different calipers was then compared to reveal any systematic difference in readings by the different calipers. To compare the validity of readings with the three calipers the mean of the observers' readings with each caliper at each site was correlated with body density. For each caliper the best single and multiple correlations were found and a formula was derived for prediction of body density from the selected skinfold measurements.

**RESULTS**

The mean body density of the subjects was 1.0694 (SD ± 0.0119) g/ml. The mean body fat, calculated from density by Brozek's revised formula and expressed as per cent of body weight, was 13.18 (SD ± 4.81).

The differences between readings by the two observers at each site with each caliper are summarized in Table 1. On the thigh the differences were significantly less (p < 0.01) with the Harpenden and MN L calipers than with the Lange. On the abdomen the differences were significantly less with the Harpenden than with the MN L caliper (p < 0.05). At the scapular and arm sites the differences were significantly less with the Harpenden than with either of the other calipers.

The mean of the readings by the two observers at each site was not significantly higher or lower with any one caliper than with either of the others (Table 2).
Table 1

Differences between skinfold measurements by two observers.

(*mm*, *mean ± SD*)

<table>
<thead>
<tr>
<th>Site</th>
<th>MNL</th>
<th>Harpenden</th>
<th>Lange</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thigh</td>
<td>0.77 ± 0.71</td>
<td>0.83 ± 0.69</td>
<td>1.43 ± 1.32</td>
</tr>
<tr>
<td>Abdomen</td>
<td>1.15 ± 1.39</td>
<td>0.45 ± 0.47</td>
<td>0.76 ± 0.65</td>
</tr>
<tr>
<td>Scapula</td>
<td>1.08 ± 0.76</td>
<td>0.51 ± 0.60</td>
<td>0.99 ± 1.18</td>
</tr>
<tr>
<td>Arm</td>
<td>1.59 ± 1.83</td>
<td>0.43 ± 0.41</td>
<td>1.05 ± 0.96</td>
</tr>
</tbody>
</table>

The correlation coefficients with body density of the readings at each site with each caliper are given in Table 3. The skinfold measurements are the means of the readings by the two observers. The multiple correlations of readings at two sites (one on a limb and one on the trunk) with body density are given in Table 4.

Table 2

Mean measurements of skinfold thickness by two observers.

(*mm*, *mean ± SD*)

<table>
<thead>
<tr>
<th>Site</th>
<th>MNL</th>
<th>Harpenden</th>
<th>Lange</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thigh</td>
<td>12.32 ± 3.95</td>
<td>11.69 ± 3.62</td>
<td>12.05 ± 4.04</td>
</tr>
<tr>
<td>Abdomen</td>
<td>7.39 ± 4.78</td>
<td>8.08 ± 4.15</td>
<td>8.11 ± 4.85</td>
</tr>
<tr>
<td>Scapula</td>
<td>9.25 ± 4.70</td>
<td>9.86 ± 4.13</td>
<td>10.25 ± 5.50</td>
</tr>
<tr>
<td>Arm</td>
<td>8.18 ± 3.04</td>
<td>8.19 ± 2.66</td>
<td>8.29 ± 3.11</td>
</tr>
</tbody>
</table>

Table 3

Correlation coefficients between body density and mean skinfold measurements

<table>
<thead>
<tr>
<th>Site</th>
<th>MNL</th>
<th>Harpenden</th>
<th>Lange</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thigh</td>
<td>-0.66</td>
<td>-0.65</td>
<td>-0.73</td>
</tr>
<tr>
<td>Abdomen</td>
<td>-0.76</td>
<td>-0.78</td>
<td>-0.78</td>
</tr>
<tr>
<td>Scapula</td>
<td>-0.75</td>
<td>-0.75</td>
<td>-0.76</td>
</tr>
<tr>
<td>Arm</td>
<td>-0.78</td>
<td>-0.68</td>
<td>-0.67</td>
</tr>
</tbody>
</table>
Table 4

Multiple correlation (R) between skinfold measurements and body density

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MNL</td>
<td>0.85</td>
<td>0.84</td>
<td>0.81</td>
<td>0.83</td>
</tr>
<tr>
<td>Harpenden</td>
<td>0.87</td>
<td>0.85</td>
<td>0.84</td>
<td>0.83</td>
</tr>
<tr>
<td>Lange</td>
<td>0.88</td>
<td>0.84</td>
<td>0.83</td>
<td>0.84</td>
</tr>
</tbody>
</table>

Multiple regression equations are presented for the prediction of body density from arm and trunk sites (Table 5).

Table 5

Prediction of body density from skinfold measurements

Table:<br>**MNL**<br>
\[ X_1 = 1.0933 - 0.0019X_2 - 0.0011X_3 \]
\[ X_1 = 1.0957 - 0.0019X_2 - 0.0011X_4 \]

**Harpenden**<br>
\[ X_1 = 1.0989 - 0.0019X_2 - 0.0017X_3 \]
\[ X_1 = 1.1018 - 0.0019X_2 - 0.0017X_4 \]

**Lange**<br>
\[ X_1 = 1.0939 - 0.0015X_2 - 0.0014X_3 \]
\[ X_1 = 1.0950 - 0.0015X_2 - 0.0012X_4 \]

where<br>
- \( X_1 \) = body density (g/ml)<br>
- \( X_2 \) = arm skin fold (mm)<br>
- \( X_3 \) = abdominal skin fold (mm)<br>
- \( X_4 \) = scapular skin fold (mm)

**DISCUSSION**

Body fat may be calculated from body density by any one of a number of formulae (Rathbun and Pace 1945, Brožek and Keys 1951, Brozek and Henschel 1961, Siri 1961, Brozek et al. 1963). Brozek's latest formula, based on analysis of the body composition of 3 male cadavers, has been used by a number of investigators.

Several formulae are available also for the prediction of body density from selected skinfold measurements (Brožek and Keys 1951, Pascale et al. 1956, Chinn and Allen 1960, Durnin and Ramahan 1967, Sloan 1967). The simple prediction of body fat from two skinfolds is the best (Pařížková et al. 1960, Damon and Goldman 1964) and it is desirable that one limb and one trunk site should be measured (Ham-
mond 1955). Each of the formulae is based on skinfold measurements with a particular type of caliper on a particular group of subjects and it has not yet been established whether the prediction is valid for other groups, though reasonable agreement may be expected if the subjects in the other group are of the same sex and age-group (Edwards 1956, Wilmore et al. 1970).

The most reliable of the calipers tested, in the sense that it gave the smallest difference between the readings by two trained observers, is the Harpenden. It is also the caliper in which each of the observers felt the greatest confidence.

All the calipers in common use today exert a constant pressure (with a moderate tolerance) at different degrees of separation of the jaws. For the MNL caliper the pressure is 28.5 g/mm² and for the Harpenden and Lange calipers it is 10 g/mm². According to Keys and Brozek (1953) differences in pressure within the range 10-90 g/mm² have only a small effect on skinfold measurements. In the present investigation no systematic reduction in skinfold measurements was found with the caliper exerting the higher pressure.

Many recent reports from Great Britain are based on measurements made with the Harpenden caliper and many from the United States of America are based on the Lange caliper. The results of the present investigation suggest that these findings are comparable since no significant difference was found between readings by the two calipers on the same individuals. The formula for prediction of body fat based on measurements with one of the standard calipers is similar to that derived for each of the others.

In a previous investigation of body fat in young men, using the MNL caliper only (Sloan 1967) the best skinfold measurements for prediction of body fat were on thigh, abdomen, scapula, and arm, and the best prediction formula was from thigh and scapula, the multiple correlation with body density being of the same order ($R = 0.82$) as in the present study with each of the calipers tested. Since arm skinfolds are more convenient to measure than those on the front of the thigh the combination of arm with abdominal or scapular sites is recommended.

It has been found that different formulae are required for men and for women (Durnin and Ramahan 1967, Edwards 1951, Sloan et al. 1962, Sloan 1967) and it is probable that different formulae will be required for different age-groups up to old age, since the distribution as well as the total amount of body fat changes with advancing years.
Skinfold Measurement

(Brozek 1952, Skerlj et al. 1953). Whether a formula derived for Caucasians is equally applicable to Mongolian or Negro populations is still to be determined.

ACKNOWLEDGMENTS

Our thanks are due to Miss M. Reingold for technical assistance and to Mr. P. B. Derriman for statistical analysis. The work was supported by the South African Medical Research Council and by the Staff and Herman Research funds of the University of Cape Town.

LITERATURE CITED


