Prediction of body density from skinfold measurements in lactating women

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1. Regression equations predicting body density from skinfold measurements were derived for a group of lactating women.

2. It was concluded that specific equations for lactation were not necessary, since the resultant equations were not significantly different from those published for non-lactating women.

3. The ability to predict an individual's body density from skinfold thickness measurements was unsatisfactory for either clinical or research applications.

Skinfold thickness has been shown to be negatively correlated with body density. Regression equations which predict body density from skinfold thickness have been used to calculate body fat of adult men and women (Sloan *et al.* 1962; Young *et al.* 1962; Durnin & Rahaman, 1967; Katch & Michael, 1968; Wilmore & Behnke, 1970; Durnin & Womersley, 1974; Pollock *et al.* 1975; Ward *et al.* 1975) at different ages. Maximum accuracy is attained when prediction equations are derived from samples of the population to which they will be applied. Differences in the published equations defined for specific age and sex groupings have been attributed to changes in fat distribution, skinfold compressibility and the density of fat-free mass. Since the distribution of subcutaneous fat undergoes significant changes in the pregnant and lactating female, the applicability of available equations has been questioned. The density of the fat-free mass may change during pregnancy; however, pregnant women do not store high-density materials (non-fat solids) in excess of those accounted for by the products of conception, increase in the size of the reproductive organs and increased blood volume (Seitchik *et al.* 1963). Approximately 4 kg fat are laid down during a normal pregnancy (Hytten & Leitch, 1971). This fat is not distributed uniformly, but preferentially over the thighs, abdomen and back (Taggart *et al.* 1967). In addition, the metabolism and mobilization of adipose tissue changes during lactation (Poo *et al.* 1939; Flint *et al.* 1980). Predictive equations derived from pregnant and lactating women have not been published.

In the present study, the relation between body density and skinfold thickness was investigated in a group of lactating women. Resultant regression equations were compared with those of Durnin & Womersley (1974). Although derived equations were not significantly different from those of Durnin & Womersley (1974), in both cases the ability to predict an individual's body density from skinfold measurements was poor.

MATERIALS AND METHODS

Anthropometric and densitometric measurements on forty-five lactating women, mean age 28·0 (SD 3·1) years (range 21–36 years), were performed at months 1, 2, 3 and 4 post partum. Ethnic background was distributed as follows: forty-one Caucasian, two Hispanic, one

Asian and one West Indian. The sample population and study design have been described fully in a previous publication (Butte *et al.* 1984).

Skinfold thicknesses were measured to the nearest 0·5 mm using Lange calipers at the following sites: triceps, biceps, suprailiac and subscapular (Durnin & Rahaman, 1967). These measurements were made generally by one person. Maternal weight was measured on a beam balance and height was measured with an upright extension meter.

Body density was derived from water displacement measurements in a Whitmore Volumeter (San Antonio, TX). Residual lung volume was estimated by a modification of the standard oxygen-dilution technique (Wilmore *et al.* 1980). Gastrointestinal gases were approximated to be 100 ml. Body fat was calculated according to Siri (1956).

Statistical analysis (Ryan *et al.* 1981) included the calculations of means and standard deviations, and correlation matrices of the anthropometric and densitometric variables. Trends over time were tested by fitting polynomial regressions to individuals. Linear regression was used to generate prediction equations. Differences in slopes and intercepts of regression equations were tested by repeated measures of analysis of covariance. McNemar's test was used to compare classification of individuals by two methods (Glantz, 1981).

RESULTS

The anthropometric and densitometric measurements are shown in Table 1. Triceps and biceps skinfold thicknesses did not change significantly over the 4 months. Measurements of the suprailiac and subscapular skinfolds ($P < 0.001$) and the sum of all sites ($P < 0.002$) decreased significantly over time. Skinfold measurements at the various sites were correlated significantly (r ranged from 0·50 to 0·77, $P < 0.01$) with body density; the suprailiac site was the single highest correlate, on a par with the sum of the skinfolds (r ranged from 0·64 to 0·78, $P < 0.01$). Significant intercorrelations between skinfold sites were observed ($P < 0.01$). The distribution of the sums of the skinfold thicknesses in the present study were non-normal, therefore a logarithmic transformation of the sum of the skinfold thicknesses at each month was performed to normalize and linearize the data.

The linear regression equations for the estimation of body density from the logarithm of the sum of skinfold thicknesses are shown in Table 2 for each of the 4 months of observation. Highly significant linear correlations were demonstrated at each month ($P < 0.001$). No significant differences between the slopes could be detected between the four lines, although the intercepts were different ($P < 0.05$). On average, 54% of the variability seen in body density was explained by the log of the sum of skinfold thicknesses.

The four regression equations were compared with the equation published by Durnin & Womersley (1974) for non-pregnant, non-lactating females aged 20–29 years (Table 2). A *t* test of the slopes and intercepts did not detect significant differences between our equations and the equation of Durnin & Womersley (1974).

The 95% confidence and prediction intervals calculated at the mean from the respective sets of values are presented in Table 3. The average confidence interval of ± 0.0032 units translates into $\pm 1.5\%$ body fat and the average prediction interval of ± 0.0215 units represents $\pm 10\%$ body fat. Analogous calculations using the values from Durnin & Womersley (1974) resulted in similar intervals.

Body fat predicted from our four regression equations and from the equation of Durnin & Womersley (1974) was used to classify the forty-five subjects into three arbitrary categories of body fat: $< 15\%$, 15–30%, $> 30\%$. Predicted body fat derived from our equations correctly categorized 67, 58, 73 and 73% of the subjects for months 1, 2, 3 and 4 respectively. Application of the equation of Durnin & Womersley (1974) resulted in appropriate classification in 64, 56, 68 and 58% of the cases over the same 4 months. The

Table 1. *Anthropometric measurements of forty-five lactating women at months 1, 2, 3 and 4 post partum*

(Mean values and standard deviations)

Month post partum...	1		2		3		4	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Height (m)	1·63	0·063	1·63	0·063	1·63	0·063	1·63	0·063
Wt (kg)	61·3	9·5	60·7	10·0	60·2	10·4	59·3	10·5
Triceps (mm)	16·9	4·6	17·0	4·7	17·3	5·3	17·2	5·2
Subscapular (mm)	16·8	6·4	16·4	7·4	15·7	7·2	15·1	7·3
Biceps (mm)	6·9	3·2	6·9	3·3	7·3	4·6	6·8	3·4
Suprailiac (mm)	25·7	6·9	25·2	7·6	23·1	8·1	22·2	8·0
Sum skinfolds (mm)	66·3	18·9	65·5	20·6	63·4	22·9	61·7	21·8
Body density × 10^3 (kg/m³)†	1·036	0·016	1·038	0·014	1·039	0·016	1·040	0·016
Body fat (% body-weight)†	28·0	7·4	27·2	6·3	26·3	6·8	26·3	7·6

† From densitometric measurements.

Table 2. *Linear regression equations for the estimation of body density from skinfold thickness*

(Y is density × 10^3 (kg/m³) and X is logarithm of the sum of the skinfold thicknesses at the triceps, biceps, suprailiac and subscapular sites)

Month post partum	Linear equation	r	R^2	SD of Y
1	$Y = 1·1889 - 0·0851X$	0·71	0·51	0·01143
2	$Y = 1·1671 - 0·0719X$	0·67	0·45	0·01034
3	$Y = 1·1710 - 0·0744X$	0·76	0·58	0·01021
4	$Y = 1·1854 - 0·0826X$	0·80	0·64	0·01001
Durnin & Womersley (1974)	$Y = 1·1599 - 0·0717X$	—	—	0·0109

Table 3. *95% confidence and prediction intervals calculated at the mean for body density and body fat*

	Density × 10^3 (kg/m³)			Body fat (% body-wt)*		
Month post partum	Mean	95% Confidence	95% Prediction	Mean	95% Confidence	95% Prediction
1	1·0357	±0·0036	±0·0234	27·94	26·28–29·60	17·38–38·99
2	1·0375	±0·0032	±0·0211	27·11	25·64–28·58	17·60–37·01
3	1·0390	±0·0032	±0·0209	26·42	24·96–27·89	17·03–36·20
4	1·0398	±0·0032	±0·0206	26·05	24·59–27·52	16·80–35·68
Average	1·0381	±0·0032	±0·0215	26·83	25·37–28·31	17·16–36·92
Durnin & Womersley (1974)†	1·0294	±0·0022	±0·0216	30·86	29·84–31·89	20·98–41·17

* Body fat (%) = [(4·95/density) − 4·50] × 100 (Siri, 1956).

† Calculations based on their respective values for women 20–29 years of age (Durnin & Womersley, 1974).

proportion of individuals categorized correctly with our equations relative to those categorized correctly by the equation of Durnin & Womersley (1974) was not statistically different (McNemar's test).

DISCUSSION

Present evidence does not indicate a requirement for prediction equations of body density from skinfold measurements specific to lactating women, despite the significant deposition of body fat during pregnancy. Regression equations generated from actual measurements made on this group could not be distinguished statistically from a previously published prediction equation derived from non-pregnant, non-lactating women (Durnin & Womersley, 1974).

Two points germane to the application of either equations should be emphasized. The ability to predict an individual's percentage body fat from skinfold thickness is limited. The wide prediction intervals for individual observations makes this method non-discriminating. For example, one may be 95% confident that the true body fat of an individual with a predicted value of 26·83% lies between 17·16% and 36·92%. Classification into broad categories did not screen individuals correctly more than 73% of the time. The accuracy of this indirect method has been assessed previously (Durnin & Rahaman, 1967; Durnin & Womersley, 1974) by the standard error of the estimate, which would be equivalent to a '67% prediction interval'. This criterion would be unacceptable for most research or clinical applications.

The arithmetical transformation of body density into percentage body fat results in an increased coefficient of variation from the change in scale and distribution of values. A small incremental change in body density can result in a change of body fat of practical consequences. For instance, a 1·0% error in body density (1·052 v. 1·063) caused by overestimating residual volume by 0·5 litres can result in a 4·8% difference in body fat (15·7% v. 20·5%).

In conclusion, the use of skinfold measurements for the prediction of body fat is justified in situations when the population mean is of interest, but inaccurate when applied to individuals.

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