Fat-free body mass from skinfold thickness: a close relationship with total body nitrogen

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Fat-free body mass is an important component of body composition which is of particular interest to nutritionists and related workers. Fat-free mass has been determined from the simple measurement of skinfold thickness and it has been demonstrated that there is a close correlation with total body nitrogen even though the test subjects had a wide range of nutritional status.

Since fat-free body mass (FFM) can be assessed rapidly and cheaply by measuring skinfold thickness (Durnin & Womersley, 1974), it is of great potential value to workers in many fields of medicine, physiology and nutrition. Although values of FFM measured in this way have been compared with those obtained from measurements of body density (Durnin & Womersley, 1974), body water (Keys & Brozek, 1953) and total body potassium (Forbes, Gallup & Hursh, 1961), they have not been related to direct measurements of total body nitrogen (TBN). The purpose of this report is to show that there is a close relationship between FFM (assessed from four skinfolds) and TBN (measured by neutron activation analysis) when these are measured in adult subjects with varying degrees of weight loss.

SUBJECTS AND METHODS

Thirty-three subjects were irradiated with 14 MeV neutrons and the induced radioactivity was counted in a whole-body counter. These estimates of TBN were correlated with those of FFM derived from measurements of four skinfolds and body-weight using the method described by Durnin & Womersley, 1974.

The subjects comprised nine normal subjects (eight males, one female; mean age 35·9 years, SD 11·3 years); twelve surgical patients, with only minimal weight loss (3–4 %, over the previous year) who were awaiting an elective major operation (ten males, two females; mean age 51·8 years, SD 14·9 years), and twelve surgical patients who were awaiting an elective major operation in whom there had been an average loss of 22·3 % of body-weight over the previous year (seven males, five females; mean age 53·8 years, SD 14·5 years). All the subjects were in a normal state of hydration at the time of the study and none were oedematous. Skinfold thickness was taken as the mean of three measurements in each of four locations; mid biceps, mid triceps, subscapular and suprailiac according to a standard technique (Weiner & Lurie, 1969).

The in vivo determination of TBN was made using a sealed tube neutron generator producing 14 MeV neutrons. The right hand side of the supine patient was irradiated for 40 s, the patient rotated through 180° and the left side irradiated for 40 s. The radiation dose was 0·5 msievert (50 mrem). The patient was then transferred to the whole-body radiation monitor, which took about 5 min and the gamma radiation of the patient's radioactivity, induced by the neutron irradiation, was measured for 30 min in a static

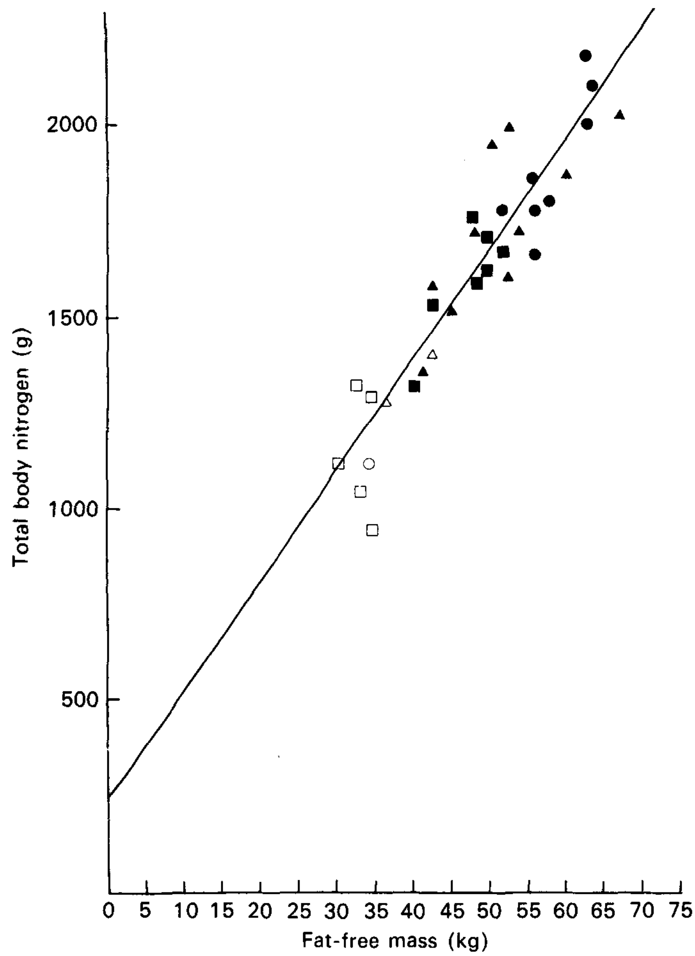

Fig. 1. Relationship between total body nitrogen and fat-free mass in thirty-three adult subjects. Normal subjects: ○, female; ●, male. Patients with minimal weight loss: △, female; ▲, male. Patients with massive weight loss: □, female; ■, male.

array of NaI (Tl) radiation detectors (Burkinshaw, Marshall, Oldroyd & Oxby, 1972) connected to a multi-channel analyser and a small computer. The resultant complex spectrum was analysed by computer for Na, Cl, K, P, Ca and N. The result for N was corrected for interfering radioactivity produced by P, Cl and O. The result was also corrected for the effect of the body build of the subject. This correction was derived from experiments on phantoms of differing sizes.

The precision of the method was tested by the repeated measurement of an anthropomorphic phantom, and also by performing duplicate measurements on nine people. Eight of these were patients who were measured on consecutive days; one was a healthy volunteer who was measured a second time after an interval of 6 weeks. The experiments indicated that the coefficient of variation was 2·5 % (Oxby, Appleby, Brooks, Burkinshaw, Krupowicz, McCarthy, Oldroyd, Ellis, Collins & Hill, 1978).

RESULTS

The relationship between TBN and FFM is shown in Fig. 1. The correlation coefficient for all the subjects was 0·91, for the controls alone 0·95, for the patients with minimal weight loss 0·79 and for the patients with considerable weight loss it was 0·89. There were, however, no significant differences between the regressions of TBN on FFM for these three groups. There are too few females in this study to demonstrate any sex differences in the relationship. The regression equation for all the subjects is:

$$\text{TBN(g)} = (28{\cdot}8^{*}\ \text{FFM (kg)} + 228) \pm 8{\cdot}5\,\%$$

but the value of the intercept is not significantly different from zero. The mean value of the ratio, TBN:FFM is 33·8 g/kg which is almost identical to that obtained from direct chemical analysis of the adult human body (34 g/kg) (Widdowson, 1965).

These results show that, even though subjects cover a wide range of nutritional states, there is a close relationship between FFM calculated from simple anthropometry and TBN measured by a technique requiring large sophisticated and expensive equipment.

Our work shows that FFM can be used as a reliable indicator of TBN; especially when groups of patients are being studied.

This project was approved by the Ethical Committee of the Leeds General Infirmary.

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