從 DEXA 及其它方法測出的無脂肪組織

Fat-free mass from dual-energy X-ray absorptiometry and from other procedures

Alex F. Roche, Shumei Guo, Rita Wellens, Wm. Cameron Chumlea, Xiaoyin Wu and Roger M. Siervogel

Division of Human Biology, Department of Community Health, Wright State University, Yellow Springs, OH USA.

Fat-free mass (FFM) values were obtained for 99 males and 114 females (8–68 years) who are participants in the Fels Longitudinal Study. These participants were assessed by dual-energy X-ray absorptiometry (DEXA) and by densitometry using (i) a multi-component model including measures of total body water (TBW) and total body mineral (Fels), (ii) a model with age- and sex-specific values for the density of FFM (Lohman), and (iii), a 2-component model (Siri). In males <25 years, the mean DEXA and Siri values were similar, but both were significantly smaller than the Lohman and Fels means. In females <25years, the mean DEXA values are smaller than those from the other methods. In men aged 25–54 years, the mean DEXA and Fels means showed good correspondence, but the Lohman and Siri means were significantly smaller. In women aged 25–54 years, the DEXA means were considerably smaller than those from the Siri, Lohman and Fels models. At ages >54 years, the findings are tentative because of the small sample sizes but they indicate that the DEXA and Fels means are similar in men and that both are larger than the Lohman and Siri means. In women aged >54 years, the DEXA, Siri and Lohman means are similar, but they are smaller than the Fels means. In another overlapping group (50 men; 78 women; 18–67 years), FFM was obtained from TBW and from the Siri method. The technical errors for TBW-Siri comparisons were 1.7 kg (men) and 1.8 kg (women) with large coefficients of reliability (87%, men; 90% women). It was concluded that DEXA estimates of FFM are not interchangeable with those from the other methods tested. These findings are relevant to the selection of methods for the measurement of body composition and the interpretation of the literature.

Introduction

Since the introduction of dual-energy X-ray absorptiometry (DEXA), many studies have addressed the accuracy of this procedure for the measurement of total body bone mineral (TBBM) and a few have compared other body composition values from DEXA with those from neutron activation. There is also a considerable literature relating values from DEXA to corresponding values from hydrodensitometry. In most of these studies, a two-component model was used to derive percent body fat (%BF) from body density. Much less attention has been given to comparisons based on other methods to obtain %BF from body density or on fat-free mass (FFM), despite the importance of FFM for health and function. Such studies are necessary. Although DEXA has advantages over hydrodensitometry in regard to compliance and precision, it has limitations in regard to body size. Furthermore, there is uncertainty about its accuracy for body composition measures other than bone mineral, partly due to a lack of data and partly due to incomplete disclosure by the manufacturers of the algorithms they employ.

To address some of the above topics, comparisons were made among values for FFM obtained from (i) DEXA, (ii) body density applying a multi-component model (Fels), (iii) body density applying gender- and age-specific values of the density of FFM (Lohman), and (iv) body density applying a fixed value for the density of FFM (Siri). Furthermore, estimates from total body water (TBW) in a sub-set were compared with those obtained from body density with the Siri model.

Subjects

The subjects included in this investigation were white participants in the Fels Longitudinal Study. Sample A (DEXA and body density measurements) included 99 males and 114 females aged 8–68 years. Sample B (TBW and body density measurements) included 50 males and 78 females aged 18–67 years. The Fels Longitudinal Study participants are a general population with distributions of anthropometric values similar to those for US national samples. It was necessary to exclude 15% of the adults because they were too large for DEXA measurements. These participants were either too tall (stature > 193 cm), their trunks were too large (width >59 cm or depth > 20 cm), or they had values for $\sqrt{\text{weight/stature}}$ that exceeded 0.7214. These limitations are recommended by the DEXA manufacturer (Lunar).

Methods

The DEXA measurements were made using Lunar equipment (Lunar Radiation Corporation, Madison, WI, USA) with version 3.4 software. This provided FFM and body fat as

Correspondence address: Alex F. Roche, Division of Human Biology, Wright State University, 1005 Xenia Avenue, Yellow Springs, OH 45387–1695, USA.

a percentage of soft-tissue mass. The latter value was converted to fat as a percentage of body weight (%BF). Body density was calculated from underwater weights obtained using load cells and basing the calculations on the mean from the last three trials if these were representative of all ten trials. Residual volume was measured on land using a computerized spirometer. Calculations of %BF,and subsequently FFM, from body density were made using the multi-component Fels model:

$$\%BF = \frac{(2.747 - 0.714\,W + 1.146B - 2.0503)100}{D_b},$$

where D_b is the density of the whole body (g/cc), W is the fraction of the body that is water, and B is the fraction of the body that is bone mineral. To apply this equation, TBBM was measured by DEXA and TBW was measured by dilution of deuterium oxide (D_2O). The concentration of D_2O was measured in saliva by magnetic resonance spectroscopy. This multi-component Fels model should adjust fully for variations in the density of FFM, but it is not free of errors because the measurements made are not completely precise.

Group values for the density of FFM that differ by gender and age have been suggested for ages 7–25 years[1]. These values were derived from a review of the relevant literature which is sparse. Smoothed versions of these values were used in the present study to calculate body composition values from body density[2]. This approach will be called 'the Lohman Method'. Additionally, Siri's equation[3] was applied:

$$\%BF = \frac{(4.94 - 4.5)\,100.}{D_b}$$

This model assumes that the density of FFM has a constant value of 1.1 g/cc. Finally, FFM was calculated from TBW with the assumptions that all the body water is in the FFM where it has a concentration of 73% and that 4% of the administered D_2O exchanges with non-aqueous hydrogen[4,5].

Findings

The individuals in Sample A were separated into three age groups (8–25, 25–54 and 54–68 years) although the numbers were small for the oldest group (Table 1). As expected, the means for males are larger than the corresponding means for females. In males, the means increase from younger to older age groups but in the females the means decrease from the group aged 25–54 years to the older group.

Table 1: Summary statistics for FFM (kg) in Sample A using the multi-component Fels method.

	n	Mean	SD
Males:			
8–25	54	43.3	15.9
25–54	32	60.4	6.1
54–68	8	63.3	4.6
Females:			
8–25	47	36.6	8.7
25–54	45	42.5	4.8
54–68	19	40.3	3.4

Differences were calculated between means for FFM from the Fels multi-component model and the means of values obtained from the DEXA method and when the Lohman and the Siri models were applied to the body density data. These differences are expressed relative to the values from the Fels method partly for convenience and partly because it is likely that the Fels method is the more accurate. Comparisons with the Lohman values were necessarily restricted to the 8–25 year age group.

The DEXA values were significantly smaller than the Fels values at 8–25 years in each gender and at all ages in the females, but the pairs of means were in good agreement for men aged more than 25 years. The Lohman values for those aged 8–25 years were significantly smaller than the Fels values for males but significantly larger for females. Although the Fels-Lohman differences were significant for each gender, the means differed by less than 1.0 kg. The mean Siri values were significantly less than the mean Fels values at all ages in men by amounts that varied from 1.09 to 1.99 kg. In women, the differences between the mean Fels and Siri values were not significant; indeed these means were remarkably similar for the groups aged 8–25 and 25–54 years. For each gender in Sample B, FFM values from TBW were significantly less than those from the Siri model when data for all ages were combined.

In each gender, coefficients of reliability between Fels and either DEXA, Lohman or Siri values were excellent at 8–25 years, good at 25–54 years but less (78–88%) at 54–68 years. Additionally, the technical errors for pairs of methods (Fels-DEXA, Fels-Lohman, Fels-Siri) were about 1.5 kg in each age group. These technical errors tended to be larger in the group older than 54 years.

Discussion

The present findings indicate that values for FFM from the Fels multi-component model exceed those from the two-component Siri model. This conclusion is in agreement with several reports for whites[6–9], but one study reported only a small difference for women[7]. In black women, however, FFM values from a multi-component model are smaller than those from the Siri two-component model[8,9]. Presumably, the density of FFM in black women exceeds 1.1 g/cc due to a greater bone mineral content.

Some studies of white men, in agreement with the present findings, have reported that DEXA values from Lunar equipment for FFM are larger than those from the two-component Siri method[10,11], but opposite findings have been reported by others[7,12,13]. There is, however, a tendency for DEXA values for FFM to be less than those from the Siri model when Norland equipment is used[12,14]. The only study of black and Asian men reported that FFM values from DEXA were smaller than those from the Siri two-component model[13]. There is evidence that the means for FFM from DEXA are smaller than those from the Siri model in white, black and Asian women[8,11,13,15] but some data support an opposite conclusion for white women[7]. Reported FFM estimates from

Table 2. Differences between mean estimates of FFM (kg) in Sample A by the Fels method and by other methods.

	Age (years)		
	8–25	25–54	54–68
Males:			
Fels-DEXA	1.67**	0.04	0.23
Fels-Lohman	0.69*	–	–
Fels-Siri	1.58**	1.09**	1.99**
Females:			
Fels-DEXA	1.82**	1.23**	1.11**
Fels-Lohman	-0.77**	–	–
Fels-Siri	0.35	0.08	0.82

*P<0.05; **P<0.01.

DEXA tend to be larger than those from TBW for white men but not for white women[7]. Among black men and Asian men and women, the DEXA values for FFM are smaller than those from TBW but there are no differences between pairs of corresponding values for black women[13].

The coefficients of reliability in the present study show close correspondence among methods at ages up to 25 years but the technical errors indicate that estimates of FFM by the methods considered are not interchangeable, especially at older ages. The present study was, of necessity, restricted to a sample in which body size allowed DEXA measurements to be made. Consequently, the findings from this study may not be applicable to those who are markedly overweight or have very large frame sizes.

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