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ESTIMATION OF BODY COMPOSITION BY WHOLE BODY VOLUMETRY IN HUMAN SUBJECTS

R. GUPTA AND P. S. SHETTY*

Nutrition Research Centre,
Department of Physiology,
St. John's Medical College,
Bangalore - 560 034

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INTRODUCTION

Body density measurements have been used since 1757 for studying body composition in human subjects. Robertson was the first to apply the Archimedes principle to underwater weighing (14). Behnke was however the first one to use a correction for residual volume and to obtain a good indiction of the fat mass by underwater weighing (2). Rathbun & Pace (12); Brozek et al (3) and Siri (13) evolved a series of equations for the estimation of percent body fat in Western subjects. These equations may however not be applicable to Indian populations.

Many workers have obtained body density by body volume measurements using water displacement method. Notable amongst these are Durnin and Satwanti (5), Chandraja & Bhardwaj (4) and Satwanti & Jones (10). In order to obtain some idea of body composition in Indians, we have measured whole body voulmes in a group of well nourished normal young adults using a volumeter, similar to that described by Jones et al (9), and modified according to Garn & Nolen (8). The whole body volume measurement does not require training of subects, is non invasive, relatively simple and a rapid nethod.

SUBJECTS AND METHODS

The volumeter consisted of a drum, (152 cms. high and 164 cms. circumference) as a main chamber. This was connected by a side tube to an angled read out scale kept at 30° to the horizontal. The volumeter was calibrated by successive addition of 1 litre of water and a calibration factor of 98 ml/mm was obtained. Our previous attempts to calibrate the drum by addition of 100 and 500 ml water increments were unsuccessful because the changes in water level produced were inconsistent and minimal. Temperature of water was kept at 37°C and water at the level of 0 in the side tube. A little Savlon was added to the water to disinfect and to reduce the surface tension of water, so that the time lag between changes in main drum and the side tube was reduced.

Twenty two normal healthy young males of age range 17-21 yrs volunteered for the study. They were given activated charcoal (Carbindon, Indo-Pharm) 300 mg 3 times a day for two days prior to the day of measurements. This was done to reduce to a minimum gastrointestinal gas content. They fasted over night and come to the laboratory at 8 a.m. after a shower and evacuation of bowels. Anthropometric measurements obtained prior to estimation of body density included height, nude body weight and skinfold at four sites (i e. biceps, triceps, sub-scapular and supra-iliac) using Holtain skin calipers. Body volume was measured at the end of maximal expiration in the whole body volumeter as recommended. Maximal expiration was ensured by observing the effect of respiratory excursions on water level in the read-out scale. Five measurements were made and the mean value was taken for the final calculations

Corresponding Author

Measured body volumes were corrected for residual voume. Assuming it to be 1.2 L and 200 ml for gastrointestinal gas.

Calculations: The following calculations have been used to derive body composition data from the body density measurements made:

(i) Body density (D) = $\dfrac{\text{nude body weight (Wt)}}{\text{corrected body volume } (V_c)}$

(ii) Percent body fat (% Fat) = $\left(\dfrac{4.57}{D} - 4.142\right) \times 100$ (3)

Fat content (in kg) = % Fat x Wt

Fat Free Mass (FFM in kg) = Wt − Fat content

(iii) Derivation of body density (D) from sum of the four skinfolds (Σ 4 i.e. sum of biceps, triceps, sub-scapular and supra-iliac); method suggested by Durnin & Womersley (6)

$$D = C - m \times \log \Sigma 4$$

Where C and m are age dependent constants

(iv) Derivation of body density (D) using Sen & Banerjee's equations (15)

Specific Gravity (SG) = 1.1034 − triceps skinfold × 0.002313

$$D = SG \times 0.9934$$

RESULTS

The mean (± SEM) age of the subjects who were studied was 18.0 ± 0.2 years. Their mean body weight (in Kg) was 56.1 ± 1.2 and their mean height (in cm) 171.0 ± 1.0. The measured body volumes of the subjects were corrected for the residual volume in the lungs and the corrected body volumes ranged from 43.24 to 63.59 L. The body density was obtained by dividing the body weight by the corrected body volume.

The body densities from skinfold measurements derived using Durnin and Womersley's equation as well as those derived using Sen and Banerjee's equation were compared with actual measurements made (Table). The differences in the means of body densities obtained from the measurements by volumetry and those derived by use of equations were not statistically significant. The Table also shows the men a data on percent body fat, total body fat and FFM. The estimated mean FFM was lowest by Durnin & Womersley's equation (1.57 kg less as compared to that estimated by Volumetry). However, the differences in the FFM obtained by the three methods were not statistically significant. The correlations between the two predicted FFMs derived from skinfold measurements and the actual measurements were good; when plotted against that obtained by Durnin & Womersley's equations they were r=0.925 while the correlations between FFM from volumetry and those based on Sen & Banerjee's equations were r=0.927.

DISCUSSION

Body composition studies using whole body densities are based on the assumption that the body consists of lean tissue and fat, which are intermixed but have fixed densities of their own. Lean tissue is in fact heterogenous and contains muscles, bones, ligaments, cartilage, etc. The density values are subject to alterations with altered nutritional status.

TABLE I : Comparison of body composition data (n=22) estimates made based by body volumetry with estimated on Durnin & Womersley's and Sen & Banerjee's equations.

	Estimated by volumetry	*Estimated by Equations*	
		Durnin & Womersley	*Sen & Banerjee*
Body density	1.072±0.002	1.066±0.002	1.075±0.002
Percent body fat	11.85 ±1.05	14.58 ±0.76	10.95 ±0.64
Fat content (kg)	7.09 ±0.68	8.36 ±0.57	6.27 ±4.68
FFM (kg)	49.32 ±0.95	47.75 ±0.82	47.75 ±0.82

All values are Mean ± S.E.M.

Our mean for body density at 1.072 is considerably higher than that reported by Krzywicki et al (11) of 1.060 for the same age group. It is however quite close to that reported by Sen and Banerjee i.e. 1.076 (15). Body fat as estimated by volumeter is considerably lower than that predicted by Durnin & Womersley's methoa which is known to overestimate fat in Indian subjects (1). Jones et al (10) have found body densities by volumetry in South Indian subjects to be 1.076, Rajputs 1.079 and Gurkhas 1.081; variations being mainly attributed to the different ethnic groups.

The level of expiration at the instance of body volume measurement is a crucial factor affecting the results, with higher residual volumes overestimated body fat. Welch et al (16) have reported significant lowering of body density at half maximal expiration as compared to full expiration. Durnin and Satwanti (5) have shown that levels of expiration, state of fasting or gastrointestinal gas do not significantly effect the results when acting singly, but may significantly influence results when they act simultaneously at extremes. Simultaneous mesurement of residual volume of Functional Residual capacity would however eliminate this source of error and give fairly accurate values.

Body volumetry being a simple, non invasive, rapid method, it could be used in the assessment of body composition of large population groups, even though an individual prediction of fat may not be as accurate because of the variability in their fat free masses.

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