PREDICTION OF BODY COMPOSITION FROM ABSORPTIOMETRIC LIMB SCANS

by

Richard Mazess
 Department of Radiology
 University of Wisconsin Medical Center
 Madison, Wisconsin

1159

It has been shown that absorption measurements at two energies can be used to measure the fractional composition of a two-component absorber, and this approach has been used to determine the fat and lean cellular mass of soft tissue (Mazess et al, 1970; Sorenson and Cameron, 1964; Preuss and Schmonsees, 1972). Absorptiometric scanning with low-energy nuclides to determine fat, lean-cellular, and bone mass in vivo has been developed at the University of Wisconsin Bone Mineral Laboratory. The relationship between these local measurements, usually on the limbs, and total body composition is unknown, but a high degree of association was expected since even poor measures of local composition, such as skinfolds or limb circumferences, are fairly highly correlated with total body composition. This preliminary report describes the results obtained in normally hydrated and dehydrated subjects.

Methods

Measurements were made on ten adult males at the NASA Ames Research Center. Anthropometric determinations, including skinfolds (Harpender caliper) and circumferences, were made on each subject. Subjects ranged from 6 to 33% body fat and from 66 to 126 kg in body weight. In addition measurements were made of total body water (deuterium oxide dilution) and body density (underwater weighing, with determination of residual volume). Absorptiometric scans were made with ^{125}I and ^{241}Am across the middle of the upperarm and the forearm, and across the lower part of the calf. At least two scans were done with each radionuclide at each site. Sites on both sides of the body were measured. Four of the subjects were remeasured after several days of voluntary dehydration in which they lost 1.6 to 4.0% of body weight, or 2.4 to 5.6% of body water.

Measurements were made on standards on about eight occasions (Table 1). There was a low coefficient of variation for "tissue" mass measurements, and slightly higher variation for "bone" mass measurements. More important, however, is the low variation (less than 1%) for the $^{125}\text{I}/^{241}\text{Am}$ absorption ratio which indicates the relative amounts of lean and fat. Previous studies also showed a long-term precision of about 1% for this ratio (Mazess et al, 1970).

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

rhp

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Table 1. Coefficients of Variation for Measurements of Standards

		n=7 <u>SMALL</u>	n=9 <u>LARGE</u>
125-I	TISSUE	.62%	.60%
	BONE	.55%	1.51%
241-Am	TISSUE	.60%	.46%
	BONE	2.88%	1.81%
RATIO	TISSUE	1.00%	.66%
	BONE	2.66%	2.53%

Results

There was only a slight difference between the right and left side determinations on the subjects (Table 2). The variation of tissue mass from ^{125}I or ^{241}Am scans was 3 to 4%, but this variability was largely anatomical as seen by the similar magnitude of variability in tissue width. The variability in $^{125}\text{I}/^{241}\text{Am}$ ratio, however, was quite low (1%) showing the relative uniformity of composition from side to side. Moreover the overall variability among the measurements of $^{125}\text{I}/^{241}\text{Am}$ ratio in these subjects was small (1%). There was little if any advantage to dividing the total mass by tissue width, nor was there any advantage to dividing the scan into peripheral or central segments. In contrast, there was a high variability in fat-fold measurement (15%).

Table 2. RMS variation between right and left sides on 14 determinations at three scan sites.

	<u>UPPERARM</u>	<u>FOREARM</u>	<u>CALF</u>
125-I	3.40%	4.02%	2.75%
241-Am	3.56%	3.87%	3.11%
Width	2.38%	2.46%	3.03%
RATIO	.64%	1.18%	.76%

Local absorptiometric measurements were highly correlated with total body fat as estimated by the formula of Siri (1956) from both density and total body water. The best estimate in the normally hydrated men was given by an average of all three scan sites; the dehydrated men tended to fall slightly below this regression line (Figure 1). The regression line itself deviated somewhat from the theoretical line. The upperarm scan was of major influence in predicting total body fat, the calf measurement was only moderately associated and the forearm measurement was even of lower degree of association (Table 3). The upperarm fatfold (average of both sides) was moderately correlated with total body fat, and the sum of eight fatfolds was very highly correlated ($r = 0.97$).

In dehydrated subjects the calf seemed most markedly affected and measurements at this site, and also at the forearm site, had a higher prediction error. Upperarm scans were not affected by dehydration and

MASTER

Figure 1. Relationship between average absorptiometric scan ratio and the percentage of body fat in 10 normally hydrated and in 4 dehydrated adult males.

Figure 2. Relationship between the absorptiometric scan ratio on the upperarm and the percentage of body fat in 10 normally hydrated and 4 dehydrated adult males.

predictability was just as good for data from dehydrated subjects (Figure 2). The correlation for all 14 determinations for upperarm ratio and body fat was 0.93 and the standard error of estimate was 3.2%. Fatfolds were also not affected by dehydration and their prediction accuracy remained high.

Table 3. Correlations between local measurements and percent body fat (Siri 1956), and the standard error of estimates in predicting body fat; measurements in ten normally hydrated men.

		<u>r</u>	<u>SEE</u>
SCANS	UPPERARM	-0.91	3.56
	FOREARM	-0.70	6.22
	CALF	-0.85	4.56
	3 SITES	-0.93	3.24
FATFOLDS	UPPERARM	0.86	4.45
	SUM of 8	0.97	1.96

It is interesting that the regression relationship between upperarm absorptiometric ratio and body fat is close to the theoretical relationship between this ratio and fat concentration. Theoretically at 100% lean the ratio should be about 2.10 while at 100% fat the ratio should be about 1.53; the values from the regression are 2.10 and 1.49. The forearm and calf scans have a different relation to body fat as does the average ratio derived from all three sites. The upperarm site seems to be the choice in terms of ease of measurement, highest precision, best prediction of total body fat, and close approximation to theoretical expectation.

The absorptiometric scans also permitted measurement of bone mineral content, and total skeletal weight was predicted from these scans as described by Mazess (1971). Total mineral weight in these adult males averaged 2817 g; this was 3.53% of total body weight and 4.38% of lean body mass. Total mineral and body water were used to calculate lean body mass; the density of lean body mass was 1.093 versus the usually accepted value of 1.10. The lower density was a result of the lower mineral weight in these subjects. Up until the present time it has been erroneously assumed that the total mineral is a much higher proportion of total body weight and of lean body mass, and no accurate prediction of mineral mass has been possible.

Discussion and Conclusions

Absorptiometric scans on the limb, especially the upperarm, are related not only to the local composition in the scan path but to the total body composition (as determined by indirect techniques). It has already been shown that absorptiometric determinations of lean-fat composition are very accurate and precise (1% error), and the present results show that they are representative of total body composition as well. Other local measures, such as fatfolds, when used with care are also very

highly correlated with total body fat. However, fatfolds are quite variable and cannot be determined with precision. There is a 15% side to side variation in fatfolds for example, and the long-term precision is even poorer. Moreover, the compressibility of adipose tissue varies with age and sex, and this together with anatomical variability means that the relationship between fatfold and total body fat will change with age, sex, nutritional status, and other factors. On the other hand absorptiometric determinations are very precise direct measurements of lean-fat composition, and it appears unlikely that the relationship between these measures and total fat will be appreciably changed by age, sex, or hydration. An additional advantage of absorptiometry is that bone mineral content is also measured and this allows a prediction of total skeletal weight; this value can be used to correct the prediction of body fat and lean body mass.

For surveys of nutritional status the fatfolds are obviously advantageous, but for quantitative research or clinical studies the more precise absorptiometric technique is preferred.

Acknowledgements

This research was supported by NASA Y-NGR-50-002-051, NASA Y-NGR-50-002-183, and AEC-(11-1)-1422 . The work was performed while the author was on a NASA Faculty Fellowship at Ames Research Center during the summers of 1970 and 1971. The aid of John Greenleaf, Don Young, Wayne Howard, Jim Bosco, and Laszlo Juhos is gratefully acknowledged.

References

1. Mazess, R. B., Cameron, J. R. and Sorenson, J. A., 1970. Determining body composition by radiation absorption spectrometry. Nature 228:771-772.
2. Mazess, R. B., 1971. Estimation of bone and skeletal weight by direct photon absorptiometry. Invest. Radiol. 6:52-60.
3. Preuss, L. E. and Schmonsees, W., 1972. ^{109}Cd for compositional analysis of soft tissue. Int. J. Appl. Radiation Isotopes. 23:9-12
4. Siri, W. E., 1956. The gross composition of the body. In: Lawrence, J. H., and Tobias, C. A., (eds). Advances in Biological and Medical Physics, Vol. IV. Academic Press, N. Y.
5. Sorenson, J. A. and Cameron, J. R., 1964. Body composition determination by differential absorption of monochromatic x-rays. In: Symp. Low-Energy X- and Gamma Sources and Applications. Technology Research Institute, Chicago. AEC Report ORNL-11C-5: 277-289.