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A scanning principle utilizing a dual beam of penetrating radiation and a new instrument designed to measure the fat to fat-free ratio of the soft tissue of the upper arm by differential absorptiometry were tested in 24 volunteers for short and long-term precision. Reproducibility of the adiposity measurements was generally good, and positive correlations were obtained with other variables such as weight and skinfold. Regional adiposity measurement by absorptiometry shows promise for clinical application.

This report describes a short-term, pre-clinical volunteer study designed to determine the usefulness of dual-beam absorptiometry, using an experimental instrument designed and built at Henry Ford Hospital which regionally measures the lipid content of the upper arm in vivo (1). We also correlated these values with other physiological parameters in order to evaluate the usefulness of the triceps muscle site as an indicator of total body adiposity.

Our laboratory has developed a method of and a device for analyzing in vivo the fat-to-lean ratio of mammalian tissue by using the x- and gamma rays produced by radioisotopic sources (2,3). Tissue samples containing different fractions of lipid absorb radiation according to fat content. Thus, a measurement of the absorption by soft tissue from a dual energy radiation beam indicates fat content.

By in vitro measurement of mammalian tissue and chemical lipid extraction, we have shown this method to be accurate and sensitive within ±0.01 of true fat fraction (4,5). At present, no equally simple means of accurately measuring fat-to-lean ratio in a body cross section exists. Although Lange calipers have been used to measure regional adiposity, they measure only the thickness of the subcutaneous fat layer or skinfold thickness; they cannot detect deeper lying, intermuscular fat. The radiation absorptive method is superior because it assays all lipid substance within the tissue section penetrated by the beam so that an accurate, quantitative value can be generated.

An automated instrument has been designed in our laboratory to give high reproducibility to the measurement. The beam source is Cadmium - 109, with dual emissions at 88 and 22 kev. The earliest experimental devices held the radiation source and detector rigidly in place while an in vitro sample was interposed. In later models, an in vivo scan was made, usually of the upper arm (6), but this method had a low precision level, due to the combination of patient movement and the configuration of fat, muscle, and bone in the arm. The present instrument eliminates this problem and accumulates lipid fraction data from a number of discrete points, stepped laterally across the triceps area, rather than from continuous scanning. Proper mathematical treatment of the data obviates errors due to anatomical configuration. In addition, two restraint devices minimize patient movement and improve precision.

The principal aim of this study was to define the reproducibility levels obtainable with this instrument and to test for speed of measurement and comfort to the subject.

Method

All 24 subjects were volunteers who gave verbal assurance of good health; 17 were men; 7 were women. Their ages ranged from 24 to 64 years.

The upper arm (triceps region) of each person was scanned approximately midway between the elbow and the shoul-

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der perpendicular to the long axis of the bone. The measurement was repeated three times, with the arm removed briefly between scans, to test the immediate reproducibility of the fat-to-fat-free tissue ratio (the average of these three values was used in later comparisons). A small reference mark was made on the arm to indicate precisely the tissue cross section of interest. Two other measurements—of arm girth with tape measure and of skinfold thickness with Lange calipers—were made at the index point. Other measurements recorded were height, weight, and waistline.

Each scan measurement lasted about 12 minutes. A more intense radiation beam could reduce this time significantly without increased dosage to the arm, for the shortened time would provide the same total photon exposure. Long-range reproducibility was tested by repeating the triple scan on 16 volunteers. Elapsed time between initial and repeat scans varied from 90 days to 13 months. Scan data were automatically recorded on a tape printout and later transferred to punch tape for computer processing.

Results

To determine short-term reproducibility, standard deviations for each of three individual scans were calculated; the maximum in any one set was 3.4%. The standard deviation was 1.5% or less in 62% of the cases. Thus, fat ratios are obtained with acceptable precision, and movement of the subject is not a serious source of error.

Long-term reproducibility is important because the change in regional adiposity must reflect an actual shift in composition and not random fluctuation. Twelve volunteers retained the same weight (other parameters were invariant) between the first and second measurements, and their fat values as determined by dual beam scan changed less than 1% over this time period (Fig. 1). As indicated by the close proximity of the identity and least squares lines, good correspondence existed between the percent lipid measured in the first and second scans. The slope of the least squares line is 0.93 and the coefficient of correlation between first and second measurement is 0.98.

To determine the relationship between lipid measurement and other body parameters, we measured skinfold thickness with Lange calipers. Although this method is not considered highly accurate, we found some correspondence between caliper measurements and differential absorptiometry (Fig. 2). However, a larger patient sample is needed to define the relationship more precisely. We also calculated the correlation between gross weight and arm lipid measurement by absorptiometry. For men, this was r = 0.79, indicating that the greater the body weight, the larger amount of fat in the arm. The correlation is not

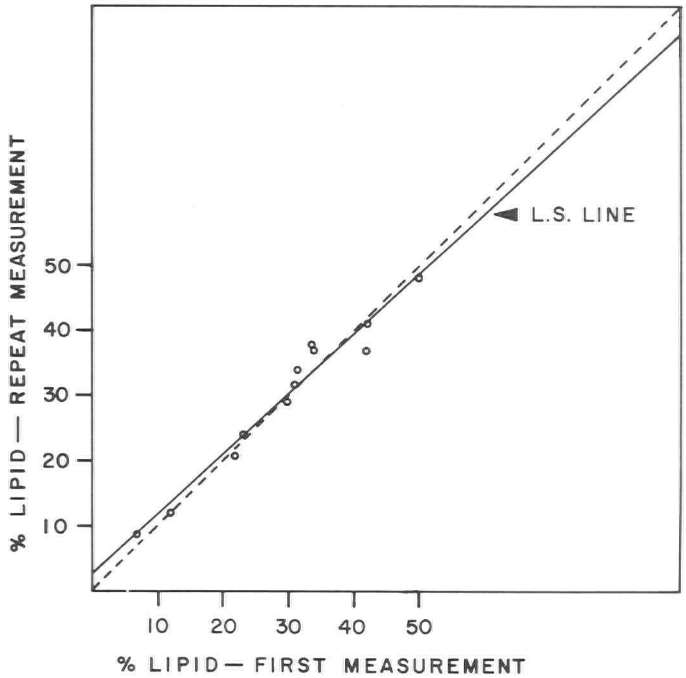

Fig. 1

Long-term precision (3-13 months) of triceps adiposity measurement by absorptiometry for 12 volunteers. Equality (dotted) and least squares (solid) lines are in near coincidence.

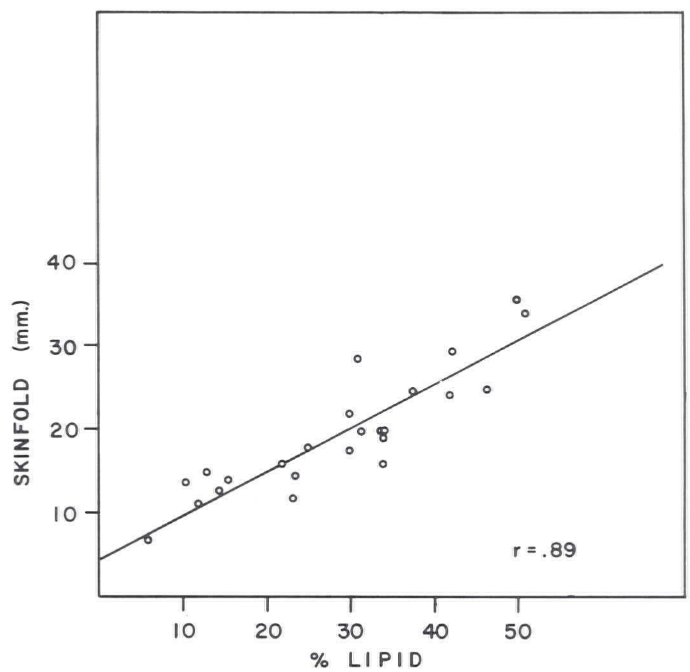

Fig. 2

Correlations between Lange caliper measurements and adiposity values obtained by differential absorptiometry for 24 volunteers, at the triceps muscle site. The correlation coefficient is 0.89. The plot should not intersect the origin, since the Lange caliper will always provide a positive value, even when there is essentially no subcutaneous fat layer.

striking, perhaps because variables of height, age, and health were not accounted for. However, for women the correlation was only r = 0.16. This low value may indicate that high arm lipid values are possible even for those with low weight, and that upper arm adiposity is not a good measurement site in women. Further studies should clarify this point.

Finally, Table I illustrates one use of this measurement in a long-term study of changing adiposity. Men were selected whose gross weight changed during the study in order to compare this change with their initial and final absorptiometry readings. There is a direct relationship between positive weight change and positive lipid fraction change. The relationship suggests that changes in arm section lipid by absorptiometry scan reflect overall body adiposity change, and that the dual beam triceps value has potential for use as a measurement of overall body composition and its change in men.

TABLE I

Long-Term Gross Weight Change in Triceps Fat for 11 Male Volunteers

Initial Weight	Final Weight (lbs.)	Initial Lipid	Final Lipid	Weight (lbs.)	Lipid %
200	180	29.9	22.3	- 20	- 7.6
160	155	22.1	21.1	- 5	- 1.0
215	210	42.3	41.3	- 5	- 1.0
182	182	30	29.2	0	- 0.8
200	200	34.1	37.3	0	+ 3.2
170	172	23.2	24.4	+ 2	+ 1.2
150	151.2	11.9	12.0	+ 1.5	+ 0.1
130	133	6.9	9.0	+ 3	+ 2.1
135	143.5	25.1	27.5	+ 8.5	+ 2.4
195	205	31	31.8	+ 10	+ 0.8
147	164	23.6	28	+ 17	+ 4.4

Summary

Our laboratory has made a preliminary study of the precision of the dual beam absorptiometric principle when applied to in vivo, regional human measurements. Although additional studies are called for, the results on reproducibility indicate that absorptiometric lipid measurement may confidently be used in long-term studies. This method of scanning is reproducible over short and long periods and offers the possibility of valid regional body composition measurements. Body composition changes may reflect such metabolic conditions and disease states as diabetes, endocrinopathies, obstructive lymphedema, dietary regimens, and hyperalimentation. More studies are planned to verify this conclusion.

In addition, a definite relationship seems to exist between upper arm lipid measurement made by the dual beam method and other body parameters, indicating that this measurement reflects overall body adiposity and can possibly be used as an aid in diagnosis and treatment.

Further studies are called for to clarify the correlation between in vivo regional lipid measurements and total body weight and adiposity.

Acknowledgment

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