Available data indicate an increase in body fat up to about age 50, with women gaining more than men. It is suggested that "the secret to a long life for a body pleasantly surfeited with fat may be found by studying older women."

Age Changes in Body Composition

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EVALUATION of age changes in the composition of the body is hampered by the inadequacy of current procedures for determining body composition. Although a number of techniques have been proposed, only a few of these have been validated by direct carcass analysis. Validation has been done only on experimental animals.

In order to simplify the problem of determining body composition, the body may be said to be composed of the skeleton, fat, and fat-free tissue (muscle). For any individual, the weights of the skeleton and of fat-free tissue appear to be fixed within relatively narrow limits. The weight of body fat, however, covers a relatively wide range.

The methods used in determining body composition provide, at best, estimates of the size of either the fat or fat-free tissue. Either one or both of these components may be measured, but usually only one is determined. The mathematical equations that have been developed for computing the percentage composition of the body contain factors that make allowances for the weight of the skeleton. Minerals are one of the chief components of the skeleton, but since minerals account for a relatively small percentage of the body weight, any variation in the size of this component will have only a minor influence on body composition.

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Although it would be desirable to know the changes that occur with age in all body components, most of the work in the field of body composition has been concentrated on determination of the amount of fat. This stems from the interest engendered during the past few years in obesity in general. Changes in the skeletal mass have been largely neglected.

On the basis of clinical experience it has been proposed that changes do occur in the skeletal mass. Many clinicians working in the field of geriatrics are impressed by the fragility of the bones in their older patients. This has been assumed by some to be due to a negative calcium balance, with a consequent depletion of bone minerals. However, a recent study suggests that "the onset of bone fragility in the aged is a composite effect of many factors and is probably more intimately related to endocrine changes, decreased activity, and loss of muscle tone than to level of nutrition" (*1*).

Methods of Determining Body Composition

A brief review of some of the procedures proposed for determining body composition will give some idea of the limitations and difficulties in this field. Although there are a number of methods for estimating the composition of the body, none of them is ideal. Each procedure has its limitations. The method that has been used most frequently as a reference or standard is the densitometric technique based on weighing the individual under water.

Because of its simplicity, comparison of the individual's height and weight with values listed in standard tables is probably the most commonly used procedure for obtaining crude estimates of body fatness, and thus, indirectly, of body composition.

Standard Height-Weight Tables

The height-weight tables most often used for evaluating body fatness are those compiled by the Association of Life Insurance Medical Directors on the basis of medical examinations performed on individuals applying for insurance during the years 1885 through 1910 (*2*). One of the most serious limitations in using these tables is the absence of a correction factor for the clothing and shoes worn by the individuals who were weighed (*3*). Another limitation is the disagreement as to the deviation in weight that must occur before an individual is considered obese. Values ranging from 5 to 20 percent have been proposed as the upper range of "normal" body weight for any height.

These tables make no allowance for variation in body build. Keys and Brozek (*4*) have shown that the variation in body build could be illustrated by the data of Munro (*5*). Munro found that the groups of selective service registrants of the same age and stature who had chest circumferences of 32, 37, and 42 inches had average weights of 130, 158, and 198 pounds, respectively. In general, the heaviest men had the largest body frames; yet the height-weight tables suggested only one weight (150 pounds) for individuals of this height. When compared with the values in the table, the men with the largest body frames would be as much as 36 percent overweight. That all of the heaviest men were not obese is suggested by the work of Welham and Behnke (*6*). Using the densitometric technique (described below), they found that professional football players who were in peak physical condition were 20 or more percent overweight according to the standard height-weight tables. However, on the basis of body density, these "overweight" men had very little fat in their bodies. If obesity is defined as a condition in which there is a surplus of body fat, these men obviously were not obese.

Subcutaneous Fat Determinations

Body fat has also been estimated from the thickness of skinfolds on various parts of the body. The skinfold is "lifted up" with the fingers from the underlying muscle. A variety of calipers are available for quantitating these measurements. This procedure is based on the observation that in man a large proportion of the total body fat is found in the subcutaneous tissue (*4*).

Unfortunately, there are practically no data on human beings to indicate the relative distribution of fat throughout the body in the lean and the obese. X-ray evidence is available for rats which became obese as a result of an ad libitum consumption of a high-fat diet (*7*). These rats, compared with their littermates fed a low-fat diet, showed a tremendous increase in the amount of fat in the subcutaneous area (see illustration). Associated therewith is a marked increase in the amount of fat in the abdominal cavity. The lean rat shows a proportionately smaller amount of fat, not only in the subcutaneous areas but in the abdominal cavity as well. Comparable data for guinea pigs have been presented by Pitts (*8*). The mass of the subcutaneous fat in the guinea pig was almost directly proportional to the total body fat.

The most extensive evaluation of the skinfold-thickness method for determining body fat has been made by Keys and Brozek (*4*). In their study the skinfold thickness at a number of sites on the body was determined for a large number of subjects. At the same time, total body fat in each subject was estimated by the densitometric method. On the basis of these measurements equations were developed for estimating the body fat from the skinfold thickness (*9*). Similar work has been done by Pascale and others (*10*, *11*). The equations provide values which at best only approximate the body fat content as calculated from body density. A partial explanation for the inconsistent body fat values derived from the skinfold measurements stems from the finding that there is considerable individual variation in the distribution of subcutaneous fat throughout the body (*4*).

A few attempts have been made to determine the amount of fat in the body from X-rays of

X-rays of lean and obese littermate rats.

selected areas. Stuart and co-workers (*12*, *13*) have used X-rays of the antero-posterior view of the right leg at the maximal width of the calf. These studies were confined largely to children. Reynolds (*14*) has extended this technique to the study of adults. He reported that the ratio of thickness of adipose tissue to bone width of the leg is much greater in women than in men. The ratio decreases with age in men but increases in women.

A recent report by Garn (*15*) on the fat content of adults as determined by X-rays suggests that there is very little difference in the absolute amount of fat in men and women. Since the body weights of the women were considerably lower than those of the men (58.3 as compared with 76.4 kilograms), the percentage differences in fat content were significant. Garn found that the average weight of fat in 107 healthy American women ranging in age from 20 to 60 years, with a mean of 39 years, was 13.7 kilograms, while that in 81 men in the same age range was 12.6 kilograms. The fat content of the women was 23.7 percent, for the men 16.8 percent.

Densitometry

A procedure that has been studied rather extensively during the past few years determines body density and, from this, the relative composition of the body. The difference in density of body fat and the fat-free residue is great enough to permit calculating the amount of fat in the body from the body's density. This density has been determined by two different methods.

One method of determining body density is based on weighing the subject under water. This procedure received its greatest stimulation as a result of the studies of Behnke and co-workers (*16*). The technique is fraught with difficulties. The primary one is the inability of readily determining the residual air and the air that may be retained in the gastrointestinal tract at the time of the underwater weighing. Body density can be corrected for residual air, but to do it accurately would make the determination both cumbersome and time-consuming. A standard correction cannot be made for residual air since there is considerable variation among individuals, as well as an increase in the absolute residual air volume with increasing age (*4*). A second difficulty is trying to weigh under water an individual who has any fear of being submerged. The latter is likely to be important with older people, especially those who have never learned to swim.

The other method for determining body density involves measurement of the body's volume. The volume of the body can be calculated by the displacement of helium in a chamber of known volume. This method has been used by Siri (*17*) for human beings and by Walser and Stein (*18*) for animals.

Theoretically, the gas-displacement technique should be far superior to the underwater-weighing procedure since any air in the lungs at the time of measurement should have practically no influence on the density. The anxiety associated with the method should be minimal. To what extent this modification of the densitometric method will be used is at present hard to predict.

Wedgewood and Newman (*19*) modified the Drinker respirometer so that the volume of the subject can be calculated from the changes in pressure associated with the pulsations of the bellows. The sensitivity and applicability of this technique have yet to be assayed.

Body Water

There are many data showing that in normal animals the relation between the amount of water and the amount of protein is fairly constant (*20*). The fat-free weight of the body can be calculated on the basis of this relationship. Since the minerals represent only a small fraction of the body (*21*, *22*), slight variations in this component have a negligible effect on the results. The difference between the body weight of the individual and the calculated value for fat-free body tissue represents the weight of body fat.

A number of substances, such as urea, thiourea, deuterium oxide, tritium oxide, antipyrine, and acetylaminopyrine, have been used in estimating body water. (For discussion of the various techniques and references thereto, see reference 4). A known amount of the substance is given by mouth (urea) or injected intravenously (the other substances). Blood samples are taken at intervals and analyzed for concentration of the injected substance. Total body water content can be calculated from the concentration of the substance in the blood at the different time intervals and the amount of the substance given. All the methods require from 1 to 3 hours for uniform distribution of the compound throughout the body water. The procedures necessitate all the care and safety precautions used in any intravenous therapy.

There are a number of situations in which the relationship between body water and protein deviates from the usual ratio. In most of these cases, especially those associated with edema, the abnormality is due primarily to a marked increase in the extracellular fluid. By determining the volume of the extracellular fluid as well as total body water, a correction can be made for the abnormal hydration. Recent work indicates that the extracellular fluid space as measured with thiocyanate decreases steadily from a little more than 40 percent in infancy to a constant value of 23 percent in adulthood (*23*).

Fat Solvents

Cyclopropane has been used at New York University for estimating the amount of fat in the body directly in studies with rats (*24*). The air the animal inhales contains a known amount of cyclopropane. The volume of gas retained in the body is proportional to the amount of fat in the body. So little has been done with this procedure, however, that it is difficult to evaluate its applicability and usefulness in studies with man.

Factors Influencing Body Composition

There is surprisingly little factual information on the changes that occur in the human body as it grows older. All of the studies have compared young individuals with older people. Since so many years separate a man's youth from his old age, it is doubtful whether there will ever be any extensive longitudinal studies on adults to bridge the present gap.

Influence of Age

The height-weight tables of the Association of Life Insurance Medical Directors indicate that a half century ago both men and women continued to increase in weight even though there was no change in height as they became older (*2*). Changes comparable to these are still occurring. Recent data show that from age 25 to 60 years men in the United States who are 67 inches tall gain 8 percent in weight, while women of the same ages who are 63 inches tall gain 15 percent (*25–27*).

It has frequently been assumed that the increase in body weight with age is primarily, if not solely, due to an increase in body fat. Evidence for this assumption has been presented by Brozek (*28*), who compared a group of young men (18–25 years) with older men (45–54 years). Although the average heights for the two groups were the same, the older men were, on an average, 11 pounds heavier than the younger men. Underwater weighings corrected for residual air at the time the weights were recorded showed that the younger men had 14 percent fat in their bodies while the older men had 24 percent.

The increase in body fat associated with the increase in body weight that accompanies the aging process is accentuated by the apparent replacement of a certain portion of muscle mass with fat, according to evidence adduced by Brozek (*28*). Thirty-three young men (22 through 29 years) and an equal number of older men (48 through 57 years) were matched for height and weight. Specific gravities indicated that although there was no difference in height or weight between the two groups, the younger men had 16 percent fat in their bodies while the older men had 23 percent.

Influence of Activity

Physical activity, especially if it is strenuous, is associated with a marked reduction of body fat even though the body weight may be considerably in excess of the "standard" as listed in height-weight tables. Welham and Behnke (*6*) emphasized this point in their studies with younger men. Brozek (*28*) and Brozek and Keys (*29*) found a similar situation among older men. The physically active men were seven pounds heavier than the inactive men even though the heights were the same in both groups. However, the heavier body weights were associated with a lower body fat content (24 percent as compared with 27 percent).

Males vs. Females

Garn and Harper (*30*) have studied the distribution of fat in males ranging in age from 20 to 69 years by means of roentgenograms. Thickness of the subcutaneous fat over the iliac crest showed the greatest increase with age. Fat in the trochanteric and deltoid regions also increased, but to a lesser extent than that in the iliac region. There were no measurable changes in the thickness of the adipose tissue on the anterior surface of the leg and the middle area of the lower arm. On the basis of the amount of fat in the trochanteric area, Garn and Harper estimated that the body fat increased from 16 percent in younger men to 22 percent in older men. These values are similar to those reported by Brozek (*28*).

For women the total body fat increased from 26 percent at age 25 to 38 percent at age 55, as shown in the tabulation. These values were for women whose body weights were, on an average, from 95 to 97 percent of those listed in the standard height-weight tables (*31*). When these values are compared with those for men equally lean according to the standard height-weight tables, it is obvious that the body fat content of women is much greater than for men at each age group.

Age (years)	*Total body fat (percent)* Men	*Total body fat (percent)* Women
25	13.1	26.5
35	17.3	30.5
45	21.6	34.5
55	25.9	38.5

NOTE: Percentages were calculated using a linear prediction equation based on the least square fit of the values obtained by the densitometric method corrected for residual air (*31*).

In women, the increase in body fat with age is associated with an increase of the fat in the abdominal area (*32*). Since this conclusion was based on skinfold measurements, it was not possible to determine whether the increase in inner fat was due to the fatty infiltration of the organs. There was little change in the skinfold thickness of the extremities with age in women, but there were marked changes in the thickness of subcutaneous fat on the chest, side, waist, and back.

Edwards (*33*) determined the skinfold thickness in 53 areas of the body in males and females ranging in age from 5 to approximately 50 years. He found that the distribution of fat in the different parts of the body was the same in both sexes before puberty. After puberty, women had about 1.2 times as much fat on their legs, in proportion to the total amount of subcutaneous fat, as men. In all groups, the women had approximately 1.7 times as much fat in the subcutaneous areas as the men. It is difficult to determine from these data any absolute changes that occur with age.

Conclusion

Factual data on body composition are notably scarce. What we have indicate an increase in body weight up through approximately age 50 and a decrease thereafter (*28*). There are no data which indicate that the weight of the individual decreases after age 55.

The difficulty with the reported body weights of older people is the impossibility of determining whether the decrease in weight is due to the earlier deaths of the heavier individuals or represents an actual loss of weight with age. Although there is an increasing body of data from longitudinal studies of children, such information is woefully lacking for adults, especially for individuals over 60 years of age. Only longitudinal studies permit determination of the actual changes that occur with age.

Few studies bear upon changes in body composition occurring in women with the passage of time. The prominent attention that obesity has received during the past few years would make such studies desirable. The work of Skerjl and others (*32*) indicates that in older women of "standard" weight, more than one-third of their body is fat. Even under that "stress," if it is stress, women outlive men by a significant number of years. This suggests that the secret to a long life for a body pleasantly surfeited in fat may be found by studying older women.

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