IN THE absence of obvious clinical signs of malnutrition, accurate assessment of the nutritional status of individual children may be difficult. Graphs and tables used by physicians to evaluate linear growth and weight of children distinguish poorly those on the margins of normality. For this reason other methods of measurement have been sought. Skinfold thickness has been proposed as a useful index of obesity since the subcutaneous adipose tissue is a major component of body fat. Because the state of caloric equilibrium and the volume of fat stores are related and because this method is being applied increasingly to assess the adiposity of adults, the Committee on Nutrition has reviewed the available results of such measurements and on this basis evaluated both its usefulness and limitations when applied to children.

The thickness of skin and subcutaneous fat can be measured with calipers or by roentgenograms. The construction and use of calipers for measuring skinfold thickness have been standardized to a certain extent during the past decade; however, relatively few data obtained from normal children in the United States have been reported.

DATA CURRENTLY AVAILABLE

The triceps area is ideally accessible to measurement of two thicknesses of skin-plus-subcutaneous fat. The relation between age and triceps skinfold thickness has been assessed in children from different populations. In the past decade, Parizkova reported such measurements in Czech boys and girls, compared the results with other anthropometric parameters, and evaluated the predictive value of each for determining body composition. Unfortunately, the data were grouped unusually; comparison with other available data was difficult. Skinfold measurements in British and Canadian children between 2 and 16 years of age have been published. Recently, Rauh and co-workers determined the triceps skinfold thickness in some 1,500 Cincinnati school children. These children comprised a subgroup of a sample of 10,000 school children in whom height and weight were also measured.

The triceps skinfold thicknesses of school children in Canada, Britain, and the United States (Cincinnati) are shown in Table I; the 10th and 90th percentile values at various ages in boys and girls are plotted in Figures 1 and 2, respectively. It is of interest that the shapes of all three curves of the 90th percentile data are similar while this is not true of the 10th percentile curves. In the latter curves, there is a marked difference between the data from England and the other two samples. Only in the case of the Cincinnati children are the shapes of the 90th and 10th percentile curves comparable. It is apparent that the 90th percentile of the Cincinnati group coincided with the "obese" designation by Mayer.

CORRELATIONS BETWEEN HEIGHT, WEIGHT, AND RELATIVE FATNESS BASED ON SKINFOLD THICKNESS

Obesity or leanness, as measured by skinfold thickness, should be defined in relation to normal values for age peers as well as to the subject's weight and height. However, even these simple anthropometric variables, when studied in relation to time, geography, and ethnic origin, are found to be influx.

In 1965 median weights of Cincinnati school children were consistently above the median values of norms in the Iowa
American children are somewhat heavier today than they were 25 years ago in Iowa or 10 years ago in Canada and Great Britain. Although average heights for girls remain the same, boys, after the age of 14 or 15 years, are now slightly taller than they were 25 years ago. Garn has presented evidence to support the contention that, for well nourished populations, secular trends in body size are diminishing. Bakwin and McLaughlin have also discussed this topic. The relation of body weight to height provides some clue to the relative fatness of the individual, but the changes in normal habitus identified previously indicate some of the difficulties inherent in attempting to relate skin thickness measurements to levels of obesity or leanness.

The relation of skinfold thickness, at least in obese children, to body fat content is virtually independent of height. It has been suggested that a grown individual between 20 and 30 years of age may be considered obese if only his triceps skinfold thickness exceeds one standard deviation above the mean normal value calculated for his age. Triceps skinfold thicknesses which indicate childhood obesity to some writers are given in Table II. These data suggest that 16% of the population less than 30 years old is obese. These values (Table II) approximate the 90th percentile values (Fig. 1 and 2) and Table I of the Cincinnati male children studied by Rauh and coworkers. By way of reference, a 10% incidence of obesity in the Cincinnati school children was estimated from an analysis of the cross-sectional distribution of physique-types based on the Wetzel Grid. How often might one note skinfold thickness above the 10th percentile in individuals suffering from chronic caloric undernutrition? This would seem to be an unlikely occurrence. On the other hand, well nourished and normally growing children engaged in athletic activity requiring intensive training may well be found to have amounts of subcutaneous fat which is similar to that found in undernourished individuals.

### TABLE I

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* Percentiles.

### TABLE II

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<th>Age (yr)</th>
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* Values given in millimeters.

† Percentiles.
THEORETICAL OBJECTIONS AND PRACTICAL LIMITATIONS

If estimates of body fat from a measure of subcutaneous fat tissue are valid, they must reflect volume dimensions. Unfortunately, changes in tissue thickness in an extremity cannot necessarily be equated with a change in the total volume of the tissue. For example, an increase in length of the extremity may more than compensate for a decrease in thickness of the soft tissue at a time when the total amount of soft tissue in the extremity has actually increased. The circumference of an extremity summates the contribution of the individual tissues (bone, muscle, and subcutaneous fat), and the proportion of each must be taken into account when estimating tissue volumes. Interpretation of skinfold thickness is based on the assumption that the major variable measured is subcutaneous fat. However, in addition to the subcutaneous fat, the caliper measures the thickness of the dermal layer. In a thin person, the two-skin thicknesses incorporated in a skinfold account for more than half the total skinfold thick-

Fig. 1. Triceps skinfold thickness, white males. The lines have been smoothed for illustrative purposes. The X's refer to the "lower level of triceps skinfold thickness indicating obesity" according to Mayer. Measurements were made on from 60 to 80 boys or girls in each age group in the Cincinnati study, and approximately two-thirds of these children were Caucasian.
ness; in obese individuals, the subcutaneous fat accounts for a high percentage of the thickness. Differences in skinfold compressibility with increased age complicate the interpretation of apparent changes in thickness in adults. The same may be true in childhood. One of the consequences of aging is a decrease in the thickness of the dermal layer due to atrophy of connective tissue.

The thickness of subcutaneous fat in an arm or leg does not necessarily reflect the amount of fat present elsewhere, e.g., within the abdominal cavity. Sex differences in the distribution of subcutaneous and internal fat are obvious in adults and occur in prepubescent subjects as well, but the differences are not so marked in the first decade. Unfortunately, body density is more difficult to measure in children than in adults and, as an index of total body fat, body density is more imprecise in children since the individual contributions of bone, muscle, and fat vary with age.

Most evidence which has been marshaled in support of using skinfold measurement to estimate total body fat has been based on correlations between skinfold thickness and whole body density, total body water, or body potassium. Most of these studies have...
been carried out in adults and might be acceptable if the densities of lean and adipose tissue in adults were constant. The prerequisite is essential since calculation of body fat from whole body density (or body water or potassium) is based on these assumed constants. There are obvious situations (e.g., osteopetrosis and osteomalacia) and some less common examples where such constancy cannot in fact be assumed.

There is generally an inverse relation between skinfold thickness (relative fatness) and a number of measurements of body composition, including body density, specific gravity, total body water, or estimates of total body potassium determined from potassium-40 or exchangeable potassium; it is at best, however, a first order approximation of body fat and may provide only a crude index of adiposity.

It is virtually impossible to obtain the precise relation of body density to body composition in humans unless the latter is determined by carcass analysis. However, as larger numbers of growing animals are studied by direct and indirect methods of measuring body composition, we may be better equipped to interpret indirect studies in growing children. Hankins and Ellis found a close relationship between the average back fat thickness and the percentage of the ether extractable fat of the swine carcass \( R = 0.84 \). Lynch and Wellington found a relation between percent whole body fat and specific gravity of the grown living hog, expressible in the equation \( Y = 536.3 - 493.8 \times \) where \( Y \) is percent of fat and \( X \) is specific gravity. They found a correlative coefficient value of \( R = .707 \). For the relation between specific gravity of the living hog and back fat thickness, they found an \( R \) value of \( -0.78 \). However, there are very few studies of this nature dealing with immature and growing pigs.

It is interesting to contrast the skinfold thicknesses and body fat estimates reported by Forbes, et al. with those of Crook et al. The study by Forbes et al. includes children 7 years of age while in the latter study all subjects were over 18 years of age. Forbes noted skinfolds between 2 and 10 mm in subjects whose fat content was estimated from K-40 to be between 15 and 40%; in the older age group studied by Crook, et al. similar skinfold thicknesses were equivalent to between 7 and 17% fat content in the body.

Young has reviewed the difficulties encountered in deriving an estimate of an individual's body fat from a skinfold measurement. Equally difficult is the estimation of body density from skinfold measurements. There is simply insufficient information on the physiologic changes in density of tissue components of the human body during childhood to be able, in population studies, to interpret the significance of correlations between skinfold thicknesses and total body density or the other measurements mentioned here; likewise, insufficient data are available in children to translate either density measurements or skinfold thickness into estimates of body fat in the case of an individual.

**CONCLUSION**

Standardized techniques for caliper measurement of skinfold thickness have been established during the past decade and investigators are accumulating data. The skinfold thickness appears to serve as an indicator of relative fatness in adults in whom correlations between this and other methods which estimate body fat have been obtained. Even in adults insufficient data are available to judge the precision of the method. Uncontrolled variables such as skin compressibility and the normal flux in subcutaneous fat thickness characteristic of growing subjects may reduce the significance of measurements in early life. Although this technique may ultimately provide a practical clinical tool for assessing adiposity of individual children, basic reference data must be accumulated before either the precision or the usefulness of the method can be established.

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**David Baird Cousin, M.D.**

**Felix P. Heald, M.D.**
REFERENCES

MEASUREMENT OF SKINFOLD THICKNESS IN CHILDHOOD

Pediatrics 1968;42:538

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MEASUREMENT OF SKINFOLD THICKNESS IN CHILDHOOD

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