and concentrated fish oils so that more information on the dietary requirement of both α-linolenic acid and of long-chain polyunsaturated n-3 fatty acids can be obtained.

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Three limitations of the body mass index

Dear Sir:

In a recent editorial entitled "Three limitations of the body mass index," Garn et al (1) clearly discussed the characteristics of body mass indices (weight/stature) that present serious limitations in analysis and interpretation of weight and stature in data sets that do not include other anthropometric dimensions. As Garn et al (2) and others (3, 4) have previously observed, total body fat is highly correlated to weight but is independent from stature in adults (although not in children). Because weight is highly correlated with stature, it may be useful to develop an index of weight that is independent of stature. As clearly pointed out by Garn (1) and illustrated in our concurrent article (5), the Quetelet index (weight/stature^2), often called the body mass index, is not independent of stature in all sex and age groups. However, Garn did not consider that it is possible to minimize this limitation of body mass indices (BMIs), viz, correlation to stature, by determining the appropriate exponent for stature for a given population (5). Other BMIs can and should be determined for sex and age groups that remain independent of stature while remaining highly correlated with weight (5).

Secondly, Garn is also correct in stating that BMIs reflect both fat and lean body mass. The correlations of BMIs that are independent of stature in various age and sex groups in NHANES I and II with various indirect estimates of body fatness (eg, subscapular skinfold thickness, arm fat area) range from 0.72 to 0.85, while correlations with estimates of lean body mass (arm muscle area) range from 0.63 to 0.71 (5). We suggested that the correlations of BMIs with arm circumference (representing both fat and lean tissue) are higher than those with triceps skinfold thickness (representing fatness alone) because of the possible unreliability of skinfold measurements. However, it is clear that the contribution of lean body mass itself to the body mass index is also consistent with this observation. Nonetheless, BMIs represent body weight (whether due to lean or fat mass) corrected for stature.

The concept of weight (lean and fat) controlled for stature remains useful in consideration of Garn's (2) earlier observations that during childhood and adolescence fatter individuals are also taller, developmentally advanced (ie, will mature earlier) and have more lean body mass than less fat individuals. Garn's third limitation (1), that BMIs reflect relative sitting height (sitting height/stature), is also very instructive here. The developmental period when the lower body grows proportionately faster than the upper body is of shorter duration in individuals who mature early (6). Thus, those individuals who are developmentally advanced and presumably taller, heavier, and fatter (with more lean body mass and greater BMIs) at a given age during development, would also be expected to have greater relative sitting height at the time of maturity. Because stature, sitting height, and skeletal frame size become relatively fixed after maturation, relative sitting height may be useful in discriminating adults who experienced a particular pattern of growth and development during childhood and adolescense. In accordance with this pattern, adult frame size is also correlated with BMIs: eg, $r = 0.36–0.56$ for elbow breadth (5). Thus, the latter two limitations of adult BMIs described by Garn may partially be a reflection of the characteristic patterns of growth and development in individuals. Discrimination of individuals based upon early experiences that may effect growth and development (eg, nutrition) currently appears important in epidemiologic studies of breast cancer (7) and other diseases.

However, regardless of the biological relations or statistical characteristics of BMIs, their appropriate use does not replace the need to collect additional anthropometric data beyond weight and stature in order to adequately describe the biological characteristics of human populations or test hypotheses regarding the relations between nutrition, growth, body size, and disease.

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Reply to letter from Miccozi and Albanes

Dear Sir:

The printed comments by Micozzi and Albanes and MacLaren (1) both show and letters written directly to us also confirm that there is wide disaffection for the body mass index (BMI) and similar ratios of weight and height. As one caller complained, weight divided by height squared is not even Quetelet's index, as originally described! Wt/ht, wt/ht^2, wt/ht^3, and their various transformations cannot separate the weight of fat from the weight of lean tissue (2), which is why Behnke introduced hydrostatic weighing four decades ago.

Similar limitations attend weight, relative weight, and percent of standard weight as measures of leanness and/or fatness. Many underweight children and adults are deficient in the lean body mass not in the weight of fat. Conversely some *overweight* women are, like many athletes, actually low in fat and scarcely need to diet (3). There are far better approaches to body composition than weight affords.

It is true that such indices as the BMI can be improved for particular applications by generating population-specific exponents, as with the Benn index, of recent popularity (4). However, this suggestion fails to point out that exponents which approximate 1.0 are scant improvement over the unadorned indexes, though more impressive.

There are situations where weight and length are the only measures that were taken and it may be useful to regress weight on length and then express the residuals. However the residuals from the regression lines are no substitute for direct approaches to one tissue compartment or the other. Though the measurement of subcutaneous fat in the form of compressed double folds of fat plus skin may seem simplistic compared with electrical impedence measurements, it is fortunately true that most of the fat in the human body is just beneath the dermis (5). Of course, anthropometric measurements other than weight and length are to be desired, granting that all measurements on human beings are properly *anthropometric*.

There is a finite limit to what can be accomplished with weight and length alone, however these two variables are juggled as an index or plugged into regression equations. Though there is a convenience in using weight and length alone in nutritional epidemiology, this entails a loss of crucial information bearing on morbidity, mortality, and reproductive efficiency as well.

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