Current perspective on assessment of human body proportions of relevance to amputees

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ABSTRACT

Weights of segmental components of the human body are important when evaluating the nutritional status of an amputee. Original standards for components were compiled in 1889 using three male cadavers. Since that time, studies of living subjects have shown men and women to be similar in percentage weight of body components. Cadaver data from 1955 and 1969, which were based on 21 male subjects, showed that human bodies carry greater weight in the head and torso and less weight in legs and arms than indicated by the earlier data. Some differences in component weight may be attributable to ethnicity and aging, but further research is needed to define these differences. The 1955 and 1969 data — whether the result of larger sample size, ethnic differences, or actual change in human body proportions over a 60-year period — are different from the standards for body proportions in the 1889 data, which are presently used, and should be incorporated into the assessment of weight status of amputees. *J Am Diet Assoc. 1995; 95: 215-218.*

As part of the patient evaluation process, the health care provider takes various physical measurements of each patient. Height and weight are physical parameters that are included in a patient's medical chart and are updated on an ongoing basis. Body weight, in particular, is used in prescribing drugs, assessing fluid status, and determining adequacy of nutrition intake.

For a clinical dietitian, a key factor in assessing a person's nutritional status is evaluation of that person's present body weight relative to ideal body weight. The situation is more complex if the person being evaluated has a missing limb or missing component of a limb as a result of diabetes, cardiovascular disease, or trauma. An illustration from Brunnstrom's text (1) is often cited as a basis for estimating body proportions in many nutritional resource handbooks (2,3).

The purpose of this article is to review these, and other data relative to estimation of body proportions, and to ascertain appropriate guidelines for use in clinical practice.

BODY CONSTITUTION DATA

In 1889 in Germany, Braune and Fischer (4,5), who were studying the center of gravity for the human body, weighed the body components of three adult male cadavers. The age of one was unknown and the other two were 45 and 50 years old. The subjects, who had committed suicide, all had muscular builds.

Measurements of other cadavers were not published until 1955. At that time, Dempster (6), who was assessing the space requirements of the seated operator for the US Air Force, studied the bodies of eight white men who died from a variety of natural causes (seven unpreserved and one preserved) at the University of Michigan morgue. The cadavers were free from obvious physical defects, were not obviously emaciated, and were nontubercular. The ages of two cadavers were unknown, but the ages of the others ranged from 52 to 83 years. Body segments were separated at joint centers by means of a method similar to that of Braune and Fischer (4,5). Position of joints at the time of separation differed in the two studies, however. Dempster (6) used a midrange position in the separation process to have compromise in separa-

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Table 1
Ratio of segment weight to body weight as reported in several cadaver studies (4-6)[a]

Body segment	Braune and Fischer, 1889 (n=3)	Dempster, 1955[b] (n=8)	Dempster, 1955[bc] (n=8)	Clauser et al, 1969 (n=13)
	←	%		→
Head	7.0	7.9	(8.1)	7.3
Trunk	46.1	48.6	(49.7)	50.7
Upper arm	3.3	2.7	(2.8)	2.6
Forearm	2.1	1.6	(1.6)	1.6
Hand	0.8	0.6	(0.6)	0.7
Total arm	6.2	4.9	(5.0)	4.9
Forearm and hand	2.9	2.2	(2.2)	2.3
Thigh	10.7	9.7	(9.9)	10.3
Calf	4.8	4.5	(4.6)	4.3
Foot	1.7	1.4	(1.4)	1.5
Total leg	17.2	15.7	(16.1)	16.1
Calf and foot	6.5	6.0	(6.1)	5.8
Sum[d]	**99.9**	**97.7**	**100.0**	**100.0**

[a]From Clauser et al (7).
[b]Refers to data from the cadaver portion of the study, not to data from the living subjects.
[c]Adjusted values.
[d]The sum is calculated as head + trunk + 2 × (total arm + total leg).

Table 2
Change of ratio of segment weight to body weight from the 1889 data of Braune and Fischer (4,5) to 1955 data of Dempster (6) and the 1969 data of Clauser et al (7)

Body segment	Percent change from 1889	
	1955	1969
Head	+16	+4
Trunk	+8	+10
Upper arm	−15	−21
Forearm	−24	−24
Hand	−25	−12
Total arm	−19	−21
Forearm and hand	−24	−21
Thigh	−8	−4
Calf	−4	−10
Foot	−18	−12
Total leg	−6	−6
Calf and foot	−6	−11

tion of segment masses. Braune and Fischer (4,5) sawed across straightened limb segments.

Even though Dempster (6) was thorough and exact in measuring his subjects, he reported a limitation of his work: the subjects were elderly and smaller than the average white male population. Nevertheless, they were a good representation for their age.

In 1969, Clauser and associates (7) studied the body dimensions of 13 male cadavers; all bodies had been preserved so that a wide variety of body types could be selected. Methods of dismemberment were similar to those of Braune and Fischer (4,5) and Dempster (6). Because the cadavers used by Clauser and coworkers (7) were preserved, special care had to be taken in dissection not to allow the fluids to leak out. Cadaver dimensions were similar to those reported in US Air Force studies of living subjects (6), and the same relationships of body components in the living were found in cadavers.

The data of Braune and Fisher (4,5), Dempster (6), and Clauser et al (7) were collected by LeVeau (8) and are shown in Table 1. Although the investigators did not use identical techniques, the differences were minimal enough to allow data to be viewed somewhat comparatively. The more recent data indicate that a lower proportion of body weight is carried in the limbs.

To estimate body segments accurately without using cadavers, in 1964 Hanavan (9) developed a computerized segment model of the human body. This model required that 25 standard anthropometric measurements of the body be taken.

Gender

Drillis and associates (10) addressed the issue of gender relative to weight of body components. They discussed the 1936 research done in Moscow by Bernstein and coworkers (11) in which the body segments of living subjects were studied. The study group contained 76 male and 76 female subjects aged 12 to 75 years. The investigators found that male and female subjects had similar segment weights as a percentage of body mass. In 1989, Wilson and Loesch (12) studied 99 men and 103 women aged 18 to 78 years. Data collected were adjusted by standardized procedures, for size of subject and age. By use of principal-component analysis of the data, the investigators found shape variables of trunks and limbs to be similar in both sexes.

Age

Age of subjects is another area that must be considered when assessing body proportions. In 1986, Jensen (13) looked specifically at growth relative to body proportions in a longitudinal study of 48 boys. Results indicated a decrease in head mass proportion during growth, which was balanced by increases in thigh, shank, upper arm, and foot mass proportions as a child aged. In 1994, Forbes (14) stated that children of the current generation are heavier and taller than those of previous generations and reach puberty earlier.

Jensen (13) also cited Stoudt, who concluded in 1981 that there is likely a redistribution of body mass with aging. Ausman and Russell (16) reported that lean body mass declines with age and that fat stores increase in the abdomen and muscle. In middle age stature also begins to decline progressively (14).

Ethnicity

Martorell et al (17) studied the body proportions of children and youths of three ethnic groups in 1988 using data from the second National Health and Nutrition Examination Survey and the Hispanic Health and Nutrition Examination Survey. They found that length measurements were related to poverty status in preadolescent children; poor children were more likely to be short. However, poverty did not affect relative body proportions, a finding that is consistent with the 1978 observation of Tanner et al (18).

Martorell et al (17) also observed that blacks had longer lower extremities than Mexican Americans or non-Hispanic whites. Kautz and Harrison (19) reported that Mexican-American children are greater in weight for length than white children and have larger chest and thigh circumferences and subscapular skinfolds. Other investigators have reported ethnic differences in body dimensions and components (18), but actual segments of bodies have not been weighed.

Tanner et al (18) wrote that "the largest differences between races, when all are growing up in good environments, are those of shape" (p139). They used data from boys in London, England, as a baseline in the maturation process and found that Chinese boys had greater sitting height to leg length at maturity, whereas African boys had a much lower sitting height for leg length. The characteristics were shown by female subjects and male subjects. When shoulder width was compared to hip width in male subjects, Africans had slimmer hip width than shoulder width, whereas European and Asian men were similar in those proportions. Forbes (14) confirmed these observations along with defining differences in lean body mass and total body potassium and calcium content.

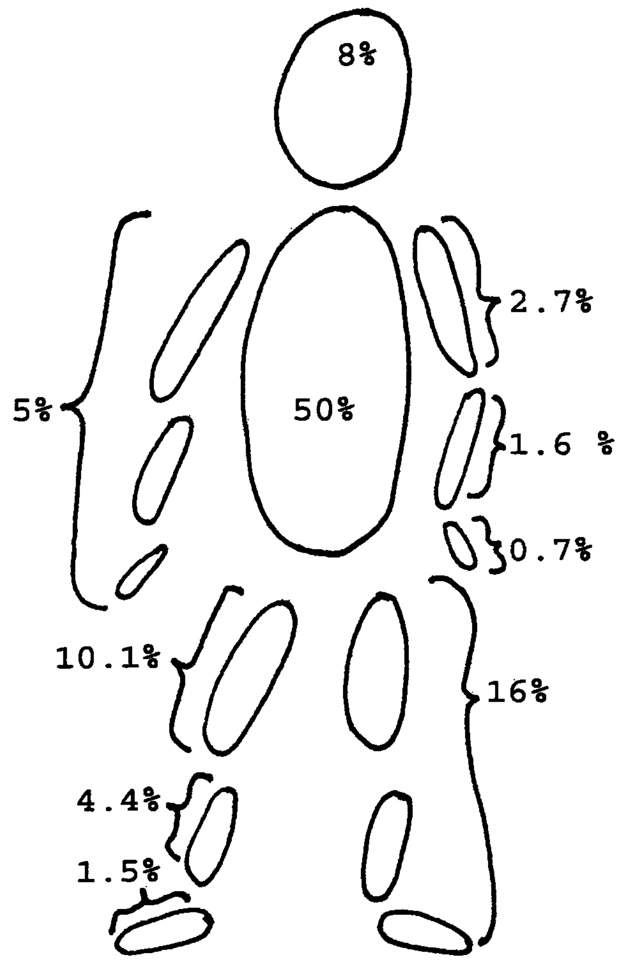
Not only are there ethnic differences in body measurements, but the measurements are changing. In 1982 Tanner (20) observed that the trunk to leg proportions of the Japanese have become similar to those of northern Europeans during the past 20 years, whereas Japanese adults are shorter than adult northern Europeans. Takamura et al (21) observed an increase in arm length of the Japanese during the past 20 years, but leg changes were seen first and the arm length changes were seen later.

CHANGES OF BODY PROPORTIONS

Difference in body components seem to be observable in several contexts, that is, relative to gender, age, ethnicity, and possibly evolution. Although data seem to validate a similarity of weight proportions of body components between genders, it has been shown that ethnic differences in proportions exist (though there is evidence that those differences may be changing). A difference in weight of body components is likely attributable to aging. Pinpointing where an individual patient is in relation to these factors is a complex, if not impossible, process. Not only are few data available to validate theories, but the individual patient probably cannot provide a personal history that gives the caregiver an adequate perspective. Therefore, general guidelines to assess body components are necessary.

Because Braune and Fischer in 1889 (4,5), Dempster in 1955 (6), and Clauser et al in 1969 (7) used similar techniques in dissecting cadavers, one might consider just adding the later data to the data from the three subjects measured by Braune and Fischer. However, because of the differences in the populations studied and the large lapse in time between sampling populations it seems more logical to consider the data of Dempster and Clauser et al as a group. In Table 2, the 1955 data of Dempster (6) and the 1969 data of Clauser et al (7) are compared with the 1889 data of Braune and Fischer (4,5). The intent is to show change from the earlier to the later studies. As discussed, the 1955 and 1969 data show that a greater percentage of body weight is in the head and torso, whereas the extremities carry less weight than that seen in the 1889 data. These differences might be the result of size of sample, ethnicity, or the beginning of evolutionary forces.

Given these differences in physique, are we observing leaner musculature and less dense bones in the extremities, or are we seeing generally smaller extremities? Could cultural change from the 19th to the 20th century have influenced body components? What were the working and living conditions for the men measured in 1889 relative to the men measured in 1955 and 1969? The answers to these questions are not known.



Ratio of segment weight to body weight based on 1955 data of Dempster (6) and the 1969 data of Clauser et al (7) (N=21).

We do know that the major metabolic activity of the body occurs in the trunk and head. Therefore, the decrease in weight of the extremities relative to the torso and head shown in the 1955 (6) and 1969 (7) data indicates that this less metabolically important tissue is diminishing as a percentage of body weight. To visualize the more recent body proportion measurements, adjusted data from Dempster (6) and Clauser et al (7) are pictured in the Figure.

EFFECT OF COMPONENT WEIGHT ON NUTRITION ASSESSMENT

Let us use as an example a 183-cm tall man who weighs 83 kg. He is admitted to the hospital to have his right leg amputated because of complications from cardiovascular disease. Nutrition assessment at admission classifies him as having appropriate weight for height. Thus, assessment of the adequacy of the patient's nutrition intake will use his admission weight for baseline calculations.

> A key factor in assessing nutritional status is evaluation of a patient's present body weight relative to ideal body weight; the situtation is more complex if the patient has a missing limb

The percentage segment weight for the leg according to Braune and Fisher (4,5) is 18.5%; the data of Dempster (6) and Clauser et al (7) indicate 16%. Therefore, the estimate of leg weight using the 1889 (4,5) data is 83 kg × 18.5%=15.4 kg, whereas the estimate using the 1955/1969 data (6,7) is 83 kg × 16%=13.3 kg. Adjusted body weight for the patient after the amputation would be 83 kg–15.4 kg=67.6 kg using the 1889 data (4,5) and 83 kg–13.3 kg=69.7 kg using the 1955/1969 data (6,7).

Now let us assume that the patient needs to be fed a nutrition formula after surgery. To provide 35 kcal/kg body weight for each of the adjusted weights means 67.6 kg × 35 kcal=2,370 kcal/day using the 1889 data (4,5) and 69.7 kg × 35 kcal=2,440 kcal/day using the 1955/1969 (6,7) data. There is a 70-kcal/day difference in what would be recommended for the patient. After healing is complete, the patient's energy needs would likely drop back. Even if 30 kcal/kg per day were provided, the difference between the 1889 and 1955/1969 data would be 63 kcal/day. Of course, the best course to take is to weigh the patient or to use a calorimeter. In a clinical setting, however, this is not always possible or accurate because of complications in dealing with a bedridden patient or limited availability of the sophisticated equipment to do such a measurement.

The consequences of receiving inappropriate dietary intake are many; they range from the medical problem of poor wound healing to the administrative aspect of cost containment. Dietitians, therefore, must be able to provide informed clinical advice.

APPLICATIONS

Relatively recent data from two studies (6,7) concerning the weight of components of the human body (using data from 21 male subjects) show a change from data on weight distribution collected in 1889 (4,5) (based on 3 male subjects). All studies used similar standardized techniques for measurement. The trunk and head are larger as a percentage of body weight in mid-1900s data than they were in data collected earlier; legs and arms have become lighter in weight relative to the rest of the body.

Although all measurements were done on male cadavers, studies of living subjects have shown the body components of men and women to be essentially equivalent (10-12). Aging and ethnicity are possible variables, but studies need to consider actual weight of body components with these variables.

Findings from this review of the literature indicate that, in the absence of calorimetry, the newer data (6,7) are important to consider when evaluating a patient who is having an extremity amputated. In addition, the patient's ethnicity and age must be considered as part of the assessment process.

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