Fat-Free and Fat Mass Percentiles in 5225 Healthy Subjects Aged 15 to 98 Years

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OBJECTIVES: Fat-free mass (FFM) and fat mass (FM) are important in the evaluation of nutritional status. Bioelectrical impedance analysis (BIA) is a simple, reproducible method used to determine FFM and FM. Because normal values for FFM and FM have not yet been established in adults aged 15 to 98 y, its use is limited in the evaluation of nutritional status. The aims of this study were to determine reference values for FFM, FM, and percentage of FM by BIA in a white population of healthy adults, observe their differences with age, and develop percentile distributions for these parameters between ages 15 and 98 y.

METHODS: Whole-body resistance and reactance of 2735 healthy white men and 2490 healthy white women, aged 15 to 98 y, was determined by 50-kHz BIA, with four skin electrodes on the right hand and foot. FFM and FM were calculated by a previously validated, single BIA formula and analyzed for age decades.

RESULTS: Mean FFM peaked in 35- to 44-y-old men and 45- to 54-y-old women and declined thereafter. Mean FFM was 8.9 kg or 14.8% lower in men older than 85 y than in men 35 to 44 y old and 6.2 kg or 14.3% lower in women older than 85 y than in women 45 to 54 y old. Mean FM and percentage of FM increased progressively in men and women between ages 15 and 98 y. The results suggested that the greater weight noted in older subjects is due to larger FM.

CONCLUSIONS: The percentile data presented serve as reference to evaluate deviations from normal values of FFM and FM in healthy adult men and women at a given age.


KEY WORDS: bioelectrical impedance analysis, fat-free mass, body fat, fat-free mass measured with bioelectrical impedance analysis, body composition, reference standard, sex

INTRODUCTION

Significant changes in body composition occur with aging and are believed to be a consequence of imbalances between energy intake and energy needs associated with an increasingly sedentary lifestyle. Progressive increases in fat mass (FM) and progressive reductions in fat-free mass (FFM) have been noted. In adults, over- and undernutrition contribute to increased mortality and morbidity. In the elderly, the age-related loss of muscle mass, or sarcopenia, is prevalent and strongly associated with impaired mobility, increased morbidity and mortality, and lower quality of life.1

Much of our current understanding of the changes in body composition with advancing age comes from studies that are 30 y old.2 National surveys for reference data for body composition measures that have large samples and are suitable for describing differences between individuals and between levels of muscle and FM are needed. Because weight and body mass index (BMI) alone are not an adequate guide of underlying changes in FFM and FM during menopause3 and aging in general,4 body composition should be measured in clinical management programs and epidemiological and clinical studies of aging.4 Simple measurements for evaluating body composition such as skinfold measurements are easy to perform but not accurate or reproducible.5 Other methods require subject cooperation (underwater weighing) or sophisticated equipment and skilled technicians (tracer dilution, dual-energy x-ray absorptiometry [DXA], and neutron activation analysis).

More recently, bioelectrical impedance analysis (BIA) has been shown to be more accurate for determining leanness or fatness in humans.6 BIA provides a more reliable measurement of body composition with respect to FFM and FM than does BMI5 or simpler methods such as skinfolds and height and weight.7,8

Two previous studies have reported percentiles for FFM, FM, and percentage of FM (%FM). Heitmann9 reported BIA-determined 10th and 90th percentiles for FFM, FM, and %FM in a large Danish adult population aged 35 to 65 y. Pichard et al.10 published BIA-determined percentiles for the same parameters in adults aged 18 to 65 y using different BIA equations for men and women and for obese and non-obese subjects. Although FFM and FM values for adults younger than 64 y are available, no data are available in older subjects, primarily due to a lack of appropriate BIA formulas applicable in elderly subjects and fewer healthy subjects being available. The recent validation of a single BIA equation in subjects 15 to 94 y with BMIs between 17 and 33.8 kg/m² now permits the evaluation of FFM and FM in subjects older than 65 y.11

The aims of this study were to determine reference values for FFM, FM, and %FM by BIA in a large white (Western European) population of healthy subjects in Switzerland, including elderly subjects, observe their differences in age groups of 10 y in those 15 to 98 y, and develop percentile distributions for those parameters. The percentile data presented serve as reference to evaluate devi-
**ANTHROPOMETRIC AND BIOIMPEDANCE CHARACTERISTICS OF A HEALTHY WHITE POPULATION***

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**Women**

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* Values are presented as mean ± standard deviation. Ranges are shown in parentheses.
BMI, body mass index; IBW, ideal body weight (Metropolitan Life Insurance, 1983)

**SUBJECTS AND METHODS**

**Subjects**

Healthy adults (2735 men and 2490 women), aged 15 to 94 y, were recruited non-randomly through advertisements in local newspapers, by offering free BIA on an exhibition stand at trade fairs and fun runs, among public administration staff, and by invitations sent to members of leisure clubs for the elderly to participate in the study. The anthropometric data and number of healthy subjects per age group are shown in Table I. All subjects were ambulatory whites (Western European) who had no known pathologies or physical handicaps. Subjects were questioned on their use of medications and reasons for visiting their physicians within the previous 6 mo to exclude those with acute or chronic diseases, and subjects with water or electrolyte imbalances (e.g., edema and ascites), skin abnormalities (e.g., pachydermia secondary to hypothyroidism), and abnormal body geometry (e.g., amputation and limb atrophy) that might interfere with BIA measurements were excluded.

The study protocol complied with the requirements of the Geneva University Hospital Ethics Rules.

**Anthropometric Measurements and BIA**

Body height was measured to the nearest 0.5 cm and body weight to the nearest 0.1 kg on a balance-beam scale. Subjects wore indoor clothing without shoes, heavy sweaters, or jackets. One kilogram per subject was deducted for pants and shirt. Percentages of ideal body weights were derived from the 1983 Metropolitan Life Insurance Tables. Values used were the midpoints for medium frame for each height, recalculated in centimeters and kilograms.

FFM and FM were assessed by BIA as previously described. Whole-body resistance (R) was measured with four surface electrodes placed on the right wrist and ankle. Briefly, an electrical current of 50 kHz and 0.8 mA was produced by a generator (Bio-ZZ, Spengler, Paris, France) and applied to the skin using adhesive electrodes (3M Red Dot T, 3M Health Care, Borken, Germany) with the subject lying supine. The skin was cleaned with 70% alcohol. Several BIA instruments were used in this study to permit inclusion of a large number of subjects at one time. The Bio-ZZ generators were cross validated at 50 kHz against the RJL-109 and 101 analyzers (RJL Systems, Inc., Clinton Township, MI, USA) and the Xitron 4000B analyzer (Xitron Technologies, Inc., San Diego, CA, USA). The Xitron 4000B analyzer was 54.0 ± 10.7 kg. BIA-predicted FFM was 54.0 ± 10.5 kg, with a bias of 0.03 ± 1.7 kg (r = 0.986,
We also validated the Bio-Z2 in 250 of the 343 subjects included in the above study (unpublished data) with the BIA equation and found that the FFMs were 54.2 ± 10.7 kg with DXA and the Bio-Z2 was 0.13 ± 1.7 kg; the mean difference between DXA and the Bio-Z2 was 0.13 ± 1.7 kg (r = 0.99, SEE = 2.0 kg). The BIA equation was further validated against DXA in 205 healthy elderly subjects.15

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The results are expressed as mean ± standard deviation. Age- and sex-specific percentile distributions were calculated for FFM, FM, and %FM. The data were stratified by intervals of 10 y as reported in any of the calculated statistics of the men and women with no known pathologies. Age- and sex-specific percentile distributions for FFM, FM, and %FM of white adults are presented in Tables II, III, and IV and Figs. 1, 2, and 3.

### Statistics

The statistical analysis program StatView, version 4.1 (Abacus Concepts, Berkeley, CA, USA), was used for statistical analysis. The results are expressed as mean ± standard deviation. Age- and sex-specific percentile distributions were calculated for FFM, FM, and %FM. The data were stratified by intervals of 10 y as reported in any of the calculated statistics of the men and women with no known pathologies. Age- and sex-specific percentile distributions for FFM, FM, and %FM of white adults are presented in Tables II, III, and IV and Figs. 1, 2, and 3.

### RESULTS

Table 1 shows the anthropometric and bioimpedance characteristics of the men and women with no known pathologies. Age- and sex-specific percentile distributions for FFM, FM, and %FM of white adults are presented in Tables II, III, and IV and Figs. 1, 2, and 3.

### BMI and Weight

Weight and percentage of ideal body weight were lowest in men and women 15 to 25 y old and highest in men and women 65 to 74 y old. Mean BMI was lowest in men and women 15 to 24 y old and highest in men and women 65 to 74 y old and decreased thereafter (Table I).

### BIA-Derived Body-Composition Parameters

Mean FFM (Table II) was greatest in men 35 to 44 y old at 60.3 ± 5.8 kg and decreased thereafter. Of these men, 90% had FFMs between 51.9 and 66.4 kg. Mean FFM was 8.9 kg or 14.8% lower in men older than 85 y than in men 35 to 44 y old. Mean FFM was significantly higher in men 25 to 34 y than in men 15 to 24 y old and significantly lower in men 45 to 54 y old than in men 35 to 44 y old and older than 74 y. The percentiles developed for men 25 to 44 y generally exceeded comparable percentiles calculated for men in younger and older groups. A diagrammatic display of these trends is presented in Fig. 1.

For women, the mean FFM was greatest between 45 and 54 y at 43.3 ± 4.7 kg and decreased thereafter. Ninety percent of women had FFMs between 37.0 and 48.0 kg. Mean FFM was 6.2 kg or 14.3% lower in women older than 85 y than in those 45 to 54 y. FFM increased slightly but not significantly in women 15 to 24 y old compared with women 45 to 54 y, decreased thereafter
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Women

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* P < 0.001 versus preceding age group, analysis of variance.
† P < 0.05 versus preceding age group, analysis of variance.

TABLE IV.

PERCENTILES FOR FAT MASS (%) BY 50-kHz BIOELECTRICAL IMPEDANCE ANALYSIS FOR HEALTHY WHITE ADULTS

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<td>All</td>
<td>2735</td>
<td>19.7 ± 5.6</td>
<td>10.9</td>
<td>12.6</td>
<td>15.7</td>
<td>19.2</td>
<td>23.5</td>
<td>27.0</td>
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<td>15–24</td>
<td>424</td>
<td>16.2 ± 4.5</td>
<td>9.3</td>
<td>10.7</td>
<td>13.1</td>
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<td>25–34</td>
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<td>18.5 ± 4.8†</td>
<td>11.0</td>
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<td>&gt;85</td>
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<td>27.9 ± 4.7*</td>
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<td>31.4</td>
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* P < 0.05 versus preceding age group, analysis of variance.
† P < 0.001 versus preceding age group, analysis of variance.
and decreased significantly in women older than 75 y. These age-related trends also were apparent in the percentile distributions. Figure 1 shows these trends in graphic form.

FM (Table III) and %FM (Table IV) were lowest in men 15 to 24 y and highest in men older than 85 y. Of these men, 90% had FMs between 8.3 and 22.3 kg and %FMs between 12.6 and 27.0. The FM increase was significant for all age groups until 74 y, except 45- to 54-y-old versus 35- to 44-y-old men. The mean FM in men older than 85 y was nearly double the FM in men 15 to 25 y old.

FM for women (Table III) was lowest in those 15 to 24 y old and highest in those 65 to 74 y old and decreased thereafter. Of these women, 90% had FMs between 10.7 and 25.9 kg. The largest mean FM, observed in women 65 to 74 y, exceeded the smallest mean, noted in women 15 to 24 y, by 51.9%. The mean %FM (Table IV) was lowest in women 15 to 24 y and highest in women 75 to 84 y old. Of these women, 90% had %FMs between 20.8 and 37.6. A significant increase in %FM was noted only in women 45 to 74 y old.

Figure 2 shows trends in FM and Fig. 3 shows trends in %FM for men and women.
for men and women. Percentage of FM increased progressively and percentiles showed parallel distributions in men. In women the percentile-distribution increase did not occur until age 45 y, when considerable increases were noted in all percentiles.

**FFM and FM in Men and Women**

As expected, significant differences in FFM ($P < 0.001$) were noted for all age groups between men and women. The absolute differences in FFM between men and women were greatest (17.3 kg) between 25 and 34 y and decreased with age, but the difference remained relatively constant at 36% to 38% throughout that age span. The higher FFM was confirmed by mean FFM indices (FFM/height$^2$; data not shown) of 19.3 to 19.4 kg/cm$^2$ in men 35 to 74 y old (18.5 ± 1.3 kg/cm$^2$ in men younger than 35 y old and 18.7 ± 1.9 kg/cm$^2$ in men older than 74 y) compared to 16.2 to 16.5 kg/cm$^2$ in women 45 to 74 y old (15.4 ± 1.1 kg/cm$^2$ in women younger than 45 y old and 15.8 ± 2.1 kg/cm$^2$ in women older than 74 y).

Sex differences also were noted in FM and %FM. FM was significantly higher in women than in men, which was confirmed by the higher mean FM indices. The FM index increased with advancing age, from 5.6 ± 1.6 kg/cm$^2$ to 9.4 ± 3.5 kg/cm$^2$ in women and from 3.7 ± 1.3 kg/cm$^2$ to 7.4 ± 2.0 kg/cm$^2$ in men. Mean %FM was significantly greater ($P = 0.0001$) in women than in men. Furthermore, larger FM and %FM in older adults showed that any weight gain was explained by FM gains in both sexes.

**DISCUSSION**

Few studies have reported FFM and %FM in large population samples. In general, FM is derived by indirect methods. The development and validation of BIA now permit the determination of FFM and FM more accurately by an easy, portable, and inexpensive method. Two previous studies have reported percentiles for FFM, FM, and %FM by BIA in subjects 15 to 65 y old but did not evaluate men and women older than 65 y.

The aims of this study were to determine reference values for FFM, FM, and %FM in a white population of healthy adult subjects, observe their differences with age, and develop percentile distributions for those parameters between the ages of 15 and 98 y.

**Application of BIA Formulas in Subjects With Different Ages and BMIs**

The validity of BIA-determined FFM and FM directly depends on the equation used to translate the BIA-determined resistance and reactance values into FFM, FM, or total body water. FFM in the present study was estimated with a multiple regression equation that was previously validated against DXA in 343 healthy subjects 18 to 94 y old. Validation of the Geneva BIA equation was deemed necessary because published equations were inadequate for overweight, obese, and elderly subjects. Non-significant differences were found in subjects older than 65 y and obese subjects. Inclusion of reactance in the BIA equation allowed the distinction of lower FFMs in older subjects and improved correlation SEE and TE compared with other BIA equations.

**Comparison of BMI With Previous Studies**

The BMIs in the present study can be compared with those in other epidemiologic studies. Median BMIs of 24.6 to 25.1 kg/m$^2$ in 35- to 74-y-old men and 21.8 to 23.6 kg/m$^2$ in 35- to 74-y-old women reported in a randomly sampled Swiss population were similar to those in the current study. In other studies, mean BMIs were 24.6 ± 3.6 kg/m$^2$ in men and 25.3 kg/m$^2$ in women aged 15 to 99 y in Finland, and median BMIs were 24.5 to 25.3 kg/m$^2$ in men and 22.3 to 24.0 kg/m$^2$ in women 35 to 65 y old in France; subjects in both studies were selected randomly.

By definition, 26.6% of men and 14.5% of women were overweight (BMI > 25.0 kg/m$^2$) and 2.9% of men and 3.8% of women were obese (BMI > 30 kg/m$^2$) in the present study. In comparison, 34% to 35% of men and 24% to 25% of women in Britain, Netherlands, and Australia are overweight, as are 38% to 40% of men and 21% to 22% of women in the United States and Canada. Although some underrepresentation of subjects with BMIs above 25 is possible, due in part to excluding subjects with secondary pathologies, the results suggest that prevalence of overweight and obesity is lower in Switzerland than in other European countries and considerably lower than in the United States and Canada.

**FIG. 3. Percentile changes in percentage of fat mass (%) of white adults between the ages of 15 and 98 y.**

Nutrition Volume 17, Numbers 7/8, 2001 Reference Values of Fat-Free and Fat Masses in Healthy Subjects
Evaluation of Body-Composition Variations During Aging

**FAT-FREE MASS.** In our study, the FFM peaked in men 35 to 44 y old and women 45 to 54 y old and declined thereafter, compared with declines beginning at age 60 y in men and 45 y in women in the study by Bartlett et al. Heitmann found that FFM values were highest in 35-45-y-old men and women and decreased thereafter.

Forbes suggested that a weight gain of 2.3 kg/decade is necessary to avoid losing FFM during aging. The low body weight increases reported in our subjects (approximately +5 kg in 40 y) would have been inadequate to maintain FFM during aging and would explain the earlier decline of FFM in our subjects. Heitmann also reported small differences in weight between age groups (+1.4 kg in men and +2.1 kg in women between 35 and 55 y), which also would have been inadequate to maintain FFM during aging. In contrast, the Fels Longitudinal Study reported stable FFMs and larger weight gains in men and women 20 to 59 y than in our study, which could explain the discrepancies between the FFM values.

We found lower FFMs in men and women older than 60 y and an accelerated loss in men and women older than 75 y. Most studies have reported lower FFMs after age 60 y. In a cross-sectional study of men and women older than 60 y, Baumgartner also found the weight, BMI, and FFM decreased with age. Forbes did not find an accelerated loss in FFM in a small longitudinal study but did find an average loss of 1.5 kg of FFM/decade in subjects who maintained their weight. Thus, the accelerated decrease in our subjects who were older than 75 y is probably related to lower weight noted after age 75 y compared with weight maintenance or increase until age 74 y. In our study, linear regressions suggested declines of 1.5 and 1.2 kg of FFM/decade in men and women, respectively, 55 to 98 y old and 1.9 and 1.8 kg of FFM/decade in men and women, respectively, older than 75 y, with weights being progressively lower in older subjects. Longitudinal studies are necessary to determine changes in FFM with aging in view of changes in weight.

Thus, the differences in FFM between studies can be explained by differences in simultaneous weight changes, and FFM might increase, remain stable, or decrease between the ages of 20 and 60 y depending on weight gain or loss. FFM does appear to decrease after age 60 y, probably because weight gains are no longer large enough to offset the inevitable loss of FFM with aging.

**FAT MASS AND PERCENTAGE OF FAT MASS.** Our study showed that body weight and BMI increased until age 74 y and that the increase was predominantly due to higher FM. FM continued to increase in men after age 74 y, and %FM increased throughout the lifespan in men and women.

This study agrees with previous reports and shows higher FM and FM in men in all age ranges, which is parallel to higher weights. Because the data are cross-sectional rather than longitudinal, trends in body composition parameters observed with advancing age might have represented differences between successive generations in addition to physiologic alterations with aging. Linear regressions in subjects between 15 and 98 y in our data showed %FM increases of 1.5/decade in men and 1.7/decade in women compared with 2.3/decade in the study by Deurenberg. Confirmation of an effect of age on FM, in addition to an effect of weight gain with age, by longitudinal studies is necessary. Higher %FM and %FMs have been reported in a number of studies that included subjects with higher BMIs. Roubenoff et al. found a mean increase in %FM with age in both sexes that peaked in the fifth and sixth decades in American women and men, which is inconsistent with our results of increases in %FM until our oldest age groups in men and women. Biasoli et al. suggested that %FM increased until age 90 y. Guo et al. reported higher FM and %FM by underwater weighing in men and women aged 40 to 66 y who had BMIs higher than those reported in our study and found significant decreases in FFM and increases in total FM, %FM, body weight, and BMI with age in their longitudinal study (mean follow-up = 9 y). Thus, changes in body composition with age need to be confirmed with longitudinal studies. Comparisons between studies where height, weight, and age are significantly different are difficult to make.

Comparisons of Percentiles With Previous Studies

The P50s for FM were 2.9 kg higher in men and 2.0 kg higher in women than in our previous study. The discrepancy stems from an underestimation of FM by the BIA equations used in the previous study. Recent validation of a single BIA equation against newer versions of DXA hardware and software allows more accurate predictions of FM and FFM and can be used to follow people longitudinally during aging and when significant BMI changes occur.

Although the median BMIs reported by Heitman in a Danish population were not remarkably different from those in our study, median FFMs were higher (61.8 kg in 35-y-old men and 45.5 kg in 35-y-old women) in Danish and other populations by the much-higher-than-recommended quantities of FM in individuals.

**“Ideal” Fat Mass**

A recent round-table discussion suggested that the “best” FM percentages in terms of lowest morbidity and mortality averaged 12% to 20% in men and 20% to 30% in women. Forty-five percent of all men and 38% of all women in our study were above those recommendations (Table V). “High” FMs, defined as the P85, in this study were 25.6% in men and 35.7% in women, and “excess” FMs, defined as the P95, were 29.2% in men and 40.5% in women. Further research is necessary to determine to what extent health outcomes are affected in Swiss and other populations by the much-higher-than-recommended quantities of FM in individuals.
Study Limitations

The subjects in this study were not randomly selected. However, the BMIs in our study were similar to the median BMIs of 24.6 to 25.1 kg/m² in 35- to 74-y-old men and 21.8 to 23.6 kg/m² in 35- to 74-y-old women in a randomly sampled population in Geneva.²³ Subjects with extreme body FM are frequently underrepresented in non-randomly selected populations. Twenty-four percent of subjects had BMIs above 25 kg/m² compared with 29.2% reported in the 4th Nutrition Report in Switzerland (n = 510).³⁸ This difference is probably due to a higher percentage of younger subjects being included in our study than in the Nutrition Report.

The subjects in this study were volunteers in good health and might not have been representative of the general population. Regular physical activity (walking) and the absence of mobility problems appear to have aided in maintaining physical functioning and might have limited the loss of FFM in men and women older than 55 y.

Results in subjects older than 85 y must be interpreted with caution because of the small number of subjects. Percentiles at the 10th and 90th levels in those older than 65 y might be less certain because samples included fewer than the approximately 250 subjects needed to calculate precise percentiles from the 5th to 95th levels.

This study used single-frequency BIA methodology and therefore did not measure total body water, intra- and extracellular water, and their influence on FFM composition with aging. Further research is necessary to explore the extent to which changes in extracellular fluid occur and influence changes in FFM and body cell mass with aging.

CONCLUSION

Mean FFM peaked in men 35 to 44 y old and women 45 to 54 y old and declined thereafter. Mean FM and %FM increased progressively in men and women throughout the ages studied. The results suggested that the higher weight noted in older subjects is due to higher FM. The percentile data serve as references to evaluate deviations from normal values of FFM and FM in healthy adult men and women at a given age.

ACKNOWLEDGMENTS

The authors are indebted to the dietitians at the Geneva University Hospital for data collection.

REFERENCES

2. Chumlea WC, Vellas B, Guo SS. Malnutrition or healthy senescence. Proc Nutr Soc 1998;57:593
17. Micozzi MS, Albannes D, Jones DY, Chumlea WC. Correlations of body mass indices with weight, stature, and body composition in men and women in NHANES I and II. Am J Clin Nutr 1986;44:725
30. Chumlea WC, Guo SS, Zeller CM, Reo NV, Siervogel RM. Total body water data for white adults 18 to 64 years of age: the Fels Longitudinal Study. Kidney Int 1999;56:244