Total body potassium differs by sex and race across the adult age span

Qing He, Moonseong Heo, Stanley Heshka, Jack Wang, Richard N Pierson Jr, Jeanine Albu, Zimian Wang, Steven B Heymsfield, and Dymphna Gallagher

ABSTRACT
Background: Total body potassium (TBK) is an index of fat-free mass. Data describing changes in TBK in African American, Asian, or Hispanic populations have not been reported.
Objective: The aim was to investigate possible sex and racial differences in TBK in adults over an age range of 70 y.
Design: The study used longitudinal and cross-sectional data collected in a body-composition unit from 973 men and 1368 women of African American, Asian, white, and Hispanic race-ethnicity. Random coefficient models in which baseline weight and height were taken into account were applied to estimate sex-specific changes in TBK among the 4 racial-ethnic groups.
Results: The ages of 30 and 31 y were identified for women and men, respectively, as the cutoffs after which TBK began to decline. Both sexes had similar racial-ethnic patterns for expected mean TBK at the age cutoffs: African Americans had the highest value, followed by whites, Hispanics, and Asians. After the age cutoffs, the decline in TBK differed by race and sex. In women, African Americans showed the most rapid decline, whereas Asians had the lowest. In men, Hispanics had the most rapid decline in TBK, followed by African Americans, whites, and Asians.
Conclusion: Significant sex and racial differences exist in the rate of change in TBK with age. Further studies are needed to explore the associations of declining TBK with health risks.

KEY WORDS Total body potassium, race, sex, age, skeletal muscle mass, African Americans, Asians, whites, Hispanics

INTRODUCTION
Total body potassium (TBK) is an index of the body’s cell mass (1) and is quantifiable by the detection of γ-rays that emanate from the body by virtue of its content of the naturally occurring radioisotope of potassium (40K). It is estimated that 60% of the body’s 40K (84 g/140 g) is found in skeletal muscle, and the remainder is found in other organs and tissues (2). TBK has been used as an index of skeletal muscle mass in many previous studies (3–8) and can also provide an estimate of fat-free mass (9–11).

During the adult years, skeletal structures including muscle and bone are dynamically changing and play important roles in influencing cognitive and physical functional status, nutritional and endocrine status, quality of life, and comorbidity (12). Osteoporotic fractures may be related to the atrophy of skeletal muscle mass or its functional impairment (13). The loss of muscle mass with aging is associated with a deterioration in physical function, including poorer lower extremity performance (14). Skeletal muscle atrophy, or sarcopenia, is most prevalent in the elderly, increases with age, and is strongly associated with disability, independent of morbidity (15). Accordingly, information on changes in TBK throughout the life span may be helpful in identifying periods of high health risks for primary care settings, with implications for treatment and prevention.

Sex differences in the changes in TBK during adulthood have been reported in white populations (16–18). Changes in TBK in African American, Asian, or Hispanic populations have not been previously reported. Different patterns of skeletal muscle change or loss may have different relations to outcomes, which in turn may require different or population-specific approaches to risk management. The aims of the present study were to 1) investigate race-ethnic and sex differences in changes in TBK during adulthood and 2) identify age cutoffs when TBK values begin to decline in a cohort of African American, Asian, Hispanic, and white women and men.

SUBJECTS AND METHODS
Subjects
Subjects were 1368 women (299 African American, 197 Asian, 669 white, and 203 Hispanic) and 973 men (198 African American, 152 Asian, 444 white, and 179 Hispanic) who participated in one or more body-composition studies at our research center from 1986 through 2000. Longitudinal data were available for 166 women (55 African American, 20 Asian, 82 white, and 9 Hispanic) and 88 men (17 African American, 21 Asian, 40 white, and 10 Hispanic); the remaining subjects (89%) were measured once. Both cross-sectional and longitudinal data were used in this analysis. At the time of the first measurement, the subjects ranged in age from 20 to 90 y. The longest follow-up interval in any one...
TABLE 1  
Subject characteristics

<table>
<thead>
<tr>
<th></th>
<th>African American</th>
<th>Asian</th>
<th>White</th>
<th>Hispanic</th>
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<tbody>
<tr>
<td>(n = 299)</td>
<td>(n = 197)</td>
<td>(n = 669)</td>
<td>(n = 203)</td>
<td>(n = 198)</td>
</tr>
<tr>
<td>Age (y)</td>
<td>51.5 ± 18.8</td>
<td>46.8 ± 18.5</td>
<td>45.5 ± 18.7</td>
<td>47.9 ± 17.2</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>75.3 ± 17.3</td>
<td>54.3 ± 8.3</td>
<td>63.9 ± 13.2</td>
<td>67.7 ± 13.2</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>161.9 ± 7.2</td>
<td>157.7 ± 6.5</td>
<td>163.1 ± 6.9</td>
<td>156.4 ± 6.5</td>
</tr>
<tr>
<td>BMI (kg/m^2)</td>
<td>28.7 ± 5.9</td>
<td>21.8 ± 3.1</td>
<td>24.1 ± 4.9</td>
<td>27.7 ± 5.5</td>
</tr>
<tr>
<td>TBK (mmol)</td>
<td>2506 ± 446</td>
<td>2131 ± 315</td>
<td>2426 ± 372</td>
<td>2257 ± 327</td>
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\[ \text{TBK} \] ± SD. Total body potassium. Means in a row within each sex with different superscript letters are significantly different, two-sided \( P < 0.05 \) (one-way ANOVA with Bonferroni correction).

subject was 14 y, and the shortest was several hours. Recruitment of subjects occurred through advertisements in local newspapers, on radio stations, and in flyers posted in the local community. Inclusion criteria required that the subjects be ambulatory, not exercise vigorously, and have no orthopedic problems that could affect any of the variables under investigation. Only subjects who denied any major current health problems were enrolled in the study. Race was determined by self-report. Subjects were asked to choose from the categories Asian, Black (African American), and Caucasian. All parents and grandparents of the African American and white subjects were required to be non-Hispanic African American and non-Hispanic white, respectively. Each subject completed a medical examination that included screening blood tests completed after the subject had fasted overnight. The study was approved by the institution's ethics committee, and all subjects gave written consent to participate.

Body composition

Body weight was measured to the nearest 0.1 kg (Weight Tronix, New York), and height was measured to the nearest 0.5 cm by using a stadiometer (Holton, Crosswell, United Kingdom). The 4-pi whole body counter was used to measure \( ^{40}\text{K} \) (19). The \( ^{40}\text{K} \) net counts accumulated over 9 min were corrected for self-absorption on the basis of an earlier \( ^{42}\text{K} \) calibration study (20). The within-subject CV in our laboratory for \( ^{40}\text{K} \) counting is \( 4.7\% \) (21). TBK was calculated from measured \( ^{40}\text{K} \) (19). The TBK counter was calibrated daily by counting a standard of known activity (each standard bottle contains 5000 decays/min of \( ^{40}\text{K} \)) and adjusting all subsequent patient readings on that day by the deviation from that standard and for background counts.

Statistical analysis

The mean values for subject characteristics were compared among racial-ethnic groups by sex with the use of a one-way analysis of variance with Bonferroni correction, and statistical significance was set at two-sided \( 0.05 \). A locally weighted regression line (22) was fitted to the data to visually display the trends in TBK over the age range for women and men separately. Random coefficient regression models adjusted for weight and height were applied to estimate sex-specific changes in TBK among the 4 racial-ethnic groups. The models incorporated both cross-sectional and longitudinal data. To estimate peak TBK, we applied random coefficient piecewise linear regression modeling, allowing different intercepts and slopes before and after a range of age cutoffs (23). An optimal age cutoff was chosen as the maximum age that satisfied the following 2 conditions: 1) significant difference in slope before compared with after the specified age and 2) reversed directions of slope after the specified age. Age cutoffs between 30 and 60 y were tested in 5-y increments and were further explored at 1-y increments between the ages of 25 and 40 y. Pairwise differences in mean TBK values and slopes among the racial-ethnic and sex groups were tested by using Wald \( t \) tests in the random coefficient models. All statistics were computed by using SAS software, version 8 (24), and two-tailed \( P \) values \( < 0.05 \) were considered significant. The SAS code used for fitting the random coefficient piecewise linear regression model is provided in Appendix A.

RESULTS

Subject characteristics

The sample sizes and mean (±SD) age, weight, height, body mass index, and TBK of the subjects are summarized in Table 1. Among the women, Asians, whites, and Hispanics did not differ significantly in age, whereas African Americans were older than the other groups. Mean weight and TBK were significantly different among the 4 racial-ethnic groups, and TBK values were lowest in Asians. Among the men, mean age did not differ significantly among the 4 racial-ethnic groups. Asians had the lowest mean weight and TBK. Despite the significant differences, the distributions by race within each sex overlapped to a considerable degree.

Changes in TBK during adulthood

Effect of age

The relation between TBK and age is shown in Figure 1, A and B, for women and men, respectively. The connected data points represent baseline and follow-up measures in subjects in whom longitudinal measures were acquired. Generally, TBK declined with age, as indicated by the locally weighted regression lines shown in the figure. For women and men, the ages of 30 and 31 y, respectively, were identified as the cutoffs after which the TBK regression line began to decline.

Effects of sex and race: before the age cutoff

Separate regression models were developed for women and men before and after the age cutoff, and the regression coefficients are presented in Table 2. In general, the men had higher expected mean TBK than did the women. The SEMs of the residuals within groups were 132.6 and 166.5 for women and men, respectively. In women (Figure 2A), African Americans had the highest expected mean TBK values, followed by whites, Hispanics, and Asians. A similar pattern was seen in men (Figure 2B), in whom...
African American men had the highest values and Asians the lowest.

Effects of sex and race: after the age cutoff

When the race-by-slope interactions were excluded from the models to estimate overall slopes after the age cutoffs, the rates of decline were 87 mmol/decade (P < 0.0001) for women after the age of 30 y and 176 mmol/decade (P < 0.0001) for men after the age of 31 y. Additional analyses by race with a common age cutoff of 31 y for both men and women showed that the linear declines in TBK were significantly different between men and women for all races (all P values < 0.0001), whereas the slopes before the age of 31 y were not significantly different between men and women within any race (all P values > 0.05).

Overall, after the age cutoff, the decline in TBK in men was at twice the rate of the decline in women for Asians, African Americans, and whites. The decline in TBK in male Hispanics was 3 times that of female Hispanics. Asians had the lowest rate of decline for both women and men.

In women, TBK began to decline at the age of ≈30 y. Asian women had significantly lower rates of decline (P < 0.05) than did African Americans and whites and had the lowest TBK values throughout the age range studied. Conversely, African American women had the highest expected TBK values before the age cutoff and displayed the most rapid rate of decline throughout the age range studied, although it was not significantly different from that in whites and Hispanics. The rate of TBK decline in women was greatest in African Americans (97 mmol/decade) compared with Asians (65 mmol/decade), whites (91 mmol/decade), and Hispanics (69 mmol/decade).

In men, TBK began to decrease after the age of 31 y, with Hispanics having the most rapid rate of decline. Asian men showed the slowest rate of decline compared with the other ethnic groups (P < 0.05) and had the highest TBK estimate at the age of 90 y. The rate of decline in TBK in men was greatest in Hispanics (203 mmol/decade) compared with Asians (131 mmol/decade), African Americans (198 mmol/decade), and whites (176 mmol/decade).

**DISCUSSION**

This is the first study to describe TBK from 20 to 90 y of age in a multi-racial-ethnic cohort of African Americans, Asians,
whites, and Hispanics. In this cohort, the ages of 30 and 31 y were identified as the points at which TBK begins to decline in women and men, respectively. After these age cutoffs, African American women and Hispanic men experienced the most rapid rates of decline. Asians showed the lowest rate of decline for both women and men.

In the present study, a nearly identical age cutoff (30 and 31 y) was found for women and men. A previous longitudinal study of white subjects found that the cutoffs differed between women and men (17). In that study, minimal change in TBK was observed in women younger than 50 y, whereas TBK began to decline in men beginning at the age of 41 y (17). Results from a cross-sectional investigation, in which age- and sex-specific curves for TBK were adjusted for body weight (K/wt), showed a decrease in TBK after the age of 20 y in men and after puberty in women (19). In another cross-sectional study of 20–89-y-old women and men, the investigators fitted nonlinear models to describe the changes in TBK with age (25). Thus, differences in population characteristics, study aims, and analytic approaches make direct comparison across studies difficult.

Sex differences in the rate of change in TBK with age in adults were previously described in both cross-sectional and longitudinal studies (17, 19). In agreement with those previous findings, the current study showed that men experience a more rapid loss of TBK with age than do women. However, this sex difference varied by race. The rate of decline in Hispanic men was 3 times that of Hispanic women, whereas the rate of decline in African American, Asian, and white men was twice that of their female counterparts.

To our knowledge, this is the first investigation of racial differences in the rate of decline in TBK in adults. Racial differences in TBK loss were previously estimated in black and white women in cross-sectional studies (11, 26). In a study of African American and white women, Gallagher et al (11) reported a greater loss in TBK (weight and height adjusted) in African Americans than in whites, which agrees with the current study findings. In contrast, a cross-sectional study of 20–69-y-old women reported that the lifetime decline in TBK was 8% for black women compared with 22% for white women (26). Differences in the age range studied and in the statistical adjustments made may account for these inconsistent findings.

There have been no previous reports of changes in TBK with age in Asian and Hispanic adults. Asians and Hispanics are among the most rapidly growing racial-ethnic groups in the United States (27), with increases of 20% for non-Hispanic Asians and Pacific Islanders and 21% for persons of Hispanic origin between 1995 and 2000 (compared with 2% for non-Hispanic whites and 6% for non-Hispanic blacks). Baumgartner et al (15) reported a greater prevalence of sarcopenia in elderly Hispanics than in non-Hispanic whites (15), which agrees with the current study finding that Hispanic men experienced a greater loss of skeletal muscle mass with aging.

Whether greater risk is associated with a more rapid loss of TBK (an index of the body’s fat-free and skeletal muscle mass) in healthy adults is unknown. In patients with AIDS, those with the lowest potassium values were found to be closer to death at the time of study (28). Because skeletal muscle is attached to bone, and therefore provides support for bone, a loss in skeletal muscle may increase the risk of bone fracture. We recently reported that appendicular skeletal muscle mass (as measured by dual-energy X-ray absorptiometry) was lower in prepubertal Asians than in prepubertal African Americans and whites (29). In the current study, Asians had the lowest TBK values compared with the other racial-ethnic groups at the age of 30–31 y. However, because of the lower rate of decline in TBK in both Asian women and men after the age cutoff, other racial-ethnic groups surpassed Asian men in the level of TBK reached in later years.

The recognition of racial differences in TBK loss may be of clinical importance because body composition varies by race. It was previously reported that Asian or Hispanic heritage is one variable associated with a significantly increased likelihood of osteoporosis in postmenopausal women (30). The identification of racial differences in the rate of TBK loss needs to be followed up in metabolic studies to identify or clarify associations with health risk.

The observed racial differences in TBK may reflect in part differences in dietary intake, acculturation, body size, or physical activity, detailed information on which is not available for our study population. In one study, white women who had higher levels of habitual physical activity had 6.5% more potassium per unit of fat-free mass than did their less-active counterparts (31). In that study, an active 70-y-old had the potassium content value of a sedentary 55-y-old woman (31). Although subjects participating in vigorous or intense physical activity were excluded from...
the current study, differences in habitual or daily physical activity likely existed among the study participants, which may have contributed to the observed differences in TBK loss by race and age. Different races or ethnicities may have different diets and acculturation issues that could influence body composition. Moreover, racial differences in body composition (7, 11, 29) are likely reflected in part in the TBK differences observed. Alternatively, the observed differences may be determined to an unknown degree by genetic differences. Another consideration is that the rate of decline in TBK appeared to be related to peak values for some of the racial-ethnic groups; however, this hypothesis could not be tested with the current data.

A limitation of this study is that TBK is not the ideal index of skeletal muscle mass throughout the life span. TBK may represent a different weighting of fat-free mass components at different stages of life as the skeletal muscle declines from its dominant proportion of the cell mass. Little information is available on how age, sex, and race influence TBK concentrations in skeletal muscle mass. It has been reported that the assumed steady state value for the ratio of TBK to fat-free mass (TBK/fat-free mass = 64.2 mmol/kg) is significantly lower in weight- and height-matched pairs of older (aged > 65 y) healthy white women than in younger (aged 19–35 y) women (32). The same question has not been explored in other racial groups. Therefore, TBK loss with age should be interpreted cautiously in relation to health risks or clinical outcomes.

In this study, racial-ethnic group was determined by subject self-report. Although other large national nutritional databases have categorized groups by race or ethnicity, a question arises regarding the appropriateness of studying discrete “race” groups, identified mainly by phenotypes such as skin color (33). In particular, categorization of the Hispanic ethnic group requires acknowledgment of a cultural and genetic background of admixed populations with different combinations of Amerindian, European, and African ancestry.

In conclusion, the results of our study show that divergent patterns of TBK accumulation and loss are present for Asians and Hispanics compared with African Americans and whites throughout the adult years. Although similar age cutoffs for TBK decline were found in women and men, men attained higher peak values and experienced a much more rapid loss of TBK than did women throughout the age range studied. Because muscle mass is the major depot for protein storage against the catabolic stresses of starvation or illness, a decline in muscle mass, or sarcopenia, guarantees a loss of reserves with aging. These findings emphasize the importance of sex- and race-specific interpretation of body-composition results to define body-composition phenotypes and the need for further studies to explore and make explicit the associations of body composition with health risks.

QH was responsible for data pooling, screening, analysis, and manuscript writing. MH was responsible for data analysis and manuscript writing. SH was responsible for data analysis and manuscript writing and provided advice and consultation. JW, RNP, JA, ZW, and SBH were responsible for data collection. DG was responsible for study design, data collection, and manuscript writing and provided administrative support, supervision, and advice. No author had a conflict of interest in any company or organization sponsoring this study.

REFERENCES

APPENDIX A

SAS PROC MIXED code for fitting the random coefficient piecewise linear regression with a common intercept

%macro connect (cutage);

data temp;
    set tbkms;
        t_age = age - &cutage;
        cut_age = 1* (t_age>0);
        t_before = t_age* (1-cut_age);
        t_after = t_age*cut_age;
    run;
    proc sort data = temp; by sex; run;
    proc mixed covtest noclprint data = temp;
        by sex;
        class unit race4 ;
        model tbk = race4 basewtkg basehtcm t_before t_after t_after*race4/solution ;
        random intercept t_after/subject = unit type = un;
    %mend;

connect (25)
connect (26)
connect (27)
connect (28)
connect (29)
connect (30)
connect (31)
connect (32)
connect (33)
connect (34)
connect (35)
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1SAS Institute Inc, Cary, NC.