Energy requirements in the eighth decade of life

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ABSTRACT
Background: Knowledge of energy requirements among relatively healthy elderly is limited.

Objectives: The objectives of the study were to measure total energy expenditure (TEE)-derived energy requirements in a biracial population of older adults without limitations to daily life and to test these empirical measures against national and international recommendations.

Design: TEE (measured by the doubly labeled water method), resting metabolic rate (RMR), activity-related energy expenditure (AEE), and body composition were measured in 288 persons aged 70–79 y selected from the Health, Aging, and Body Composition Study.

Results: TEE was lower in women (530 kcal/d; P < 0.0001) than in men because of the women’s lower RMR and AEE. Fat-free mass explained the sex difference in RMR, but body weight failed to account for the women’s lower AEE (P = 0.007). Blacks had lower TEE than did whites (100 kcal/d; P = 0.03), and that was explained by blacks’ lower RMR. Physical activity level (TEE/RMR) did not differ significantly between sexes and races (1.70 ± 0.23). The World Health Organization (WHO) recommendations overestimated TEE by 10 ± 15% (P < 0.0001) in women but not in men, and the dietary reference intakes (DRIs) were accurate to 0 ± 14% (P = 0.1). Both WHO and DRI recommendations are based on an underestimated physical activity level, and WHO recommendations are based on overestimated RMR.

Conclusions: This study of well-functioning older adults confirms the racial difference in energy metabolism and supports the use of the 2002 DRIs. Because the DRIs and WHO recommendations underestimated PAL, new predictive equations of energy requirements are proposed.

KEY WORDS Aging, obesity, malnutrition, African Americans, sex, energy expenditure

INTRODUCTION
It is projected that, by 2040, 20% of the US population will be ≥65 y old; by comparison, in 1997, 12% of the US population was aged ≥65 y, and at the beginning of the last century, that proportion was only 4% (1, 2). Recent data showed that one-half of those >65 y old have a chronic disease or some other form of disability, and, consequently, the total societal burden of physical impairment will increase with the rise in the elderly population (3, 4). To mitigate any age-related decline in autonomy, particularly that engendered by nutrition-related chronic diseases, it is essential to develop strategies to promote adequate nutrition.

Among these strategies, the maintenance of energy balance is critical but complex in the elderly (5–7). Total energy expenditure (TEE) decreases with age because of an equivalent reduction in resting metabolic rate (RMR) and activity-related energy expenditure (AEE; 7, 8). However, the ability to control food intake after overeating or undereating becomes impaired with age (9, 10). These problems, in conjunction with chronic diseases, chewing problems, polypharmacy, living alone, and low income, likely explain the high vulnerability of the elderly to energy imbalances. Ultimately, an inappropriate energy intake leads to weight gain or undernutrition, which, together with physical inactivity, further contributes to the decline of bodily functions and the development of age-associated chronic degenerative diseases (5, 6).

Dietary interventions are particularly challenging in the elderly because of the paucity of data on which accurate recommendations for age-related changes in energy requirements can be based (7, 11). This scantiness of data reflects 3 main factors. First, the elderly are a highly heterogeneous population ranging from the highly active newly retired to the institutionalized. Second, accurate energy requirements must be derived from free-living TEE measured by using the state-of-art, costly, expertise-requiring doubly labeled water (DLW) method (12). Third, low minority inclusion has impaired the ability to determine the general applicability of TEE estimates (13).

The Health, Aging, and Body Composition Study (Health ABC Study) provided a unique opportunity to evaluate energy requirements in the eighth decade of life in a cohort of people free of functional limitations and disabilities of daily living. This cohort constitutes a particularly interesting population compared with those of previous reports of studies using DLW.
because of its large size and generally well functioning status. In a group of 288 elderly persons, we specifically investigated whether TEE-derived energy requirements differ by sex and race and the extent to which the current World Health Organization (WHO; 14) and the new 2002 Dietary References Intake (DRI; 15) recommendations are accurate in such a population; then we generated new predictive equations of energy requirements applicable to the growing elderly population.

SUBJECTS AND METHODS

Subjects

Initiated in 1997, the Health ABC Study consisted of a cohort of 3075 participants recruited at 2 field centers: the University of Pittsburgh and the University of Tennessee (Memphis). Participants were aged 70–79 y (3 age: 73.6 y), and the population was roughly stratified for sex and race (51.5% women and 41.5% black). Participants were eligible if they reported an ability to walk 0.4 km and climb 10 steps without rest and, in addition, were free of selected physical limitations in the activities of daily living. Additional exclusion criteria included life-threatening cancers, participation in any research study involving medications or modification of eating or exercise habits, and plans to move out of the area in the next 3 y.

The energy expenditure (EE) substudy was conducted between July 1998 and June 2000, and it included a race- and sex-stratified random selection of participants from the larger Health ABC Study. Substudy exclusion criteria included recent blood transfusion or intravenous fluid administration, use of supplemental oxygen or insulin, and overnight travel immediately before or during the EE measurement period. Participants were recruited from a list of 500 persons randomly selected from the original 3075 subjects and were balanced by race and sex. A replacement list of 200 subjects, also stratified for race and sex, was generated. Whenever a participant from the primary list was ineligible or refused to participate, a participant from the same race and sex subgroup was contacted from the replacement list to determine his or her eligibility and willingness to participate. The field centers had lower yields in several cells, and, at the end of 1999, the EE substudy was unbalanced with respect to race. The study was extended to the year 2000 and a new primary list was generated, which oversampled participants in the race and sex categories most lacking at each field center. A total of 323 subjects were enrolled in the EE substudy. No differences were noted between the EE substudy and the entire Health ABC cohort with respect to body mass index (BMI; in kg/m2), age, sex, race, knee extension strength, self-reported physical abilities, or self-reported energy intake. The substudy cohort, however, had a 5% faster time on a standardized walk. We assessed the influence of this difference by adding 400-m walking speed to the multiple regression for physical activity level (PAL). The 5% difference in speed translated to a 1.5% difference in PAL, and the substudy can therefore be considered as representative of the overall Health ABC Study cohort.

Protocol

The testing protocols were completed in the field centers during 2 visits over a 2-wk period. The participants arrived for both visits in the fasted state. During visit 1, participants received a dose of DLW for the measurement of TEE according to a protocol previously described in detail (16), and body composition was determined by using dual-energy X-ray absorptiometry (DXA). Approximately 14 d (14 ± 1 d) after the DLW dosing, the participants returned to the field centers for visit 2. Body weight was recorded, and the participants were asked to relax in a prone position for 30 min in a quiet room with a light cover for thermal comfort. After this, RMR was measured for 40 min by using respiratory gas exchange. During this visit, 2 urine samples were collected for the endpoint DLW analysis. Between visit 1 and visit 2, the subjects were asked to maintain their normal activity pattern.

The protocol was approved by the Internal Review Boards at the University of Tennessee–Memphis and the University of Pittsburgh. The participants were fully informed of the purpose and potential risks of the experimental protocol, and individual informed written consent was obtained before the study.

Total energy expenditure measurements

The TEE was determined by using the 2-point DLW method according to Schoeller et al (17, 18). The specific DLW protocol applied during the Health ABC EE substudy (ie, dose, sample preparations, mass spectrometry analyses of deuterium and 18-oxygen isotopic enrichments in biological specimens, and EE calculations) was detailed elsewhere (16). Briefly, DLW was orally dosed at 0.2 g 18O and 0.14 g deuterium/kg estimated total body water. Results were calculated according to Racette et al (19) with a food quotient estimated at 0.86 from the third National Health and Nutrition Examination Survey (20) and Black’s formula (21). Ten percent of the population displayed delayed urinary isotopic equilibration, and thus plasma enrichment was used for calculation (16).

Blinded repeat isotopic analyses were completed in 16 participants by using duplicate urine aliquots. For the total body water, the within-subject repeatability, calculated as the average percentage difference between the 2 analyses, was 0.1 ± 1.2%. The within-subject analytic repeatability for TEE was 1.2 ± 5.4%. Results were within the limits of expectation predicted for the typical analytic variation in our laboratory.

Resting metabolic rate and activity-related energy expenditure

The RMR was measured on one of 2 Deltatrac II respiratory gas analyzers (Datex Ohmeda Inc, Helsinki). After the subjects rested for 30 min, gas exchanges were measured for 40 min. Data from the first 10 min were excluded, as were the data for 2 min after any movement or loss of wakefulness. The remaining minute-by-minute data were averaged. Methanol burn tests were performed in duplicate once or twice a month. Carbon dioxide recovery averaged 100.1 ± 1.4% at the Pittsburgh site and 100.5 ± 1.5% at the Memphis site. Gas exchange ratios for methanol differed by 2.5% (P < 0.001) between sites; those at Memphis (0.666 ± 0.014; n = 71) were accurate, and those at Pittsburgh (0.683 ± 0.015; n = 48) were a little greater than theoretical. The respiratory ratios for participants enrolled at Pittsburgh were corrected accordingly.

The diet-induced thermogenesis was assumed to be 8% of TEE (22), and the AEE was calculated as 0.92 × TEE – RMR. PAL was calculated as the ratio of TEE to RMR.
Body composition

Total body fat (fat mass, FM) and fat-free mass (FFM) were measured by DXA using a Hologic 4500A Scanner (Hologic Inc, Waltham, MA) with HOLOGIC software (version 8.21; Hologic Inc) for analysis. Health ABC validation studies, however, had shown that DXA FFM systematically overestimated FFM, and DXA FFM and FM were corrected accordingly (23).

Statistical analyses

Of the 323 subjects included in the EE substudy, 35 were excluded from the statistical analysis. Nine of the 323 subjects did not return to the field centers to complete the protocol, 2 failed to collect appropriate urine specimens, 8 had inconsistencies in their stable isotope data, 2 had highly variable RMR measurements, and 14 did not undergo DXA measurements within 15 d of the EE measurements.

Before the statistical analysis, the normality of the data was ascertained by using the Kolmogorov-Smirnov test. Differences between groups were tested by a factorial analysis of variance (ANOVA) with race, sex, and site as main effects. RMR was analyzed by an analysis of covariance (ANCOVA) with race, sex, and site as main effects. None of the 3-factor interactions were significant.

RESULTS

Anthropometric data and body composition

The physical characteristics and body composition of the participants are presented in Table 1. To be consistent with the statistical analysis, the results are presented according to the main effects of the ANOVA. None of the 3-factor interactions were significant.

|               | Women |            | Men |            |            |            |            |            |
|---------------|-------|------------|-----|------------|------------|------------|------------|
|               | Black (n = 67) | White (n = 77) | Black (n = 72) | White (n = 72) | Sex | Race | Race × sex interaction |
| Age (y)       | 74.6 ± 3.2 | 74.8 ± 2.8 | 74.8 ± 2.9 | 75.1 ± 3.2 | 0.56 | 0.52 | 0.88 |
| BMI (kg/m²)   | 28.6 ± 5.9 | 26.2 ± 5.3 | 27.1 ± 4.5 | 27.6 ± 4.2 | 0.73 | 0.12 | 0.02 |
| Weight (kg)   | 73.5 ± 16.8 | 67.2 ± 13.8 | 81.6 ± 14.6 | 83.5 ± 12.5 | <0.0001 | 0.26 | 0.02 |
| Fat-free mass (kg) | 43.8 ± 6.6 | 40.1 ± 6.6 | 59.2 ± 8.1 | 58.0 ± 6.1 | <0.0001 | 0.004 | 0.13 |
| Fat mass (kg) | 29.5 ± 11.1 | 26.9 ± 8.9 | 22.0 ± 7.9 | 25.0 ± 7.6 | <0.0001 | 0.85 | 0.01 |
| Fat mass (%)  | 39.1 ± 6.4 | 38.9 ± 6.3 | 26.4 ± 6.0 | 29.4 ± 5.3 | <0.0001 | 0.04 | 0.04 |

* SD. Statistics are based on factorial ANOVA with sex, race, and site as main effects. See text for effects of site on body composition. None of the 3-factor interactions were significant.
women (30.5 ± 10.4 versus 26.0 ± 9.3 kg), whereas FM did not differ significantly between the men at the 2 sites (Memphis: 23.7 ± 8.0 kg; Pittsburgh: 23.3 ± 7.6 kg).

Energy metabolism

The energy components of the participants are presented in Table 2 stratified by the main effects of the ANOVA. None of the 3-factor interactions were significant.

Sex effects

As expected, the TEE was 25% lower in the women than in the men. This difference was due to a 21% lower RMR and a 31% lower AEE in the women. After statistical adjustment for FFM, RMR did not differ significantly between the men and the women. When AEE was normalized per unit of body weight, the difference observed in nonadjusted values was maintained. PAL did not differ significantly between the sexes, although a trend toward significance was observed.

Race effects

The TEE was 3% lower in the blacks than in the whites. Because AEE did not differ significantly between the races, the difference in TEE was mainly due to a 4% lower RMR in the blacks. The race-by-sex interaction observed for TEE shows the sex specificity of the race difference; i.e., TEE did not differ significantly between the black men and the white men. The relation between FFM and the RMR differed significantly between the races (Figure 1). To account for this difference, race-specific RMR/FFM slopes were maintained in the ANCOVA model, and adjusted RMRs were estimated at different percentiles (25th, 50th, 75th) of the covariate. At all FFM percentiles, RMR adjusted for FFM was significantly lower in the blacks than in the whites (P < 0.001 for all), and it was ≈100 kcal/d at the 50th percentile. The race difference in RMR was maintained even after adjustment for both FFM and FM. The absence of a difference between races in AEE was maintained after normalization per kilogram of body weight. PAL did not differ significantly according to race. It is interesting that age was a significant determinant of RMR. However, by plotting RMR/FFM residuals against age, we observed that the age effect did not differ significantly between the blacks and the whites (Figure 1). Thus, the race difference in slopes of the relation RMR/FFM was not due to an artifact related to age.

Site effects

The TEE was 6% higher in the Pittsburgh subjects than in the Memphis subjects (2229 ± 428 and 2102 ± 459 kcal/d, respectively; P = 0.01). This was attributable to a difference in AEE but not in RMR. Effectively, AEE expressed in kcal/d was 12% lower in the Memphis subjects (672 ± 459 kcal/d) than in the Pittsburgh subjects (760 ± 672 kcal/d; P = 0.01), and the difference (10%) was still significant after normalization for body mass (Memphis subjects: 9.0 ± 3.5; Pittsburgh subjects: 10.0 ± 9.0 kcal·d⁻¹·kg⁻¹; P = 0.04). As expected, these differences were also observed in PAL, which was 4% higher in the Memphis subjects (1.73 ± 0.22) than in the Memphis subjects (1.67 ± 0.24; P = 0.02).

Accuracy of the WHO and 2002 DRI energy requirement predictions

In Figure 2, we compared the estimated and measured energy requirements for each sex and race subgroup. Each step of calculation—i.e., RMR, PAL, and then TEE—is compared with the WHO-derived estimates. Individual age, height, and weight and an estimated PAL were used to calculate energy requirements by using the new nonlinear equation of the 2002 DRIs. Because obesity has been shown to increase EE, the cohort was divided according to BMI: normal-weight and overweight persons combined (20 > BMI < 29.9) and obese persons (BMI ≥30). Ten participants, with a PAL of 1.60 ± 0.20, had a BMI <20, and they were excluded from this analysis because the DRI predictive equations were calculated for a person at an ideal BMI of 25. By splitting our data according to BMIs <30 and ≥30, we allowed a meaningful comparison of the Health ABC Study data with the DRIs at an average BMI of 25. Several points emerged from a repeate-dmeasures ANOVA. The WHO calculations overestimated RMR by 15% (P < 0.0001). This overestimation was greater for the blacks than for the whites (19% and 12%, respectively; P < 0.0001) and greater for the obese persons than for the lean

### Table 2

<table>
<thead>
<tr>
<th>Component</th>
<th>Women</th>
<th>Men</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Black (n = 67)</td>
<td>White (n = 77)</td>
<td>Black (n = 72)</td>
</tr>
<tr>
<td>TEE (kcal/d)</td>
<td>1904 ± 369</td>
<td>1885 ± 286</td>
<td>2324 ± 436</td>
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<tr>
<td>RMR (kcal/d)</td>
<td>1131 ± 170</td>
<td>1150 ± 170</td>
<td>1363 ± 187</td>
</tr>
<tr>
<td>RMR&lt;sub&gt;FFM&lt;/sub&gt; (kcal/d)&lt;sup&gt;2&lt;/sup&gt;</td>
<td>1234 ± 110</td>
<td>1341 ± 101</td>
<td>1216 ± 136</td>
</tr>
<tr>
<td>RMR&lt;sub&gt;FFM,FM&lt;/sub&gt; (kcal/d)</td>
<td>1224 ± 109</td>
<td>1311 ± 100</td>
<td>1227 ± 136</td>
</tr>
<tr>
<td>TEE – RMR (kcal/d)</td>
<td>774 ± 297</td>
<td>735 ± 216</td>
<td>962 ± 345</td>
</tr>
<tr>
<td>AEE (kcal/d)</td>
<td>620 ± 272</td>
<td>584 ± 197</td>
<td>775 ± 313</td>
</tr>
<tr>
<td>AEE (kcal·d⁻¹·kg⁻¹)</td>
<td>8.7 ± 3.5</td>
<td>9.0 ± 3.5</td>
<td>9.7 ± 4.2</td>
</tr>
<tr>
<td>PAL</td>
<td>1.69 ± 0.24</td>
<td>1.65 ± 0.21</td>
<td>1.71 ± 0.24</td>
</tr>
</tbody>
</table>

<sup>2</sup> ± SD. AEE, activity energy expenditure; PAL, physical activity level; RMR, resting energy expenditure; FFM, fat-free mass; RMR<sub>FFM</sub>, resting energy expenditure adjusted for FFM; TEE, total energy expenditure. Statistics are based on factorial ANOVA with sex, race, and site as main effects. See text for effects of site on energy expenditure components. None of the 3-factor interactions were significant.

<sup>2</sup> Because of the nonhomogeneity of the FFM × race slopes, values of RMR were adjusted for FFM taken at the 50th percentile of the population.
or overweight persons (18% and 14%, respectively; \( P < 0.0001 \)). We also found that the WHO-proposed PAL was low by 10% (\( P < 0.0001 \)), and the difference was greater in the men than in the women (7% and 15%, respectively; \( P = 0.0003 \)). The WHO-derived energy requirements overestimated TEE by 5 ± 15% (\( P < 0.0001 \)). More detailed analysis showed that this overestimation was observed in the women, but not in the men (10% and 0.2%, respectively; \( P < 0.0001 \)), and it was more important in the obese persons than in the normal-weight persons (8% and 2%, respectively; \( P < 0.0001 \)) and more important in the blacks than in the whites (7% and 2%, respectively; \( P = 0.002 \)). Conversely, the 2002 DRI energy requirement estimates were accurate with an overall difference of 0 ± 14% with TEE (\( P = 1.0 \)). No significant effects of sex (\( P = 0.2 \)) or BMI range (\( P = 0.4 \)) were noted. A race effect (\( P = 0.002 \)) explained by an overestimation of energy requirements in black men, was observed (12%). The WHO recommendations underestimated the DRI range for PAL. The group with a BMI ≥30 included 23 black women, 14 white women, 18 black men, and 18 white men. The group with a BMI of 20–29.9 included 42 black women, 59 white women, 51 black men, and 53 white men.
less, as was seen with the WHO recommendations, the range of PAL used in the DRI predictive equations (1.4 > PAL < 1.6) was underestimated.

Health ABC Study–derived predictive equations of energy requirements

Predictive equations of RMR based on the Health ABC Study cohort are proposed in Table 3. Because the RMR:FFM relation differed by race, the RMR predictive equations were independently generated for the blacks and the whites. The frequency distribution of PAL among subjects with BMIs above and below 30 are shown in Figure 3. Because PAL did not differ by BMI, sex, or race, TEE can be predicted by multiplying the derived RMR by 1.52, 1.67, and 1.85 for persons of below-average (taken at the 25th PAL population percentile), average (50th percentile) and above-average (75th percentile) physical activity, respectively.

DISCUSSION

In the Health ABC Study, the women had lower TEEs than did the men (≈539 kcal/d), as expected from previous studies (24–26). Among the previous studies, the largest one reported an overall sex difference (≈741 kcal/d) but no effect due to race on unadjusted values of EE (24). Because FFM is a main determinant of TEE, those authors adjusted TEE to account for the difference in FFM. In doing so, they unmasked a lower TEE in blacks than in whites (≈43 kcal/d), and the sex difference was maintained (≈383 kcal/d). In the Health ABC Study cohort, unadjusted TEE was lower in the blacks than in the whites (≈72 kcal/d), and the presence of a sex-by-race interaction showed that the race effect was attributable to a difference in the men, but not in the women. We propose that it is an oversimplification to linearly adjust TEE for FFM only, because TEE differences are explained by variations in RMR, AEE, or diet-induced thermogenesis, each of which should be adjusted for their determinant or determinants. Nevertheless, to compare the Health ABC Study data with data from previous reports (24), we also adjusted TEE by FFM and confirmed the race effect (≈146 kcal/d; P < 0.001), but not the sex effect (P = 0.23); however, these studies differ in sample size and the age range of the subjects (the largest study has 65 participants with a mean age of ≈65 y; 24). Six other studies, as reviewed elsewhere (13), investigated the race differences in TEE in prepubertal or early pubertal and middle-aged subjects. One of these studies showed a tendency for lower TEE in black subjects. In this current study, FFM differences explained the sex effect in TEE, but failed to account totally for the race difference.

On the other hand, because the relation between FFM and RMR has an intercept different from zero, Ravussin and Bogardus (27) concluded that RMR values should be adjusted for FFM by a multivariate-based approach. Theoretically, however, such an analysis can be performed only if the slopes for RMR versus FFM for blacks and whites or men and women are similar (28). In previous, smaller studies, slopes were not found to be different, but the Health ABC Study cohort is the largest group thus studied; we observed nonhomogeneity of the slopes

![Figure 3](image-url)
for race but not for sex (ie, RMR differences between blacks and whites increased with FFM). Gannon et al (13) also reported that 10 of the 15 studies they reviewed had found a lower RMR in blacks than whites. The differences ranged from 81 to 275 kcal/d and were not explained by age, FFM, or method. Given the difference in the slopes, we applied the unequal-slope model of ANCOVA and calculated adjusted RMR at different percentiles of FFM in the population. Indeed, at all percentiles, the RMR adjusted for FFM was lower in blacks than in whites and was ≈99 kcal/d at the 50th FFM percentile (50.2 kg). Regarding the sex effect, our results do not support the observations of others (29–31) that RMR adjusted for FFM is lower in women than men. Given the age of our cohort, we speculate that the sex difference decreases with advanced age, perhaps because of concomitant decreases in sex hormones (32).

ANCOVA implies that FFM is a homogeneous compartment, but Heymsfield et al (33) showed that FFM is not an energetically homogeneous compartment, but, rather, that tissues vary with respect to heat production per gram of FFM. Viewed from this perspective, the nonhomogeneity of the slope suggests that, with increasing body mass, blacks respond with greater fractional increases in low-metabolic-rate tissues (ie, skeletal muscle, connective tissue, bone) than do whites. However, the similar intercepts suggest that blacks and whites are comparable in terms of the high-metabolic-rate residual mass (ie, heart, kidney, brain). Aloia et al (34) showed that body cell mass is similar in white women and black women in early adulthood, but declines with age to a greater extent in white women than in black women. Therefore, the unequal slopes observed in the present study may be specific to our age group and not simply due to the greater power resulting from the sample size.

It is widely accepted that physical activity and EE during physical activity decline with age, but activity in the elderly varies greatly, depending on health and independence. The mean values therefore depend on the subjects included in the sample. The Health ABC Study cohort was selected to reflect a relatively healthy, well-functioning group of older persons who were free of severe disabilities. Even so, the CV for AEE was 40.9%. The sex difference observed in unadjusted AEE in the Health ABC Study cohort was expected (24). No relevant race effect by inclusion of data from some black persons. To overestimate them. This overestimation was only 5 ± 15% for the overall Health ABC Study cohort, but it was greater in women, blacks, and obese persons. More important, the WHO equations are derived from overestimated RMR and underestimated PAL. This WHO-derived RMR overestimation, but not the underestimate of PAL, was previously reported (40). It is relevant that the WHO database for derived RMR equations (42) contained few persons >60 y old.

In 1985 WHO recommended (14) that energy requirements be derived from measurements of TEE, and the 2002 DRI (15) sex-based energy-requirement equations were so derived. The DRI nonlinear sex-based equations were derived for an spectrum of adults aged >19 y old, but the contribution of elderly and African American persons with normal BMIs was small. The accuracy of these equations is, nevertheless, very good—a difference of 0 ± 14% from the actual TEE was noted—but the elderly in our study had PALs above the range suggested for people with low activity (1.4 > PAL < 1.6). No relevant race effects were noted, either because the error in the energy requirement estimates overlapped the race difference in TEE or because the DRI database was somehow weighted for the race effect by inclusion of data from some black persons. To overcome the limitations of the current WHO recommendations and to account for the DRI’s underestimate of PAL, we propose RMR prediction equations that take into account both race and sex and that can be easily used by clinicians.

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SB performed data analysis and drafted the manuscript. DAS supervised the data analysis and edited the manuscript. DB consulted on study design and edited the manuscript. MED supervised the data collection and edited the manuscript. FT supervised the data collection and edited the manuscript. EMS designed the study and edited the manuscript. TBH was the principal investigator, designed the study, and edited the manuscript. SBK consulted on study design, recruited subjects, and edited the manuscript. JEE designed the study and edited the manuscript. None of the authors had personal or financial conflicts of interest.

REFERENCES


26. Tylavsky F, Lohman T, Blunt BA, et al. QDR 4500A DXA overesti-