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S. Y. S. Kimm, N. W. Glynn, C. E. Aston, E. T. Poehlman and S. R. Daniels
Am. J. Epidemiol., October 15, 2001; 154 (8): 718-724.

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Total daily energy expenditure in free-living older African-Americans and Caucasians

WILLIAM H. CARPENTER, TEKUM FONONG, MICHAEL J. TOTH, PHILIP A. ADES, JORGE CALLES-ESCANDON, JEREMY D. WALSTON, AND ERIC T. POEHLMAN
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Carpenter, William H., Tekum Fonong, Michael J. Toth, Philip A. Ades, Jorge Calles-Escandon, Jeremy D. Walston, and Eric T. Poehlman. Total daily energy expenditure in free-living older African-Americans and Caucasians. *Am. J. Physiol.* 274 (*Endocrinol. Metab.* 37): E96–E101, 1998.—Low rates of daily energy expenditure, increased energy intake, or a combination of both contribute to obesity in African-Americans. We examined whether African-Americans have lower rates of free-living daily energy expenditure than Caucasians. One hundred sixty-four (>55 yr) volunteers (37 African-American women, 52 Caucasian women, 28 African-American men, and 47 Caucasian men) were characterized for total daily energy expenditure, resting metabolic rate, and physical activity energy expenditure from the doubly labeled water method and indirect calorimetry. Absolute total daily energy expenditure was lower in women than men but was not different between African-Americans and Caucasians. However, we found race and gender differences in total daily energy expenditure after controlling for differences in fat-free mass. Total daily energy expenditure was 10% lower ($P < 0.01$) in African-Americans compared with Caucasians due to a 5% lower resting metabolic rate ($P < 0.01$) and 19% lower physical activity energy expenditure ($P = 0.08$). Moreover, total daily energy expenditure was 16% lower ($P < 0.01$) in women compared with men due to a 6% lower resting metabolic rate ($P = 0.09$) and a 37% lower physical activity energy expenditure ($P = 0.06$). Low rates of energy expenditure may be a predisposing factor for obesity, particularly in African-American women.

metabolic rate; aging; obesity; activity

OBESITY OCCURS when energy intake chronically exceeds energy expenditure. The prevalence of obesity is increasing rapidly in the United States and other industrialized nations (12). The prevalence of obesity in African-American women is estimated to be twice that of Caucasian American women. Obesity contributes to many adverse health outcomes, including type II diabetes, as well as an increase in cardiovascular and all-cause mortality. The associated rate of hypertension and mortality due to heart disease, stroke, and diabetes in African-American women is 1.5 to 2.0 times that of Caucasian women (6, 13, 19). Moreover, the prevalence of obesity-related risk factors in African-Americans increases with advancing age due to unfavorable changes in body composition and a sedentary lifestyle (16–18, 20, 25, 26, 32). The annual economic costs of obesity in the United States from medical expenses and loss of income are reported to exceed sixty-eight billion dollars (35).

The etiology of race and gender differences in obesity is complex, with behavioral, environmental, and genetic factors contributing to the development of obesity. An individual may become obese with a “normal” energy expenditure if intake is excessive, or with a normal energy intake if energy expenditure is inappropriately low. A low resting metabolic rate (RMR) is one factor that predisposes individuals to gain body weight (29). Some studies show a lower RMR in younger African-Americans compared with Caucasians (2, 9, 15) and in women compared with men (1, 7, 23, 24). Collectively, these findings suggest that African-American women may be particularly susceptible to obesity because of a low resting energy expenditure.

Body weight, however, is regulated by the dynamic balance between energy intake and daily energy expenditure in free-living individuals. No studies, to our knowledge, have examined the effects of race on daily energy expenditure in free-living African-Americans. We hypothesized that African-Americans would have a lower total daily energy expenditure than Caucasians. To address this issue, we used the doubly labeled water method, indirect calorimetry, and dual-energy X-ray absorptiometry (DEXA) to examine the effects of race on total daily energy expenditure and its components (RMR and physical activity energy expenditure) in a relatively large sample of African-American and Caucasian men and women.

METHODS

Study populations. Apparently healthy volunteers >55 yr of age were recruited by newspaper advertisements. All participants were in generally good health defined by the following criteria: 1) no clinical evidence of coronary heart disease as assessed by normal resting and exercise stress test electrocardiogram, 2) a resting blood pressure <140/90 mmHg, 3) absence of any prescription or over-the-counter medication that could affect cardiovascular or metabolic function, 4) weight stability (± 2 kg by medical history within the past 6 mo), and 5) no medical history of diabetes. No women were taking hormone replacement therapy, and all women were postmenopausal. All volunteers were nonsmokers and were not participating in a regular exercise program. The extent of racial admixture was assessed by a personal interview. African-American individuals were eligible if they identified that their parents and grandparents were of African ancestry. The procedures used were approved by the Institutional Review Boards of the University of Vermont and the University of Maryland at Baltimore. Written informed consent was obtained from each subject before the start of the investigation.

Timing of tests. All tests were performed in the morning at 0700, at which time the following measurements were made: 1) RMR, 2) body composition by DEXA, 3) peak aerobic capacity ($\dot{V}O_{2\text{peak}}$), and 4) leisure time physical activity. Subjects were provided instructions on recording dietary intake. Height was measured to the nearest 0.5 cm by using a stationary inflexible measuring tape and head board, and body mass was measured to the nearest 0.5 kg using a calibrated scale. Body composition, fat and lean tissue weights (g), total body fat, and fat-free mass were determined from a total body scan using a Lunar DPX-L densitometer (Lunar Version 1.3z DPX-L extended analysis program for body composition).

Measurement of total daily energy expenditure. Total daily energy expenditure was measured over 10 days under free-living conditions with the doubly labeled water technique. Briefly, a baseline urine sample was collected the evening before the testing for the determination of background isotope enrichments, and subjects were administered a mixed dose of doubly labeled water containing ~ 0.092 g H_2^{18}O and 0.078 g $^2\text{H}_2\text{O}$ /kg body weight. A total of four timed urine samples were collected the morning after the dosing ($n = 2$) and ~ 10 days later on a return visit to the facility ($n = 2$). The first void of the morning was discarded to avoid isotopic concentration of the urine that takes place during the night after the dosing. At the time of dosing, a weighed 1:400 dilution of the dose and sample of the water used for dilution were prepared and analyzed for each subject. Samples were analyzed in triplicate for $^2\text{H}_2\text{O}$ and H_2^{18}O using the off-line zinc reduction method and a modification of the CO_2 equilibration technique. In the modified CO_2 equilibration technique 1.0-ml aliquots were equilibrated with 0.5 ml of 99.9% pure CO_2 gas. The samples were allowed to equilibrate overnight at room temperature by shaking. The CO_2 gas was analyzed by injecting the gas into a packed gas chromatography column before introduction to the isotope ratio mass spectrometer. Isotope turnover rates and zero-time enrichments were calculated as previously described (10) and converted to energy expenditure (34).

RMR. RMR was established for each subject by indirect calorimetry for 45 min using a Deltatrac metabolic cart (Sensormedics, Yorba Linda, CA) (21). Subjects were asked to refrain from all vigorous activity before these measurements. Subjects were measured after an overnight fast in a darkened, temperature-controlled room. After being allowed to void, the subjects returned to their beds, were placed in a supine position, and had a clear plastic hood placed over their head. Constant O_2 consumption and CO_2 production were monitored as room air was drawn through the hood. Air flow rate was measured using a pneumotachograph. O_2 and CO_2 gas volumes were converted to energy equivalents (kcal/day) using the equation of Weir (34). Test-test conditions of six older female and six older male volunteers yielded an intraclass correlation of 0.94 and a coefficient of variation of 4.1%.

Physical activity energy expenditure. Physical activity energy expenditure was estimated from measurements of daily energy expenditure and RMR and by an estimation of the thermic response to feeding (10% of daily energy expenditure) (22). Thus physical activity energy expenditure was derived as follows: physical activity energy expenditure (kcal/day) = $(0.9 \times \text{daily energy expenditure}) - \text{RMR}$.

Measurement of $\dot{V}O_{2\text{peak}}$ and leisure time physical activity. $\dot{V}O_{2\text{peak}}$ was measured by a progressive and continuous treadmill test to exhaustion, as previously described (21, 32). Volunteers self-selected their running speed, and the incline was increased by 2.5 degrees every 2 min from an initial level of 0 degrees until volitional fatigue. A structured interview

evaluating the energy cost of leisure time activities (LTA) during the previous 12-mo period was carried out using the Minnesota Leisure Time Physical Activity Questionnaire (8, 31).

Energy intake and socioeconomic status. Self-reported energy intake was obtained from a 3-day, self-recorded food diary, which included two weekdays and one weekend day. Subjects were strongly encouraged not to change their normal dietary habits and were instructed by research assistants to measure food intake. Dietary scales, measuring cups, and spoons were provided to each subject to help quantify the portion consumed. Food records were checked for completeness by a research assistant at the time of their return by the subjects. The records were analyzed for energy content by using the Nutritionist 4.1 software package for Windows (First DataBank Computing, San Bruno, CA). Socioeconomic status was defined by determination of education level, income status, and living status. Volunteers were classified on percentages of having completed high school, having a household income exceeding \$20,000 per year, and whether they lived alone or with a spouse or partner.

Statistics. Values are presented as mean values \pm SD. Race and gender effects were assessed by a 2×2 factorial analysis of variance and covariance. In analysis of covariance, we used fat-free mass as the covariate because stepwise regression analysis identified this variable as the best predictor of variation (r^2) in total daily energy expenditure, physical activity energy expenditure, and RMR (r^2 values $\approx 50\%$). Moreover, analysis of covariance allows for the removal of the linear effect of fat-free mass on the dependent variables. This approach takes into account that the correlation between the dependent variables and fat-free mass is not $r = 1.0$ and that the mathematical relationship between the two variables has an intercept different from zero (23, 33). We also examined race and gender differences in energy expenditure after controlling for the effects of fat mass, educational level, annual income, and living status. Control for these variables did not change the results. Thus adjusted values for total daily energy expenditure and its components by use of fat-free mass as the single covariate are presented in the text. χ^2 Statistics were used to analyze categorical variables. An α -level less than $P < 0.05$ was considered statistically significant.

RESULTS

Table 1 shows physical characteristics for African-Americans and Caucasians. The results are presented by race and gender, which is consistent with grouping factors (i.e., main effects) derived from the analysis of variance.

Race effects. African-Americans were slightly younger ($P < 0.001$) than Caucasians. No race effect was found for standing height. Body mass index was higher ($P < 0.001$) in African-Americans compared with Caucasians and highest in African-American women ($P < 0.01$) (i.e., interaction term) compared with the other groups. African-Americans weighed more ($P < 0.001$) than Caucasians because of a greater fat mass and fat-free mass (both at $P < 0.001$). Fat mass was highest in African-American women compared with the other groups ($P < 0.01$; interaction term). African-Americans had a greater waist circumference ($P < 0.001$) compared with Caucasians. LTA was lower in African-Americans compared with Caucasians ($P < 0.05$). No difference in $\dot{V}O_{2\text{peak}}$ was found between the races.

Table 1. *Subject characteristics*

Variable	African-American Women	Caucasian Women	African-American Men	Caucasian Men	Two-Way ANOVA
<i>n</i>	37	52	28	47	
Age, yr	65 ± 8	67 ± 6	64 ± 7	70 ± 7	Race, <i>P</i> < 0.001
Height, cm	162 ± 8	162 ± 5	175 ± 7	175 ± 6	Gender, <i>P</i> < 0.001
Body mass, kg	84 ± 17	65 ± 10	87 ± 14	75 ± 10	Race, <i>P</i> < 0.001
Body mass index, wt/h ²	32 ± 6	25 ± 4	28 ± 4	25 ± 4	Gender, <i>P</i> < 0.01
Fat mass, kg	39 ± 13	24 ± 8	24 ± 8	19 ± 9	Race, <i>P</i> < 0.001
Fat-free mass, kg	45 ± 7	41 ± 3	63 ± 9	57 ± 6	Gender, <i>P</i> < 0.001
Waist circumference, cm	97 ± 13	82 ± 11	100 ± 11	92 ± 11	Interaction, <i>P</i> < 0.01
LTA, kcal/day	207 ± 212	353 ± 265	410 ± 320	454 ± 371	Race, <i>P</i> < 0.001
$\dot{V}O_{2peak}$, l/min	1.4 ± 0.3	1.4 ± 0.3	1.9 ± 0.6	2.1 ± 0.5	Gender, <i>P</i> < 0.001
Adjusted* $\dot{V}O_{2peak}$	1.6 ± 0.6	1.7 ± 0.6	1.8 ± 0.6	1.8 ± 0.6	NS
Energy intake, kcal/day	1,808 ± 421	1,623 ± 388	2,232 ± 807	2,129 ± 463	Race, <i>P</i> < 0.05
Education >high school, %	65	83	33	82	Gender, <i>P</i> < 0.001
Income >20 K/yr, %	38	75	50	86	Race, <i>P</i> < 0.001
Lone living status, %	51	33	46	20	Race, <i>P</i> < 0.05

Values are expressed as means ± SD. LTA, leisure-time physical activity; $\dot{V}O_{2peak}$, peak oxygen consumption; ANOVA, analysis of variance; *n*, number of volunteers/group; NS, not significant. * $\dot{V}O_{2peak}$ values were adjusted for fat-free mass using analysis of covariance as previously described (33).

African-Americans reported consuming more calories than Caucasians (*P* < 0.05). Fewer African-Americans had an education above the high school level compared with Caucasians (*P* < 0.001). Fewer African-Americans earned over \$20,000 per year than Caucasians (*P* < 0.001), and a greater percentage lived alone compared with Caucasians (*P* < 0.05).

Gender effects. As expected, men were taller (*P* < 0.001) than women and weighed more (*P* < 0.01). Men had lower amounts of fat mass (*P* < 0.001) but a greater quantity of fat-free mass than women (*P* < 0.001). Men had a larger waist circumference compared with women (*P* < 0.001). Reported LTA was lower in women (*P* < 0.01) compared with men. $\dot{V}O_{2peak}$ was lower (*P* < 0.001) in women compared with men. Men reported consuming more calories than women did (*P* < 0.001). No gender effects were noted for education, household income, and living status.

Absolute values (i.e., not adjusted for fat-free mass) showed that total daily energy expenditure was lower (gender effect; *P* < 0.001) in African-American women (1,987 ± 396 kcal/day) and Caucasian women (1,946 ± 371 kcal/day) than in African-American men (2,642 ± 537 kcal/day) and Caucasian men (2,584 ± 506 kcal/day). RMR was higher in African-American men (1,631 ± 205 kcal/day) and African-American women (1,390 ± 224 kcal/day) (i.e., race effect; *P* < 0.05) compared with Caucasian men (1,582 ± 225 kcal/day) and Caucasian women (1,283 ± 187 kcal/day) due to their greater quantity of fat-free mass. As expected, women displayed a lower RMR than men (gender effect; *P* < 0.001). Absolute values for physical activity energy expenditure were lower (gender effect; *P* < 0.001) in

African-American women (397 ± 290 kcal/day) and Caucasian women (469 ± 305 kcal/day) than in African-American men (746 ± 438 kcal/day) and Caucasian men (743 ± 375; values not shown in table form).

Figure 1 shows race and gender differences in total daily energy expenditure, RMR, and physical activity energy expenditure after statistical adjustment for fat-free mass. This comparison is most meaningful because it compares rates of energy expenditure per kilogram of fat-free mass and thus removes the body size dependency on energy expenditure variables. Adjusted total daily energy expenditure showed race and gender effects. That is, daily energy expenditure was lower in African-Americans compared with Caucasians (race effect; *P* < 0.01) and lower in women compared with men (i.e., gender effect; *P* > 0.01). Race and gender effects were also noted for RMR. RMR was lower in African-Americans (race effect; *P* < 0.01) compared with Caucasians, and a trend (*P* = 0.09) for a lower RMR in women compared with men was noted. Physical activity energy expenditure tended to be lower (19%; *P* = 0.08) in African-Americans compared with Caucasians and in women compared with men (*P* = 0.06).

DISCUSSION

We examined differences in total daily energy expenditure, RMR, and physical activity energy expenditure in a relatively large sample of free-living African-Americans and Caucasians that were carefully characterized for total daily energy expenditure, body composition, and socioeconomic status. This is the first study

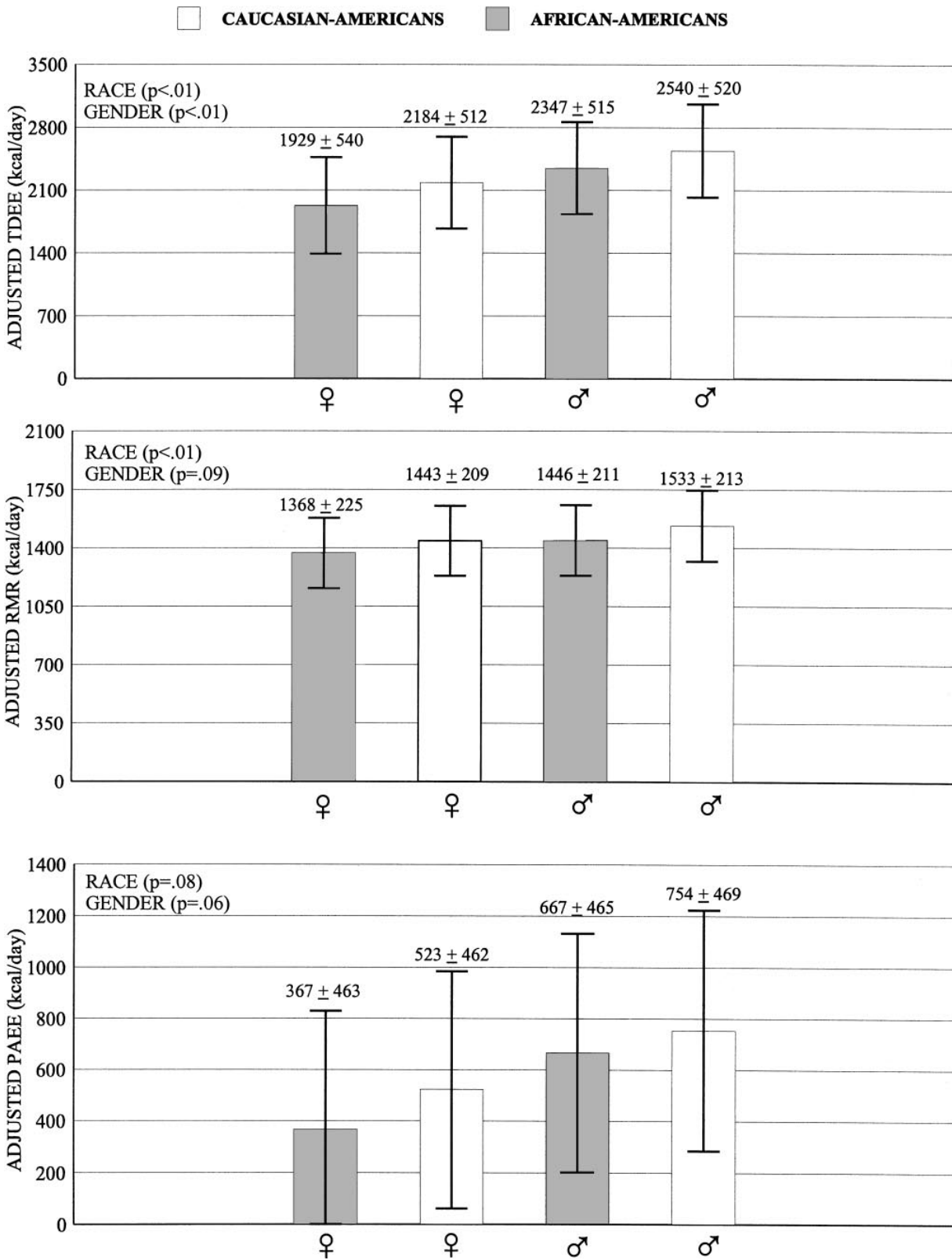


Fig. 1. Adjusted total daily energy expenditure (TDEE), adjusted resting metabolic rate (RMR), and adjusted physical activity energy expenditure (PAEE) in African-American and Caucasian men and women. Values were adjusted for fat-free mass. Statistical control for age, fat mass, education level, income, and living status did not alter these results. Slope of regression lines relating daily energy expenditure to fat-free mass are men 23.9 ± 10.8 vs. women 20.7 ± 8.4 kcal/day [not significant (NS)]; and African-Americans 30.1 ± 6.2 vs. Caucasians 36.0 ± 6.2 kcal/day (NS). ♀, Female; ♂, male.

to report that free-living African-Americans have lower levels of total daily energy expenditure than Caucasians that are independent of differences in fat-free mass. African-Americans, particularly African-American women, may have a greater predisposition for obesity because of their low energy expenditure.

Total daily energy expenditure. Our results show a lower total daily energy expenditure in African-Americans (≈ 225 kcal/day) compared with Caucasians after controlling for differences in fat-free mass. The low level of total daily energy expenditure was unmasked in African-Americans after controlling for fat-free mass. Variation in energy expenditure among individuals is primarily determined by differences in fat-free mass (28), and African-Americans had more fat-free mass than Caucasians (Table 1). Thus adjustment for fat-free mass permits a meaningful comparison of the rate of energy expenditure independent of the confounding influence of differences in body size and composition. The most striking finding was the diminished levels of total daily energy expenditure in African-American women. They showed a lower total daily energy expenditure when compared with Caucasian women (12%), African-American men (18%), and Caucasian men (24%) (Fig. 1). Thus our results suggest that African-Americans, particularly African-American women, require fewer calories for their body size to maintain body weight. Low rates of total daily energy expenditure may be an important metabolic factor predisposing African-American women to obesity and its metabolic consequences.

Differences in socioeconomic status have also been shown to relate to the higher prevalence of obesity in African-Americans (5, 6, 11, 14, 30). Because we noted racial differences in education, income, and living status among groups (Table 1), we also controlled for these variables in our model, but our results were unaltered. Thus it appears that differences in socioeconomic status, independent of differences in fat-free mass, do not explain the lower energy expenditure in African-Americans compared with Caucasians.

Only one other study, to our knowledge, has examined total daily energy expenditure using doubly labeled water in free-living African-Americans (15). These investigators did not find differences in total daily energy expenditure among young African-American and Caucasian women. Although the present study and that of Kushner et al. (15) are not directly comparable, different results between studies may be in part due to differences in sample size, age of the volunteers, and the failure to adjust total daily energy expenditure for differences in fat-free mass. The larger sample size in the present study ($n = 164$) compared with that of Kushner and colleagues ($n = 29$), as well as differences in the age of the volunteers examined (66 vs. 38 yr), may contribute to divergent results.

Physical activity energy expenditure and RMR. Differences in total daily energy expenditure are a function of its components (RMR and the energy expenditure of physical activity). Accordingly, we found lower physical activity energy expenditure (≈ 122 kcal/day)

and a lower RMR (≈ 81 kcal/day) in African-Americans compared with Caucasians, with differences being most pronounced in African-American women.

Physical activity energy expenditure is the most variable component of daily energy expenditure in free-living individuals (10). The measurement of free-living physical activity has been problematic until the advent of the doubly labeled water method. This method provides an estimation of the energy cost of physical activity in an individual's free-living environment. Low levels of physical activity are related to increasing body fatness with advancing age (25). Moreover, a low level of physical activity is recognized as an independent risk factor for coronary artery disease (27). To our knowledge, this is the first study to report low levels of physical activity-related energy expenditure in African-American women that are independent of differences in fat-free mass (Fig. 1). Low levels of physical activity have been noted in younger African-American women with the use of doubly labeled water (15) and from a study using a physical activity questionnaire (4). Thus intervention strategies aimed at increasing physical activity, particularly in African-American women, represent a major public health priority.

RMR is the largest component of total daily energy expenditure. A low RMR for an individual's metabolic size predicts weight gain (29). In agreement with the present study, several investigators reported a lower RMR (per kg of fat-free mass) in African-Americans compared with Caucasians (2, 9, 15). Thus it is possible that a low RMR for their metabolic size in African-Americans may contribute to a positive energy imbalance in African-Americans. Longitudinal examinations of changes in energy expenditure and body composition are needed, however, to rigorously test this hypothesis in African-Americans.

Women showed lower rates of daily energy expenditure (≈ 387 kcal/day) and RMR (≈ 83 kcal/day) and a tendency for lower physical activity energy expenditure (≈ 265 kcal/day) than men. This study extends findings from previous studies that showed a lower RMR and 24-h energy expenditure in women compared with men after taking into account differences in body composition (1, 7, 23, 24). Taken together, the race and gender effects on total daily energy expenditure suggest that African-American women have the highest risk for possible development of obesity because of the low total daily energy expenditure. This is consistent with the very high prevalence of obesity and its metabolic consequences of non-insulin-dependent diabetes mellitus, dyslipidemia, and hypertension found in this population.

Several limitations of our study should be noted. Our study cannot determine cause and effect because of its cross-sectional nature. Only prospective studies can elucidate whether low rates of energy expenditure eventually contribute to the development of obesity in African-Americans. Moreover, one cannot discount that episodic periods of excessive caloric intake may also contribute to the high incidence of obesity in African-Americans. Indeed, reported energy intake was higher

in African-Americans than Caucasians, although true energy intake in individuals is frequently underestimated (10). Nonetheless, our findings support the notion of a lower resting and physical activity energy expenditure in African-Americans compared with Caucasians. Our results, if confirmed, could help guide health care professions to provide more targeted interventions for increasing physical activity and reducing obesity in African-Americans.

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