Energy metabolism in African Americans: potential risk factors for obesity[1,2]

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ABSTRACT

Background: Recent reports have identified a lower resting metabolic rate in African Americans than in whites, but most studies included only females and used short-term measurements with ventilated-hood systems.

Objective: Our objective was to compare 24-h measurements of energy metabolism between African American and white women and men using a respiratory chamber.

Design: Thirty-eight African American ($\bar{x} \pm$ SD: 32 ± 7 y of age, 24 ± 10% body fat) and 288 white (31 ± 7 y of age, 26 ± 12% body fat) subjects spent 24 h in a respiratory chamber for measurement of 24-h energy expenditure (24EE), sleeping metabolic rate (SMR), 24-h respiratory quotient (24RQ), and substrate oxidation rates.

Results: After adjustment for sex, age, and body composition (by hydrodensitometry), African Americans had lower SMR (−301 ± 105 kJ/d; $P < 0.01$) and higher 24RQ (0.014 ± 0.004; $P < 0.001$) than whites, whereas 24EE was similar. A sex-specific analysis, using a subset of 38 whites with an equal sex distribution and similar age and body weight, revealed that African American women had lower SMR (−442 ± 182 kJ/d; $P < 0.05$) and lower 24EE (−580 ± 232 kJ/d; $P < 0.05$), but similar 24RQ values compared with white women. African American men tended to have lower SMRs than white men (−355 ± 188 kJ/d; $P = 0.07$), but had higher 24RQ values, accounting for a 992 ± 327–kJ/d lower 24-h fat oxidation rate ($P < 0.005$).

Conclusions: These data not only confirm the findings of a lower metabolic rate in African American than in white women, but also suggest that fat oxidation is lower in African American men than in white men. *Am J Clin Nutr* 1999;70:13–20.

KEY WORDS Ethnicity, metabolic rate, respiratory quotient, respiratory chamber, energy expenditure, blacks, whites, Caucasians, African Americans, fat oxidation, women, men

INTRODUCTION

Nationwide epidemiologic surveys indicate that the prevalence of overweight and obesity have increased recently in the United States, reaching 32.0% and 22.5%, respectively (1). It is well established that several ethnic minority populations, such as Native Americans, Mexican Americans, and African Americans, are particularly prone to obesity (2–7). Interestingly, the excess prevalence of obesity [body mass index (BMI; in kg/m^2) >30] in African Americans is mostly accounted for by women (37.4% compared with 22.4% in white women), whereas the prevalence rates in African American (21.3%) and white (20.0%) men are comparable (1). A variety of explanations have been suggested to explain the high prevalence of obesity in African American women, including differences in genetic susceptibility (8), cultural attitudes toward obesity and body image (9, 10), socioeconomic status (11, 12), parity (13), and levels of physical activity (14–16).

In studies of Pima Indians, another population prone to obesity, we identified the following 3 metabolic predictors of body weight gain using a human respiratory chamber: *1*) a low rate of energy expenditure (17); *2*) a high 24-h respiratory quotient (24RQ), ie, a low fat oxidation rate (18); and *3*) a low level of spontaneous physical activity (SPA; 19). Several recent studies have observed lower resting metabolic rates in African American than in white women (20–25). However, to date, all studies but one (25) included only women and assessed only short-term measurements of resting energy expenditure and fasting respiratory quotient with use of ventilated-hood systems (20–24). In the only study in which men were included and long-term energy expenditure was measured (by doubly labeled water), Carpenter et al (25) reported not only lower resting metabolic rates, but also lower free-living 24-h energy expenditure (24EE) in African Americans of both sexes. To our knowledge, there has not yet been a comparative investigation of 24-h energy metabolism including substrate oxidation comparing African Americans and whites. The aim of the present study, therefore, was to compare 24EE, sleeping metabolic rate (SMR), and 24-h respiratory quotient (24RQ) between African American and white men and women using a human respiratory chamber.

SUBJECTS AND METHODS

Subjects

Thirty-eight African American (15 women, 23 men) and 288 white (112 women, 176 men) subjects who spent 24 h in our

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TABLE 1
Physical characteristics of the study population

	Women			Men		
	African Americans (n = 15)	All whites (n = 112)	Pair-matched whites (n = 15)	African Americans (n = 23)	All whites (n = 176)	Pair-matched whites (n = 23)
NGT:IGT[1]	13:2	95:17	13:2	21:2	151:26	21:2
Age (y)	32.5 ± 8.7[2]	31.9 ± 8.5	31.7 ± 9.2	31.5 ± 5.9	30.0 ± 7.0	30.1 ± 6.2
BMI (kg/m^2)[3]	33.9 ± 8.8	33.1 ± 9.5	33.9 ± 8.8	28.3 ± 4.8	30.5 ± 6.8	28.8 ± 5.5
Body weight (kg)	90.8 ± 23.0	89.4 ± 25.2	91.2 ± 23.0	89.1 ± 17.6	85.2 ± 22.1	89.0 ± 17.6
Body fat (%)[3]	32 ± 8	35 ± 9	32 ± 8	19 ± 7	20 ± 9	21 ± 8
Fat mass (kg)[3]	35.5 ± 17.2	38.2 ± 18.7	37.8 ± 16.0	20.0 ± 11.1	21.2 ± 15.1	23.0 ± 12.4
Fat-free mass (kg)[3,4]	55.3 ± 8.1	51.2 ± 8.6[5]	53.4 ± 9.8	69.1 ± 8.8	64.0 ± 9.4[5]	66.0 ± 7.5
Waist-to-thigh ratio[6]	1.35 ± 0.16	1.48 ± 0.18[7]	1.41 ± 0.11	1.39 ± 0.12	1.51 ± 0.15[7]	1.52 ± 0.15[7]

[1] Ratio of subjects with normal to those with impaired glucose tolerance, according to WHO criteria (26).
[2] $\bar{x}$ ± SD.
[3] Significant effect of sex, $P < 0.0001$.
[4,6] Significant effect of race: [4]$P < 0.005$, [6]$P < 0.0001$.
[5,7] Significantly different from African Americans: [5]$P < 0.05$, [7]$P < 0.01$.

respiratory chamber were included in this analysis (**Table 1**). They were all between the ages of 20 and 50 y, were nondiabetic according to a 75-g oral-glucose-tolerance test [according to both World Health Organization (26) and American Diabetes Association (27) criteria], were nonsmokers at the time of the study, and were healthy according to results of a physical examination and routine laboratory tests. The subjects were recruited by advertising in the local community. African Americans had black parents and grandparents who had lived in the United States. African Caribbeans and blacks from countries other than the United States were not enrolled in the study. Whites had white parents and grandparents who had lived in the United States.

Before their stay in the respiratory chamber, all subjects stayed on the metabolic ward of the Clinical Diabetes and Nutrition Section of the National Institutes of Health in Phoenix, AZ, for ≥3 d, during which they were fed a weight-maintaining diet (50% carbohydrate, 30% fat, and 20% protein) and abstained from strenuous exercise. Forty-five subjects were excluded from the analysis because they were not in energy balance, ie, their energy intake differed by >20% from the energy expenditure measured during the stay in the chamber. The protocol was approved by the Institutional Review Board of the National Institute of Diabetes and Digestive and Kidney Diseases.

Body composition was estimated by underwater weighing with simultaneous determination of residual lung volume by helium dilution (28) and percentage body fat was calculated by using the formula of Siri (29). Waist-to-thigh ratio was assessed as a measure of body fat distribution, with circumferences measured at the level of the umbilicus (waist) and the gluteal fold (thigh) in the supine and standing positions, respectively (30).

Energy metabolism

All measurements of energy metabolism were performed in a respiratory chamber as described previously (31). In brief, volunteers entered the chamber at 0745 after an overnight fast and remained therein until 0700 the following morning. Subjects were fed an amount of energy determined according to equations (32), with meals provided at 0800, 1130, and 1700, and an evening snack provided at 2000. 24EE was calculated from all 15-min intervals throughout the stay in the chamber and extrapolated to 24 h (31). SPA was measured by a radar system. SMR was defined as the average energy expenditure of all 15-min periods between 2330 and 0500 during which SPA was <1.5% (31). Physical activity–related energy expenditure (PAEE) was calculated by multiplying the SPA values by the slope of the regression line of energy expenditure versus SPA (31). All measures of energy expenditure were adjusted for fat-free mass, fat mass, and age by multiple linear regression analyses. The respiratory quotient was calculated over the entire 24-h period (24RQ) and after a 10-h fast during the sleeping period (between 0530 and 0700; fasting RQ) and adjusted for percentage body fat, energy balance, and age (18). Twenty-four–hour oxidation rates of fat, carbohydrate, and protein were calculated from oxygen consumption, carbon dioxide production, and urinary nitrogen excretion (33).

Statistical analyses

Statistical analyses were performed by using the software of the SAS Institute (Cary, NC). Values are presented as means ± SDs. Two different types of analysis were performed for the comparison of African Americans and whites: *1*) an unbalanced analysis, in which the 38 African American subjects were compared with the 288 white subjects, both within the entire group with additional adjustment for sex, and separately for women and men; and *2*) a balanced analysis, in which the 15 African American women and 23 African American men were compared with 15 white women and 23 white men, who were selected from the 288 subjects to best match the African Americans regarding age (mean difference: 1 ± 5 y; NS), body weight (0.1 ± 1.3 kg; NS), and energy balance (23 ± 189 kJ/d; NS). In this analysis, women and men were also compared directly, both within the entire group (76 subjects) and separately within the African American and white subgroups. This allowed us to test whether the effect of sex on energy metabolism was different in the African Americans and in the whites.

General linear regression models (analyses of covariance) were used in both analyses to assess the effect of ethnicity on energy metabolism. In the unbalanced analysis, the measurements of energy metabolism were adjusted for age and body composition. In the balanced analysis, adjustments were made for body composition alone because small ethnic differences in fat mass, fat-free mass, and percentage body fat persisted despite the close agreement in body weight (Table 1). The slopes of the regression lines for 24EE and SMR versus fat-free mass and for 24RQ versus percentage body fat, respectively, did not differ between African Americans and whites or between women and men in either analysis.

RESULTS

The physical characteristics of the subjects are shown in Table 1. There were no significant differences in age or in the proportions of subjects with normal compared with impaired glucose tolerance between the African American and white groups in either analysis.

Unbalanced analysis

African Americans, both women and men, had a lower waist-to-thigh ratio and a higher fat-free mass than whites, whereas body weight, percentage body fat, and fat mass were not different from whites (Table 1). The energy metabolism results in the entire group of African Americans and whites are summarized in **Table 2**. After adjustment for sex, age, and body composition, SMR was lower in African Americans than in whites. In contrast, PAEE was higher in African Americans than in whites and thus there was no ethnic difference in 24EE. 24RQ was higher in African Americans whereas fasting RQ was similar to that of whites. There were no ethnic differences in 24-h energy intake (9404 ± 1255 compared with 9488 ± 1232 kJ/d; NS) or 24-h energy balance (−96 ± 661 compared with −96 ± 757 kJ/d; NS).

The individual unadjusted results for 24EE, SMR, and 24RQ are presented separately for women and men in **Figure 1**. When adjusted for age and body composition, 24EE tended to be lower in African American than in white women (−202 ± 197 kJ/d; NS) and did not differ between African American and white men (0 ± 150 kJ/d; NS). Adjusted SMR was lower in African American than in white women (−448 ± 168 kJ/d; $P < 0.01$) and tended to be lower in African American than in white men (−222 ± 129 kJ/d; $P = 0.09$). PAEE was not different in African American and in white women (148 ± 138 kJ/d; NS), but was higher in African American than in white men (385 ± 117 kJ/d; $P < 0.05$; data not shown). Adjusted 24RQ was not different in African American and white women (0.008 ± 0.007; NS), but was significantly higher in African American than in white men (0.018 ± 0.006; $P < 0.001$).

Balanced analysis

In the balanced analysis, there were no significant ethnic differences in body composition. However, despite the closely matched body weights, fat-free mass tended to be higher in African American women and men than in whites (Table 1).

Women

African American women had not only lower SMRs but also had lower 24EEs than white women, whereas PAEE was comparable (**Table 3** and **Figure 2**). 24RQ and fasting RQ did not differ between African American and white women; consequently, there were no ethnic differences in the 24-h oxidation rates of fat (3015 ± 939 compared with 3720 ± 1437 kJ/d; NS) and carbohydrate (4413 ± 1038 compared with 4226 ± 1125 kJ/d; NS) between African American and white women, respectively. Twenty-four–hour energy intake (8837 ± 1240 compared with 9014 ± 1452 kJ/d; NS) and 24-h energy balance (72 ± 668 compared with −168 ± 797 kJ/d; NS) were also not different between the African American and white women, respectively.

Men

As within the unbalanced analysis, only SMR tended to be lower in African American than in white men, but PAEE was higher in African American men; thus, there was no ethnic difference in 24EE in men (Table 3, Figure 2). 24RQ and fasting RQ were higher in African American than in white men. The difference in 24RQ was equivalent to a 992 ± 327–kJ/d lower rate of 24-h fat oxidation (2920 ± 1192 compared with 3912 ± 1087 kJ/d; $P < 0.005$) and a 1218 ± 229–kJ/d higher rate of 24-h carbohydrate oxidation (5492 ± 712 compared with 4274 ± 849 kJ/d; $P < 0.001$) in African American compared with white men, respectively (Figure 2). Twenty-four–hour energy intake (9663 ± 855 compared with 9659 ± 1067 kJ/d; NS) and 24-h energy balance (−208 ± 646 compared with −304 ± 737 kJ/d; NS) were not different between the African American and white men, respectively.

Sex differences in energy metabolism

After adjustment for age and body composition, 24EE and SMR were higher in the 38 men than in the 38 women, respectively (24EE: 9771 ± 1276 compared with 9231 ± 1402 kJ/d; $P < 0.05$; SMR: 6960 ± 975 compared with 6507 ± 998 kJ/d; $P = 0.056$), whereas 24RQ was not different (0.8595 ± 0.0023 compared with 0.8648 ± 0.0030 kJ/d; NS). The sex differences in 24EE and SMR tended to be greater in African Americans than in whites (24EE: 641 ± 369 kJ/d for African American men compared with 247 ± 356 kJ/d for white men; SMR: 570 ± 302 kJ/d compared with 109 ± 335 kJ/d), but these differences were not significant. There were no sex differences in 24RQ in either ethnic group.

DISCUSSION

Several recent reports have suggested that African American women have a lower resting metabolic rate than do white

TABLE 2
Measurements of energy metabolism in the African American subjects compared with the entire group of whites

Energy parameter	African Americans[1]	Whites[1]	Race effect[2]
24-h energy expenditure (kJ/d)	9100 ± 1310	9188 ± 1519	−88 ± 121
Sleeping metabolic rate (kJ/d)	6385 ± 946	6686 ± 1134	−301 ± 105[3]
Physical activity energy expenditure (kJ/d)	1615 ± 628	1318 ± 561	297 ± 92[4]
24-h respiratory quotient	0.873 ± 0.026	0.859 ± 0.027	0.014 ± 0.004[4]
Fasting respiratory quotient	0.835 ± 0.043	0.839 ± 0.045	−0.004 ± 0.008

[1] $\bar{x}$ ± SD. Energy expenditure measures are adjusted for sex, age, fat mass, and fat-free mass; respiratory quotients are adjusted for sex, age, energy balance, and percentage body fat.

[2] Difference ± SE.

[3,4] Significant difference: [3] $P < 0.01$, [4] $P < 0.001$.

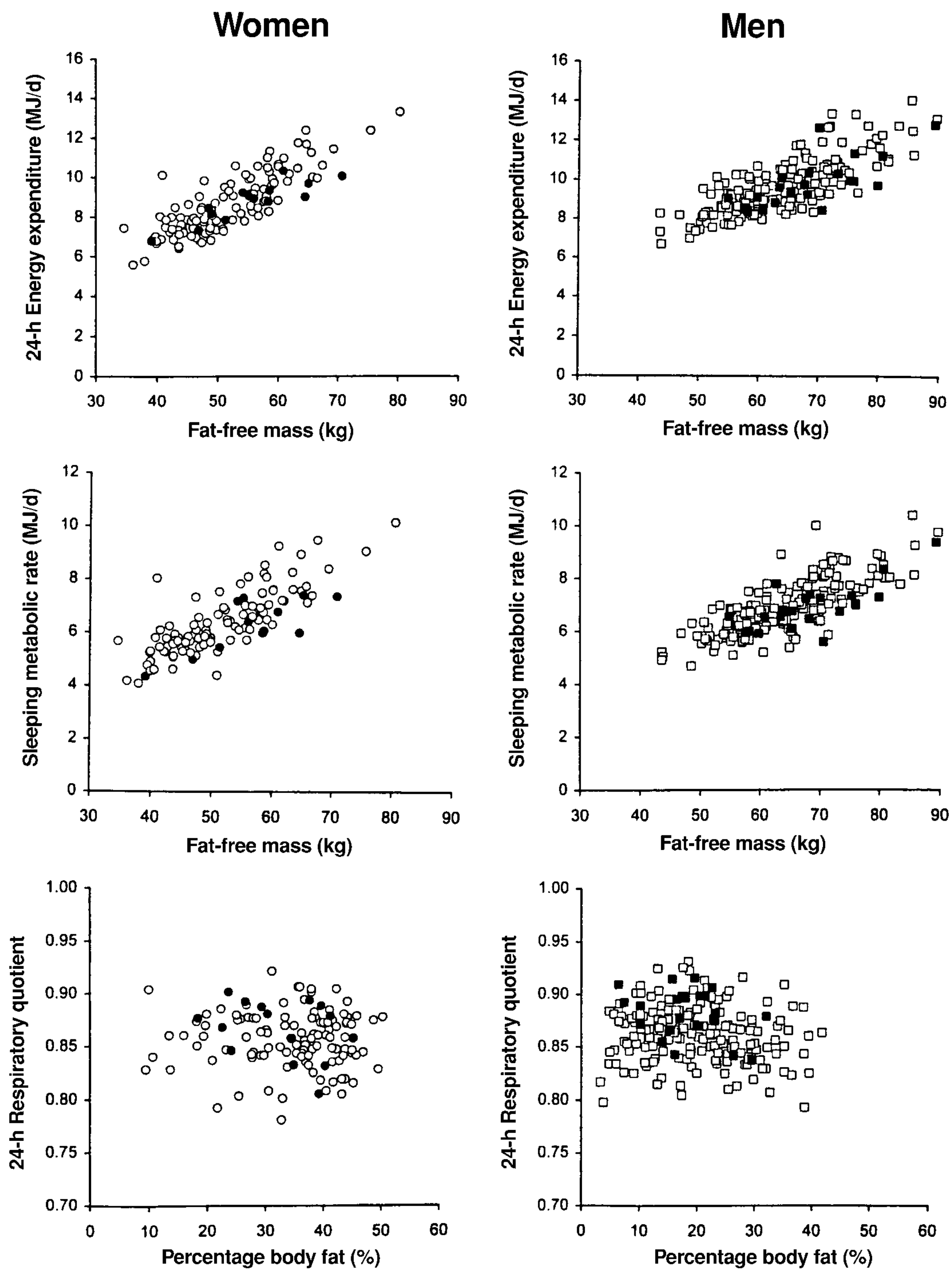

FIGURE 1. Twenty-four–hour energy expenditure and sleeping metabolic rate versus fat-free mass and 24-h respiratory quotient versus percentage body fat in 15 African American (●) and 112 white (○) women (left) and 23 African American (■) and 176 white (□) men (right), respectively. Data on energy metabolism represent unadjusted values.

women (20–25), which may contribute to the high propensity for obesity in African American women. In all such studies, however, energy expenditure was measured only over short periods of time by using ventilated-hood systems. Furthermore, little is known about energy metabolism in African American men. To further assess the characteristics of energy metabolism in African Americans, we compared long-term measurements of energy expenditure and substrate oxidation between African American and white women and men using a respiratory chamber. These included SMR, 24EE, 24RQ, and SPA, all of which are metabolic predictors of weight gain in Pima Indians.

TABLE 3

Measurements of energy metabolism in the African American subjects compared with the paired-matched subgroup of white subjects

	Women			Men		
Energy parameter	African American[1] (n = 15)	White[1] (n = 15)	Race effect[2]	African American[1] (n = 23)	White[1] (n = 23)	Race effect[2]
24-h energy expenditure (kJ/d)	8684 ± 985	9264 ± 1774	−580 ± 232[3]	9865 ± 1324	9968 ± 1218	−103 ± 192
Sleeping metabolic rate (kJ/d)	6121 ± 938	6563 ± 1050	−442 ± 182[3]	6871 ± 859	7226 ± 1077	−355 ± 188[4]
Physical activity energy expenditure (kJ/d)	1567 ± 446	1501 ± 573	66 ± 171	1702 ± 718	1285 ± 430	417 ± 174[3]
24-h respiratory quotient	0.865 ± 0.028	0.852 ± 0.033	0.013 ± 0.011	0.880 ± 0.023	0.847 ± 0.023	0.033 ± 0.007[5]
Fasting respiratory quotient	0.819 ± 0.034	0.825 ± 0.038	−0.006 ± 0.012	0.849 ± 0.044	0.814 ± 0.047	0.035 ± 0.014[3]

[1] $\bar{x}$ ± SD. Energy expenditure measures are adjusted for fat mass and fat-free mass; respiratory quotients are adjusted for fat mass, fat-free mass, and percentage body fat.

[2] Difference ± SE.

[3,5] Significant effect of race: [3] $P < 0.05$, [5] $P < 0.001$.

[4] Effect of race, $P = 0.07$.

When women and men were considered together, we found that African Americans had a lower SMR than whites but a higher PAEE, resulting in similar rates of 24EE. In addition, we found significant ethnic differences in 24RQ, indicating lower fat oxidation in African Americans than in whites. Further analysis revealed that these ethnic differences in energy metabolism seem to be sex specific, ie, energy expenditure was lower particularly in African American women, whereas in men, the major ethnic difference was found in substrate oxidation.

We also observed ethnic differences in body fat distribution and body composition. The finding of a lower waist-to-thigh ratio in African Americans than in whites is in good agreement with recent epidemiologic data in men but not in women (34). Also, our results confirm the well-established finding that African Americans have a higher fat-free mass than do whites (35–38). Because fat-free mass is the single best determinant of energy expenditure in humans (31), it is important to adjust for this variable when comparing energy metabolism in African Americans and whites (20–25).

Our results on SMR in women confirm the previous findings of lower resting energy expenditure in African American compared with white women. In addition, our data suggest that 24EE is also lower in African American women whereas PAEE is similar to that of whites. These are important findings because a lower resting metabolic rate could theoretically be compensated for by increased physical activity, thus blunting ethnic differences in energy expenditure over 24 h, as was observed in men (*see* below). Both 24EE and PAEE were measured under restricted conditions in a respiratory chamber and thus did not necessarily reflect free-living physical activity. However, in a recent study using the doubly labeled water technique, 24EE was found to be lower under free-living conditions in elderly African American than in white women (25).

In women, metabolic rate is known to be dependent on menopausal status. We did not specifically control for this factor, but the women in our study were closely matched for age and all of our findings remained the same when women aged >40 y (5 in each group) were excluded from the analysis. In premenopausal women, menstrual cycle is another, but less significant, factor affecting metabolic rate (39, 40). We can only assume that the proportions of women in the pre- and postovulatory phases were similar in the 2 ethnic groups, but given the relatively small number of subjects, random differences between groups in menstrual cycle cannot be completely ruled out.

We found no differences in either fasting or 24RQ or in substrate oxidation between African American and white women. This agrees with most previous studies in women that used short-term measurements with ventilated-hood systems, in which no ethnic difference in fasting RQ was found (21–24). In the present study, respiratory quotient was measured over 24 h and both energy balance and dietary intake and composition were well controlled. Thus, we can conclude that there were no major differences in substrate oxidation between the African American and white women. However, most of the women in our study were already overweight or obese; hence, these cross-sectional data do not rule out the possibility that preobese African American women may have a high respiratory quotient, ie, a low fat oxidation, which may predispose them to weight gain. In fact, Chitwood et al (20) reported a higher fasting RQ in young, lean African American than in white women.

The metabolic characteristics of African American men have been less extensively studied because they appear to be less prone to obesity than African American women (1). However, our data indicate that ethnic differences in energy metabolism are also present in men. SMR was lower in African American than in white men, although this difference was less pronounced than in women. In contrast with women, however, African American men had higher PAEE than white men and, thus, comparable 24EE. The finding of a lower metabolic rate at rest agrees with 2 other studies. In 1985, Geissler and Hamod Aldouri (41) reported a 10–17% lower rate of resting energy expenditure in young, lean, black African-European men compared with age- and weight-matched whites. In a more recent study by Carpenter et al (25) in elderly subjects, resting metabolic rate was also lower in African American than in white men. In contrast with our findings, however, these authors also found a lower PAEE, and thus, a lower 24EE in African American men under free-living conditions.

Several factors may contribute to this discrepancy in ethnic differences in PAEE. First, in our own recent investigation, we found no significant correlation between SPA in a respiratory chamber, as assessed by a radar system, and free-living PAEE, as measured by the doubly labeled water technique (42). Second, in a population-based survey, physical activity patterns in African American men were found to be dependent on age and level of education and characterized by lower leisure-time but higher occupational physical activity than that for whites (15).

In our study, as in all previous comparative studies on energy metabolism in African Americans and whites (20–25), meta-

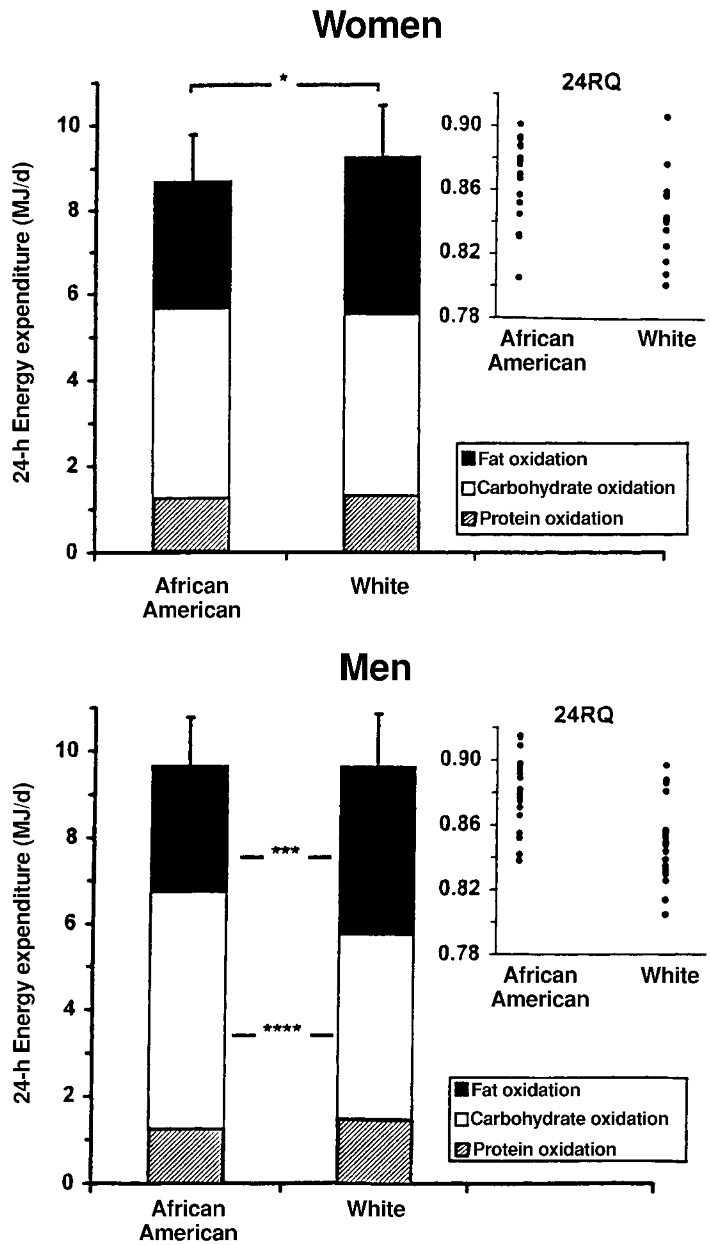

FIGURE 2. Twenty-four–hour energy expenditure (total height of the columns) and respective proportions of 24-h oxidation of fat, carbohydrate, and protein (subcolumns) in 15 African American women and 23 African American men compared with 15 white women and 23 white men of similar age and body weight, respectively. Data are adjusted for fat-free mass and fat mass (least-squares means). *Significant differences in 24-h energy expenditure in women, $P < 0.05$. Significant differences in the 24-h oxidation rates of fat, ***$P < 0.005$, and carbohydrate, ****$P < 0.001$, in men. Individual results for 24-h respiratory quotient (24RQ; unadjusted values) are given in the right upper corners.

bolic rate was adjusted for body composition. Because African Americans are known to have higher bone mineral content and density than whites (43, 44), it could be argued that our finding of a relatively lower metabolic rate in African Americans is, at least in part, due to an overestimation of fat-free mass as assessed by hydrodensitometry. However, bone mass represents only a small proportion of fat-free mass and it was recently shown in a large group of subjects that the density of fat-free mass is the same for African Americans and whites (45). Moreover, lower resting metabolic rates in premenopausal obese African American women were also reported in a recent study, in which 5 different methods were used to determine body composition, including hydrodensitometry and dual-energy X-ray absorptiometry (22).

An intriguing new finding in our study is the higher 24RQ in African American than in white men, indicating that the rate of fat oxidation in African American men is lower than that of white men. In the absence of ethnic differences in 24EE in men, lower fat oxidation may be another factor that may predispose African American men to obesity. In fact, a high respiratory quotient is predictive of weight gain in both Native American (18) and white (46) subjects.

In addition to the direct comparison of energy metabolism in African American and white women and men, our data also allowed us to directly compare energy metabolism in men and women separately in the 2 ethnic groups. Our results confirmed the well-established fact that, even after adjustment for body composition, metabolic rate is higher in men than in women. Interestingly, this sex difference in energy expenditure tended to be greater in African Americans than in whites in our study, although not significantly so, possibly because of the small number of African Americans in our study. Further studies with greater numbers of African American subjects are needed to clarify this issue.

In conclusion, this comparative study of 24-h energy metabolism in African Americans and whites with use of a respiratory chamber not only confirms the previous findings from ventilated-hood studies of a lower resting metabolic rate, but also suggests a lower 24EE in African American women than in white women. Although only marginal ethnic differences in metabolic rate were found in men, African American men seem to have a lower rate of fat oxidation than do white men. The underlying mechanisms for these sex differences and the significance of these findings with respect to the development and maintenance of obesity remains to be investigated in longitudinal studies.

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