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Review

Do African Americans have lower energy expenditure than Caucasians?

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OBJECTIVE: To review current studies that examine differences in energy expenditure between African Americans and Caucasians as possible modulators of attained differences in overweight status.
DESIGN: Literature review of recent clinical and laboratory studies.
METHODS: Studies chosen for review were those that examined directly resting metabolic rate (RMR), using indirect calorimetry, and total daily energy expenditure (TDEE) and physical activity energy expenditure (PAEE), using doubly labeled water.
RESULTS: Ten of 15 studies reviewed reported a lower RMR in African Americans than in Caucasians. The differences in RMR between African Americans and Caucasians ranged from 81 to 274 kcal/day and could not be explained by differences in age, fat-free mass (FFM) or methodological concerns. Two of six studies of energy expenditure using doubly labeled water suggest that Black adults have a tendency for lower TDEE that can be accounted for primarily by a lower PAEE.
CONCLUSIONS: If future studies indicate conclusively that African Americans do have lower RMR, TDEE and PAEE than Caucasians, then the disproportionally higher risk of obesity and associated metabolic disorders in Black adults may be preventable—especially in Black women. If these race differences are indeed a result of *both* physiological and behavioral factors, then interventions designed to reduce caloric intake and/or increase energy expenditure through lifestyle activity or structured exercise programs become especially important for African Americans and should be encouraged
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Introduction

Recent survey data from the third National Health and Nutrition Examination Survey (NHANES III) suggest that overweight (i.e. 'pre-obesity', defined as a body mass index (BMI = kg/m^2) 25.0–29.9) is present in approximately 32% of the adults living in the US.[1] The overall prevalence of overweight currently is highest in men and women age 60–69 y (45% and 34%, respectively) and then is progressively lower at older ages.[1–3] 'Obesity' (BMI > 30.0 kg/m^2) status tends to be disproportionally higher among minority women and women of lower socioeconomic and/or lower educational attainment.[1,4–6] Currently 37% of African American women and 34% of Mexican American women are considered to be 'obese', compared with about 22% of Caucasian women. Further, the prevalence of class II and III 'obesity' (BMI ≥ 35.0 kg/m^2) in African American women is 18%, compared to 13% in Mexican American women and 10% in Caucasian women.[1]

African American women have a 50% higher risk of major weight gain that White women.[7,8] Moreover, these same women are less likely to lose weight with clinical interventions (i.e. caloric restriction or exercise)[9] and are more likely to regain lost weight.[10] The higher prevalence of overweight in African Americans compared to Caucasians is observed even in childhood. For example, African American children (~age 5 y) are twice as likely to be overweight (i.e. BMI > 85th percentile) as White children, and 31% of African American girls (aged 6–11 y) are overweight compared with 22% of Caucasian girls.[11]

Overweight in later life is an independent risk factor for several diseases, namely type 2 diabetes, hypertension, cardiovascular disease and cancer.[12] Indeed, death rates for diabetes, heart disease and stroke are 1.5–2.0 times greater for Black women than for White women[13]—presumably due to a higher prevalence of severe obesity and associated metabolic disorders in Black women[1]—although disease risk for a similar BMI is actually higher in White

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women.[14] In the US, the annual economic burden due to obesity-related medical costs and loss of income exceeds $99 billion.[15] These statistics emphasize the need for prevention efforts to offset the development of overweight early in life — especially among young African American girls.

Given the health and economic impact of being overweight, it is important to examine factors that may explain its greater occurrence in African Americans than Caucasians. The etiology of race and sex differences in body weight is complex due to the competing influences of genetic, behavioral and environmental factors in its development and maintenance. In this brief review, we have focused on studies that have examined differences in *energy expenditure* between African Americans and Caucasians as possible modulators of observed differences in attained overweight. We specifically consider studies that have examined directly resting metabolic rate (using indirect calorimetry) and/or total daily energy expenditure (using doubly labeled water) in male and female Caucasians and African Americans across a wide age spectrum.

Resting metabolic rate studies in African Americans and Caucasians

Body weight is controlled by a balance between caloric intake and daily energy expenditure in free-living people. Excess fat accumulates when long-term energy intake is greater than energy expenditure. Therefore, weight gain may result from either normal caloric intake with low energy expenditure or from excessive food intake with normal levels of energy expenditure, although the relative contributions of certain metabolic aberrations on this balance is unclear.[16] Total daily energy expenditure (TDEE) is the sum of the resting metabolic rate (RMR), the thermic effect of a meal (TEM), and physical activity energy expenditure (PAEE). The largest component of total daily energy expenditure is RMR (~65% in sedentary people), while PAEE is the most variable portion (10–50%) when measured under free-living conditions.[17,18]

The RMR is a measurement of the energy used for the maintenance of basal metabolism and body functions, including resting cardiovascular, pulmonary and central nervous system functions, and cellular homeostasis. The *absolute* rate of energy expenditure from basal metabolism is determined primarily by the quantity of metabolically active tissue in the body, however, age, sex, body fat, the menstrual cycle and genetic factors can also influence the RMR.[18,19] Fat-free mass (FFM) is substantially more metabolically active than is fat tissue, and since African Americans generally have more FFM than Caucasians (due in part to greater bone mineral density (BMD)),[19–22] absolute differences in the RMR between Black and White people often can be attributed to differences in FFM. Therefore, the individual RMR must be standardized (or normalized) to FFM to allow for meaningful comparisons in energy expenditure between individuals of differing body size. Rather than simply dividing the RMR estimate by FFM, however, Ravussin and Bogardus,[23] as well as Poehlman and Toth[24] proposed a multivariable regression-based approach to the appropriate statistical control for the influence of varying body size on the RMR. Since RMR constitutes a large percentage of TDEE, several investigators have focused on the examination of this component as a primary contributing factor to race differences in overweight. The general hypothesis is that a lower RMR for a given metabolic size (i.e. FFM) in African Americans than Caucasians is a risk factor for weight gain,[25] although this hypothesis remains controversial.[26]

We found 15 studies that compared the RMR of African Americans to that of Caucasians. Ten of these studies[19–22,27–32] found that African Americans had a lower RMR than Caucasians after adjusting for differences in FFM. Indeed, the magnitude of this difference in the adjusted RMR between the two groups ranged from 81 to 274 kcal/day. Of the 10 studies observing race differences in adjusted RMR, seven were performed on adults (18–66 y),[19–22,29,30,32] and three on children (5–16 y).[27,28,31] Thus, the current data are somewhat equivocal with regard to a lower RMR in African Americans than in Caucasians as a possible determinant of race differences in overweight. Moreover, since conflicting results were observed in both older and younger study subjects, age does not appear to be a factor in the conflicting results among studies.

On the other hand, sex seems to be a strong effect modifier of the relationship between race and energy expenditure. For example, RMR appears lower in female subjects than in male subjects, even where the data are adjusted for differences in FFM.[21,37] Moreover, Carpenter *et al*[21] observed a statistically significant race–sex interaction with regard to TDEE, suggesting that the effects of race on differences in TDEE varied by sex — indeed, the lower TDEE in older African Americans than in Caucasians was most pronounced in women. This observation of a race–sex interaction was recently corroborated with data from younger people. Weyer *et al*[33] measured 24 h metabolic rates by direct calorimetry in a metabolic ward. The authors observed that race differences in FFM-adjusted sleeping metabolic rate and 24 h energy expenditure were sex-specific; i.e. the lower energy expenditure in younger African Americans compared to Caucasians was found primarily in women. Together these data suggest that women, and particularly Black women, are especially vulnerable to obesity and associated metabolic disorders. A disproportionally lower energy expenditure for their metabolic size may be a contributing factor to this increase in risk.

Methodological concerns in RMR studies

We further examined several important methodological issues in an attempt to reconcile the different findings among laboratories with regard to race differences in the adjusted RMR (Table 1). These issues pertain to: (1) the measurement of the RMR with indirect calorimetry; (2) the measurement of body composition for determining accurately FFM, and (3) menstrual cycle variation in the RMR.

Indirect calorimetry. Indirect calorimetry measures the consumption of oxygen and expiration of carbon dioxide. The assessment of gas exchange provides information on energy expenditure and substrate utilization (i.e. the respiratory quotient, RQ). For the most reliable RMR measurement with indirect calorimetry, the subject should be weight stable and refrain from any exercise the day prior to RMR assessment. Ideally, the test should be conducted under inpatient conditions with a controlled evening meal, followed by a 12 h fast, and indirect calorimetry measurements performed early the next morning. Berke *et al*[34] observed higher RMR values when people were tested on outpatient vs inpatient conditions, suggesting that the experimental conditions surrounding the assessment of RMR are a source of variation among laboratories even when similar equipment is used to assess RMR. On the other hand, Wilmore *et al*[35] reported no difference in measurements of RMR with outpatient *vs* inpatient conditions, as long as the subjects were well-rested and performed no exercise in the previous 24 h.

Of the 15 studies that considered the RMR in the etiology of race differences in overweight, 13 assessed RMR after an overnight fast,[19–22,28–31,36–40] whereas two[27,32] tested the subjects after only a 3^+h fast. These two latter studies[27,32] also reported the largest differences in the RMR between African Americans and Caucasians (i.e. differences of 274 and 243 kcal/day for the two studies, respectively). Also five studies[19,22,27,29,32] did not include an overnight stay (i.e. inpatient status) prior to the determination of the RMR. Not only did these five studies find lower RMR values in Black than in White subjects, they also found the largest differences in RMR between ethnic groups. Naturally, variation in test conditions among the studies cannot explain observed race-differences in the RMR, since within-study conditions were identified for both races. Nonetheless, we strongly urge that, whenever possible, standardization of meals, exercise restriction and fasting conditions precede all measurements of the RMR when using indirect calorimetry. Although adherence to these testing conditions is difficult and expensive in large studies, it does make it possible to compare more effectively results between laboratories.

Body composition assessment. Since FFM is the more metabolically active tissue than fat tissue and is the primary determinant of RMR, it is important to determine accurately the fat-free component of total body mass. Body composition can be measured by a variety of methods including dual-energy X-ray absorptiometry (DXA), isotope dilution, under-water weighing (UWW), bioelectrical impedance analysis (BIA), air displacement plethysmography (BODPOD)[41] and skinfold measurements. We suggest that the most meaningful results with regard to the assessment of FFM are obtained with the use of DXA. This method measures fat mass, fat-free mass as well as bone mineral density. Since bone mineral density may also vary by ethnicity (i.e. higher in African Americans), it must be considered in body composition assessments. Moreover, the high reliability and precision of DXA[42] makes it the preferred method of body composition assessment.

Of the nine RMR studies performed on adults, the results were fairly consistent despite the different methods used to assess body composition (see Table 1). Seven adult studies report a lower RMR in Blacks,[19,20–22,29,30,32] whereas two found no race differences in RMR.[34,36] Five out of six of the RMR studies in children used DXA. Two of these studies reported a lower RMR in African Americans,[27,28] whereas three found no difference.[37,39,40] These latter three studies[37,39,40] are from the same laboratory, however, and therefore caution should be used in interpreting similarities among their results, since there may be some overlap among study subjects. Thus, variation in the measurement of body composition (and specifically FFM) does not appear to influence either the observed race differences in RMR, nor the conflicting results among studies.

Race differences in bone mineral mass and density are also important to consider with regard to FFM. The metabolic activity of bone is low and, thus, failure to account for a greater bone mineral mass in African Americans may amplify spuriously differences in the FFM-adjusted RMR. Measurement error in the determination of FFM using densitometry, which does not account for the contribution of greater bone mineral mass to FFM density, will also result in a spuriously large FFM. Thus, a greater ‘metabolic’ component in the denominator of this RMR-to-FFM ratio may provide a false impression that African Americans have a lower RMR for their ‘metabolic size’ compared to Caucasians. However, several studies have observed consistent results after adjusting the RMR data both with and without the contribution of bone to calculated FFM.[22,27,28]

Menstrual cycle phase. The RMR can vary as much as 10% between the luteal and follicular phases of the menstrual cycle.[43,44] Thus, failure to adjust for menstrual cycle variations could be a potential source of error within a study. Of the six studies that measured RMR in menstruating women,[19,20,22,29,30,36] only three[19,22,29] measured the

Table 1 Summary of selected laboratory studies comparing the resting metabolic rate (RMR) between African Americans and Caucasians

Study	*Reference*	*Population*	*RMR methods*	*Findings*	*Effect size*
Geissler and Aldouri	*Ann Nutr Metab* **29**: 40–47, 1985	15 African and 15 European men; matched on BMI	3,4; SF; adjustment for LBM	↓RMR in African *vs* European men (1625 *vs* 1898 kcal/day)	LBM-adjusted difference = 274 kcal/day or 15%; $P<0.05$
Chittwood *et al*	*Int J Obes* **20**: 455–462, 1996	11 AA and 11 C normal weight women matched on body composition	2,3,4; UWW; † adjusted for LBM	↑ RER (0.90 *vs* 0.83) and ↓ VO_{2rest} (0.18 *vs* 0.20 l/min or 1267 *vs* 1447 kcal/day)[a] in AA *vs* C women	LBM-adjusted difference = 180 kcal/day or 12%; $P<0.04$
Nicklas *et al*	*J Clin Endocrinol Metab* **82**: 315–317, 1997	28 AA and 29 C; obese, post-menopausal women; matched on percentage body fat	1,2,3,4,5; DXA; adjustment for FFM	No race differences in adjusted RMR (1383 *vs* 1385 kcal/day in AA and C, respectively)	—
Kaplan *et al*	*J Pediatr* **129**: 643–647, 1996	15 AA and 19 C prepubertal children	1,2,3,4,5; TOBEC; adjustment for FFM	↓Adjusted RMR in AA *vs* C children (1312 *vs* 1524 kcal/day)	FFM-adjusted difference = 212 kcal/day or 14%; $P<0.05$
Morrison *et al*	*J Pediatr* **129**: 637–642, 1996	47 AA and 51 C girls (6–16 y) at three different stages of pubertal maturation	3,4; DXA; adjustment for body weight	↓Adjusted RMR in AA *vs* C girls (35.5 *vs* 40.3 kcal/day). Multi-variable race effect only in prepubertal stage (1156 *vs* 1399 kcal/day)	FFM-adjusted difference = 243 kcal/day or 17% in prepubertal girls; $P<0.01$
Yanovski *et al*	*Obes Res* **5**: 321–325, 1997	21 AA and 24 C normal weight, prepubertal girls, matched on BMI	1,2,3,4,5; DXA; adjusted for FFM	↓Adjusted RMR in AA *vs* C girls	FFM-adjusted difference = 92 kcal/day; $P<0.01$
Foster *et al*	*Obes Res* **5**: 1–8, 1997	44 AA and 122 C obese women (40.6 y)	2,3,4; UWW; adjusted for FFM	↓Adjusted RMR in AA *vs* C women (1617 *vs* 1752 kcal/day)	FFM-adjusted difference = 135 kcal/day or 8%; $P<0.001$
Albu *et al*	*Am J Clin Nutr* **66**: 531–538, 1997	22 AA and 20 C obese, premenopausal women of similar BMI	1,2,3,4,5; UWW, DXA, adjusted for FFM	↓Adjusted RMR in AA *vs* C women; difference varied by method of body composition from 160–212 kcal/day)	FFM adjusted difference with DEXA = 179 kcal/day or 11%;$P<0.01$
Jakicic *et al*	*Int J Obes* **22**: 236–242, 1998	22 AA and 19 C overweight, premenopausal women	2,3,4; DXA; adjusted for FFM	↓Adjusted RMR in AA *vs* C women (1704 *vs* 1890 kcal/day)	FFM-adjusted difference = 186 kcal/day or 10%; $P<0.001$
Forman *et al*	*Int J Obes* **22**: 215–221, 1998	25 AA and 22 C obese, premenopausal women	2,3,4; BODPOD; † adjusted for LBM	↓Adjusted RMR in AA *vs* C women (1697 *vs* 1899 kcal/day)	LBM-adjusted difference = 202 kcal/day or 11%; $P<0.05$

These studies measured the RMR alone using indirect calorimetry. Studies measuring RMR and total daily energy expenditure using doubly labeled water are included in Table 2.
RMR methods: 1 = inpatient; 2 = 12 h fast; 3 = no exercise for 12 h; 4 = weight stable; 5 = standardized evening meal.
AA = African American; C = Caucasian; BMI = body mass index; SF = skinfolds; DXA = dual-energy X-ray absorptiometry; UWW = underwater weighing; BODPOD = air displacement plethysmography; FFM = fat free mass; LBM = lean body mass; †tested during early follicular phase of the menstrual cycle.
[a] Extrapolated from resting VO_2 values based on standard predictive formulae.

RMR at specific times during the menstrual cycle in order to control for these menstrual cycle variations in the RMR. Chittwood *et al*[29] and Forman *et al*[19] measured RMR during the early follicular phase, while Jakicic *et al*[22] compared the RMR in three distinct groups of women: those in the follicular phase of the cycle; those in the luteal phase; and those who were no longer experiencing a normal menstrual cycle. While these three studies[19,22,29] reported a lower RMR in Black women, so did two studies that did not control for potential menstrual cycle variation in RMR.[20,30] The last study by Kushner *et al*,[36] which also did not control for the menstrual cycle, found that Black women had a 6% lower FFM-adjusted RMR than White women ($P < 0.01$). Thus, the menstrual cycle phase does not appear to be a major factor in the overall results, although it may contribute to variation in the magnitude of the RMR measurements within a given study. We would suggest, however, that more studies be performed to investigate the role of the menstrual cycle with regard to variations in RMR.

Two studies of race differences in the RMR among post-menopausal women had conflicting results.[21,38] Carpenter *et al*[21] studied 89 African American and Caucasian women (55 y or older and not on hormone replacement therapy, HRT) and observed a statistically significantly lower RMR in African Americans; however, Nicklas *et al*[38] did not observe a race difference in the RMR among the older women (aged 62–66 y, $N = 57$) in their study. Although it is not clear from these two studies alone whether older African American women have a lower RMR than older White women, the larger sample size in the Carpenter *et al*[21] study may have yielded more statistical power to distinguish small race differences from chance alone.

Summary of RMR studies

Ten of the 15 studies reviewed report a lower adjusted RMR in African Americans than in Caucasians that varied as much as 15% (274 kcal/day). Although inconclusive, these results suggest a race difference in the RMR that cannot be accounted for by age, amount of FFM, or certain methodological differences in the measurement of RMR or body composition. Why evolution would favor a more conservative metabolism in African Americans than in Caucasians is not clear. Historically, perhaps there was the need for metabolic resiliency to better defend body weight through extended periods of caloric restriction or hard physical labor due to severe environmental conditions. Sex, however, may be a strong effect modifier of the relationship between race and energy expenditure, suggesting that Black women living in the US may be particularly vulnerable to obesity due to a relatively lower energy expenditure for their metabolic size.

Total daily energy expenditure (TDEE) studies in African Americans and Caucasians

While the majority of laboratory or clinical studies of energy expenditure have measured RMR in African Americans and Caucasians, more recent work has focused on the measurement of total daily energy expenditure (TDEE). The components of TDEE in free-living individuals include RMR, TEM and physical activity energy expenditure (PAEE). The doubly labeled water technique (DLW) allows accurate measurements of total energy expended over a period of 1–3 weeks. This technique is based on the differences in turnover rates of ^2H_2O and $H_2{}^{12}O$ in body water, which are then used to calculate carbon dioxide production and, thus, the TDEE rate.[18,45] In weight-stable subjects, the calculated total energy expenditure is equivalent to long-term energy requirements.[45] Studies using DLW techniques are useful in predicting energy imbalance, since it is ultimately total energy expenditure, not simply RMR, that influences fluctuations in body weight. Thus, the application of DLW represents a powerful method to understand energy dysregulation in various race groups, because it captures an integrated assessment of TDEE in an individual's free-living environment over extended periods of time. Moreover, these assessments are unobtrusive and do not interfere with the volunteer's daily routines, although the collecting of urine may be aversive to some individuals. The widespread application for DLW techniques, however, continues to be hampered by its expense, fluctuating availability, and demanding laboratory analysis.

Physical activity energy expenditure is the most variable component of total daily energy expenditure.[46] It includes the energy expended through voluntary exercise and involuntary activity such as postural control, fidgeting and shivering. Energy expenditure from physical activity may comprise as little as 100 kcal/day in sedentary individuals such as frail older women, or may approach 3000 kcal/day in highly active people.[18] Since it is subject to volitional control and is quite variable, it can be a significant factor in TDEE and, therefore, must be assessed accurately. Once TDEE, RMR and TEM are determined, however, the daily free-living PAEE can be calculated easily by subtraction. This is an important methodological advance since PAEE has not been rigorously measured with other laboratory- or field-based methods. Indeed, unlike previous survey methods, the DLW technique allows an objective and unbiased measurement of PAEE. On the other hand, as DLW measures PAEE over 1–3 weeks, it may not accurately reflect variation in physical activity patterns over longer periods of time (i.e. 1–3 months) unless repeated measurements are made. In addition, although DLW provides information on total daily

Table 2 Summary of selected laboratory studies comparing energy expenditure between African Americans and Caucasians using doubly labeled water (DLW)

Study	*Reference*	*Population*	*Methods*	*Findings*	*Effect size*
Kushner *et al*	*Obes Res* **3**: 261s–265s, 1995	14 AA and 15 C obese, premenopausal women	RMR, TEM: 1,2,3,4,5; TDEE, PAEE by DLW; body composition by TBW	No race differences in unadjusted RMR, TEM or TDEE. ↓PAEE in AA *vs* C (831 *vs* 1023 kcal/day)	Differences in adjusted RMR = 6%; $P<0.01$ and in PAEE = 192 kcal/day or 19%; $P<0.05$
Trowbridge *et al*	*Am J Physiol* (*Endocrinol Metab*) **36**: E809–E814, 1997	44 AA and 31 C prepubertal children (5–10 y)	RMR: 1,2,3,4,5; TDEE, PAEE using DLW; body composition by DXA	No LTM-adjusted race differences in RMR, TDEE or PAEE	—
Nagy *et al*	*J Clin Endocrinol Metab* **82**: 4149–4153, 1997	47 AA and 29 C prepubertal children (5–10 y)	RMR: 1,2,3,4,5; TDEE, PAEE using DLW; body compostion by DXA	No multivariable race differences RMR, TDEE or PAEE	—
Champagne *et al*	*J Am Diet Assoc* **98**: 426–430, 1998	56 AA and 62 C pre- or early-pubertal children (10–11 y); lean and obese	TDEE by DLW; body composition by DXA	No race differences in TDEE	—
Carpenter *et al*	*Am J Physiol* (*Endocrinol Metab*) **37**: E96–E101, 1998	65 AA and 99 C older adults; normal weight	RMR: 1,2,3,4,5; TDEE, PAEE using DLW; body composition by DXA	↓Adjusted TDEE in AA *vs* C (2138 *vs* 2362 kcal/day) due to ↓RRM and ↓PAEE	FFM-adjusted difference in TDEE = 224 kcal/day (10%); $P<0.01$; in RMR = 81 kcal/day (5%); $P<0.01$ and in PAEE = 122 kcal/day (19%); $P<0.08$
Sun *et al*	*Am J Physiol* (*Endocrinol Metab*) **37**: E232–E237, 1998	59 AA and 39 C healthy prepubertal children	RMR: 1,2,3,4,5; TDEE, PAEE using DLW; body composition in DXA	No race differences in adjusted RMR, TDEE or PAEE	—
Wong *et al*	*J Clin Endocrinol Metab* **84**: 906–911, 1999	41 AA and 40 C pubertal girls matched on age, percentage fat, and energy intake	RMR: 1,2,3,4,5; TDEE, PAEE using DLW; body composition by DXA	↓Adjusted RMR (1333 *vs* 1412 kcal/day) and PAEE (809 *vs* 1271 kcal/day) in AA *vs* C	LTM-adjusted difference in RMR = 79 kcal/day or 6%; $P<0.01$ and in PAEE = 462 kcal/day or 57%; $P<0.01$

RMR methods: 1 = inpatient; 2 = 12 h fast; 3 = no exercise for 12 h; 4 = weight stable; 5 = standardized evening meal; TEM = thermic effect of a meal; TDEE = total daily energy expenditure; PAEE = physical activity energy expenditure; A = African American; C = Caucasian; DXA = dual-energy X-ray absorptiometry; LTM = lean tissue mass; FFM = fat free mass.

energy expenditure, one can not account for how or when the expenditure was accumulated throughout the day.

We evaluated seven studies that used DLW to measure TDEE and PAEE in African Americans and Caucasians. The methods used were similar in these investigations, i.e. all used an inpatient protocol and similar techniques for DLW and indirect calorimetry. Four of the studies found no race differences in TDEE[37,39,40,47] and three studies found a lower TDEE in African Americans than in Caucasians[21,36,48] (Table 2).

Two of the seven DLW studies were in adults and had similar results. Kushner *et al*[36] studied 29 young adult (26–46 y) Black and White women matched for physical characteristics and body composition. The authors observed a significantly lower PAEE and a tendency for a lower TDEE and RMR in Black, compared to White women (Table 2). In fact, 75% of the difference in TDEE between the two groups of women was due to a lower PAEE. However, after adjustment for FFM, the RMR was 6% lower in Black women than in White women (1445 ± 24 *vs* 1535 ± 24 kcal/day, respectively). The small sample size ($n = 29$) in this study, however, could have contributed to the lack of statistically significant differences in TDEE and RMR in the two groups of women. Carpenter *et al*[21] examined a larger sample ($n = 164$) of older adults (> 55 y). The authors observed a 10% lower TDEE, a 5% lower RMR, and a 19% lower PAEE in African Americans than in Caucasians, which was not influenced by differences in FFM (Figure 1). While it is not certain whether older Black people have a lower TDEE and PAEE than older White people, the larger sample size of the Carpenter *et al*, compared to the Kushner *et al*, study increases the precision of the estimate and provides more confidence in the results.

Four of the seven DLW studies were of prepubescent children. Nagy *et al*[37] examined 76 Black and White children (aged 5–10 y) and observed no race differences in TDEE, RMR or PAEE. Similarly, race differences in TDEE, RMR, and PAEE were not apparent in two other studies from the same laboratory as the Nagy *et al* study in which Trowbridge *et al*[40] tested 75 African American and Caucasian children (aged 5–10 y) and Sun *et al*[39] examined 98 Black and White children (aged 5–11 y). Champagne *et al*[47] studied 118 African American and Caucasian children (aged 10–11 y) and also observed no race differences in TDEE; however, RMR was not reported, and so PAEE could not be determined. In contrast, Wong *et al*[48] did observe significant race differences in basal energy expenditure and PAEE between *pubertal* African American and Caucasian girls.

It appears that young prepubertal African Americans do not differ from Caucasians in their TDEE and PAEE; however more studies in distinct populations of children are needed in order to make more definite conclusions. Moreover, since African American children may undergo an earlier puberty than Caucasian children, some standardized assessment of sexual maturation (e.g. Tanner stages) should be performed in studies of race differences in energy expenditure in children. Black adults, on the other hand, have a tendency towards lower TDEE values than do White adults. These observed race differences in TDEE among adults may be accounted for primarily by lower amounts of PAEE; however, since the RMR also varied by race, it is difficult to determine exactly what the relative contributions of PAEE and RMR are to the lower TDEE in African Americans. Furthermore, there is evidence that race differences in PAEE vary by sex—that is, the lower TDEE observed in Black adults may be accounted for, in part, by the lower PAEE observed in Black women. Therefore, the manner in which sex modifies the relations among race, energy expenditure, and overweight must be carefully considered, thereby justifying the need for larger sample sizes in such studies.

Summary

There is a paucity of information on energy expenditure as it relates to differences in the prevalence of overweight between African Americans and Caucasians. The divergence among studies suggest that additional research is needed to measure TDEE, PAEE and RMR in biracial populations. To our knowledge, there are no energy expenditure studies of Caucasians and African Americans aged 11–28 y and 46–55 y, and only one small study ($n = 29$) of Black and White women aged 28–46 y.[36]

Future directions

We suggest that future studies pay particular attention to experimental design. First, whenever possible measurements of RMR using indirect calorimetry should be preceded by inpatient conditions with standardized meals, exercise restriction and ~12 h fast. When inpatient conditions are not possible, procedures to maintain control over diet and physical activity are imperative. Further, estimates of the RMR must be standardized by FFM and we suggest that the use of DXA (which can also distinguish bone mineral content from lean tissue mass) to determine FFM gives the most accurate and meaningful results. Thirdly, studies of menstruating women should investigate thoroughly the role of the menstrual cycle to variations in RMR, and studies of children should assess, in a standardized way, level of sexual maturation. Also, DLW should be used for determination of TDEE and PAEE with particular attention paid to precise laboratory analysis and weight stabilization. Unfortunately,

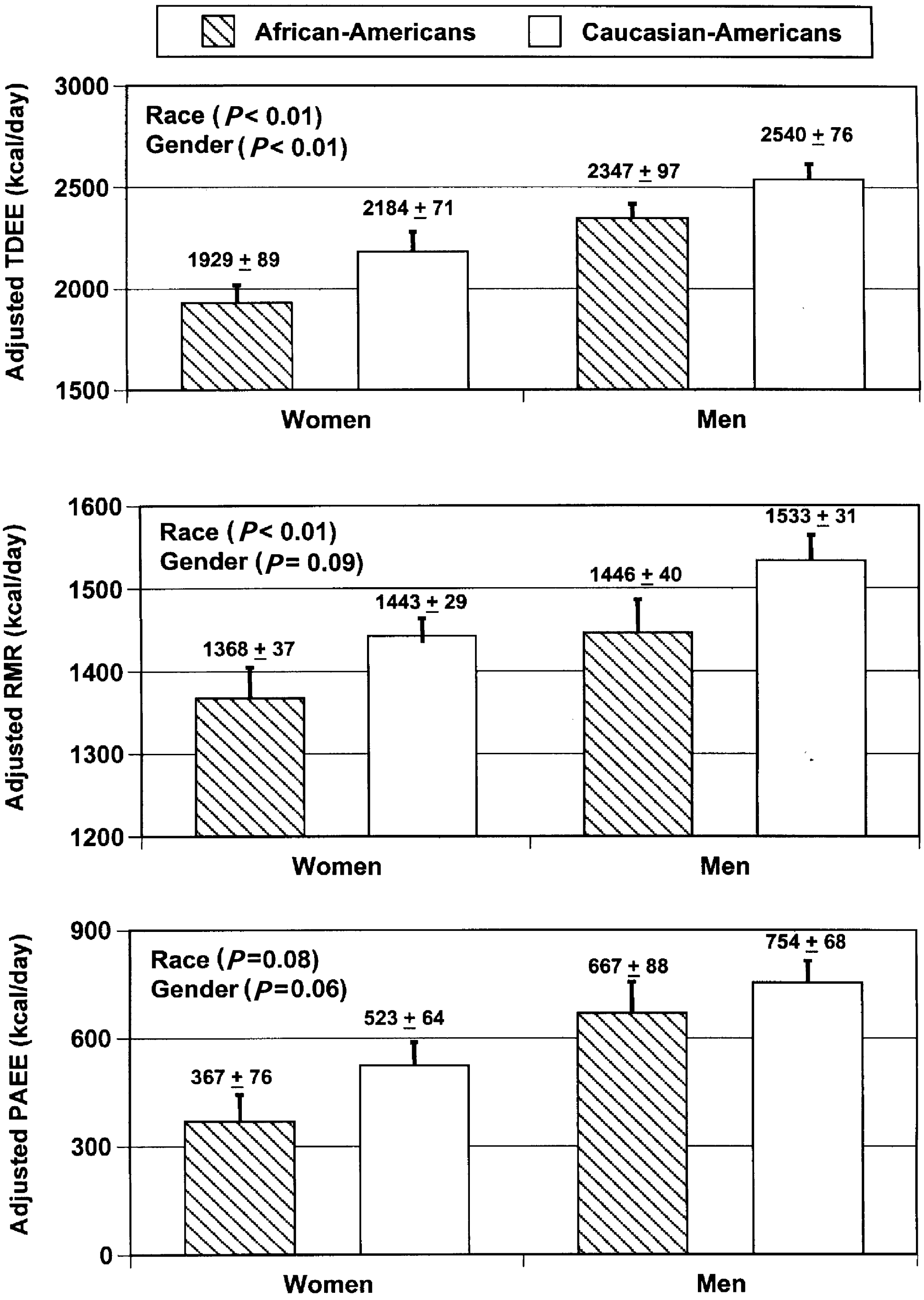

Figure 1 Adjusted total daily energy expenditure (TDEE), adjusted resting metabolic rate (RMR), and adjusted physical activity energy expenditure (PAEE) in African American and Caucasian men and women. Values were adjusted for fat-free mass. Statistical control for age, fat mass, education, income and living status did not alter these results. (From Carpenter *et al*, *Am J Physiol* 1998; **274**: E96–101).

the increasing expense and lack of availability of doubly labeled water has limited the number and size of DLW studies. Finally, because observed race differences in energy expenditure may vary by sex, study sample sizes should be large enough to yield sufficient power in testing this statistical interaction.

If future studies do indicate conclusively that free-living African Americans have lower levels of TDEE and PAEE than Caucasians, then the proportional risk of conditions such as overweight, obesity, and associated metabolic disorders may be prevented early on—particularly in younger Black women. If these observed race differences are indeed a result of *both* physiological and behavioral factors, then interventions designed to reduce caloric intake and/or increase energy expenditure through lifestyle activity or structured exercise programs are especially important among African Americans and should be encouraged.

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