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Low fitness partially explains resting metabolic rate differences between African American and white women

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Running head: Race, resting metabolic rate, and fitness

Keywords: Resting metabolic rate, fitness, physical activity, race, women

Abstract

Background: High levels of obesity among African American women have been hypothesized to be partially resultant from a lower resting metabolic rate compared to white women. The aim of the current study was to determine if differences in cardiorespiratory fitness and moderate-to-vigorous physical activity are associated with differences in resting metabolic rate among free living young adult African American women and white women.

Methods: Participants were 179 women (white women=141, African American women=38, mean age=27.7 years). Resting metabolic rate was measured using indirect calorimetry, body composition using dual energy X-ray absorptiometery (DXA), cardiorespiratory fitness via maximal treadmill test, and moderate-to-vigorous physical activityusing an activity monitor.

Results: African American women had higher body mass index (BMI), fat mass and fat-free mass compared to white women, but lower levels of cardiorespiratory fitness. No differences were observed between African American and white women in resting metabolic rate when expressed as kcal/day (1390.8±197.5 vs. 1375.7±173.6 kcal/day, P=.64), but African American women had a lower resting metabolic rate when expressed relative to body weight (2.56±0.30 vs. 2.95±0.33 mL/kg/min, P<.001). After statistical adjustment for differences in body composition between groups using linear regression models, African American women had a lower resting metabolic rate compared to white women (1299.4±19.2vs. 1400.4±9.2 kcal/day, P<.001). The addition of cardiorespiratory fitnessreduced the differences among groups by 25%. The addition of moderate-to-vigorous physical activity did not improve the model.

Conclusions: The present study confirms African American women have a lower resting metabolic rate compared to their white peers, andlow cardiorespiratory fitnessexplained 25% of

this difference.Variables associated with resting metabolic rate, such as cardiorespiratory fitness, represent possible points of tailored interventions designed to address high levels of obesity seen in certain demographic groups.

Introduction

African American females have the highest prevalence of overweight (82.1%) and obesity (58.6%) of any racial group in the United States,[1] are more likely to gain weight,[2]have a harder time losing and maintaining weight loss,[3]and are more likely to regain weight[4] compared to white women. A majority of studies have reported lower levels of resting metabolic rate inAfrican American women compared to white women, ranging from 81-274 kcal/day.[5,6]While these values may seem trivial, small differences in energy balance (e.g., a positive energy balance due to insufficient levels of energy expenditure) may result in long-term clinically relevant changes in energy storage (e.g. adiposity).[7]Many,[8-12] but not all,[13-15]studies have found a low resting metabolic rate to be predictive of subsequent weigh gain.

The primary cause of lower resting metabolic rate appears to be due to individualdifferences in fat free mass compartments, with African American women possessing larger levels of skeletal muscle mass and bone mass and lower levels of residual mass (including the brain, liver, heart, and kidneys) compared to white women.[16-21] Fat free mass is not energetically homogenous; for example, the metabolic rate of bone and skeletal muscle (approximately 2.3 and 13 kcal/kg of tissue/day, respectively) are drastically lower compared to other organs, including the brain, kidneys, heart, and liver (approximately 330 kcal/kg of tissue/day).[22-24]Most analyses only measure fat free mass, rather than the individual compartments described above, may not accurately identify sources of variation in resting metabolic rate among groups.[5,18,25]

Another potential cause of lowresting metabolic rate levels in African American women may be lowcardiorespiratory fitness, as unfit sedentary individualsoften have a 5-20% lower resting metabolic rate compared to those with high levels of cardiorespiratory fitness and moderate to vigorous physical activity.[26-28] Indeed, previous analyses from the National Health and Nutrition Examination Survey(NHANES)and elsewhere indicate African Americanshave lower levels of cardiorespiratory fitness compared to whitesby 5-10%, particularly among women.[29-31] It is possible the low levels of cardiorespiratory fitness in African American womenmay augmentexisting low levels of resting metabolic rate due to differences in metabolically active tissues.

The aim of the current study was to compare resting metabolic rate between African American and white women, adjusting for differences in body compartments and levels of cardiorespiratory fitness and moderate-to-vigorous physical activity.

Methods

The design and rationale for this study have been described in detail.[32]All study protocols were approved by the University of South Carolina Institutional Review Board, and informed consent was obtained from each participant prior to data collection. Individuals were excluded if they had a major medical condition (diabetes, hypertension, thyroid condition, etc.). All women were eumenorrheic. Given no widely accepted nomenclature exists for classification of race in academic and journalistic writing, we have adopted the categories utilized in the 2010 US Census, ‘Black or African American’ and ‘White’,[33](self-identified by participants and only one categorycould be selected).

Dual-energy X-ray absorptiometry (DXA) provided measurements on bone mineral density, fat mass, and fat free mass, both whole body and various regions (arms, legs, etc.) using a Lunar DPX system (version 3.6; Lunar Radiation Corp, Madison, WI). Skeletal muscle mass was estimated from appendicular lean soft tissue massusing the following linear regression equation:

Skeletal mass= (1.13xappendicular lean soft tissue) - (0.02x age) + (0.61x sex) + 0.97

where sex= 0 for females.[34] This equation was developed (N=321)and validated(N=93) with ethnically diverse men and women using magnetic resonance imaging (MRI) and DXA. Correlation between skeletal mass derived from the equation and MRI were high (r= 0.96, *P*<.0001).[34] Residual mass, representing brain, liver, kidneys, heart gastrointestinal tract, and other organs and tissues,was then calculated using the following equation:[21]

Residual mass= body weight – fat mass – skeletal mass – bone mass

Cardiorespiratory fitness was assessed by maximal treadmilltest (Modified Bruce protocol)with respiratory gases sampled using a TrueOne® 2400 Metabolic Measurement Cart (ParvoMedics, Salt Lake City, Utah).Resting metabolic rate was measured via indirect calorimetry using a ventilated hood and an open-circuit system, TrueOne® 2400 Metabolic Measurement Cart (ParvoMedics, Salt Lake City, Utah).An initial stabilization period of 15 minutes was followed by a 30-minute data collection period. Participants arrived for a morning visit (<9:00am) following a 12-hour dietary fastand at least 24 hours after the last bout of structured exercise.

Total daily energy expenditurewas measured using a validated arm-based activity monitor (SenseWear® Mini Armband, BodyMedia Inc. Pittsburgh, PA).[35] The participants wore the armband for 10 consecutive days and compliance criteria for adequate wear time were set at 7 days with at least 23 hours of daily wear time.Time spent in physical activity was classified by intensity according to the estimated metabolic equivalent of task (MET) based on the following criteria: Sedentary, 1.0 to ≤1.5 METs; Light, >1.5 to ≤3.0 METs; Moderate, >3.0 to ≤6.0 METs; Vigorous, >6.0 METs. Due to low amounts of time spent in vigorous activity among participants, all activity >3.0 METs was also summed to identify moderate-to-vigorous physical activity.Energy intake was measured using interviewer-administered 24-hour dietary recalls using the Nutrient Data System for Research® software (NDSR, Version 2012).Prior to data collection, study participants underwenta brief training (10-15 minutes) to estimate portion sizes of commonly eaten foods. Three interviews wereconducted on randomly selected, non-consecutive daysover a 14-day sampling window.

Statistical significance for comparison between groups was tested using t-tests. Linear regression analyses wereperformed to determine relationships amongcovariates and potential confounders and effect modifierswith the dependent variable resting metabolic rate expressed as kcal/day. Analysis of covariance (ANCOVA) was used to compare adjustedresting metabolic rate between African American and white women. Linear modeling results are presented as least squares (i.e., multivariable-adjusted) means with standard errors, and were adjusted for multiple comparisons using the Tukey-Kramer procedure. Statistical significance was set at $P<.05$ (two-sided) for all analyses. All aforementioned analyses were performed using SAS 9.3 (Cary, N.C.). Due to differences in sample size between the groups, a post hoc power analysis was performed using G*Power 3 (Germany) which yielded a power of 0.78to detect differences between group means based on an effect size of 0.5.

Results

Participant characteristics are presented in **Table 1**,including 179 individuals(141 white and 38 African American; mean age of 27.7 years). African American womenhad higher BMI, body weight, body fat percentage, fat mass, and fat free mass compared to white women; fat free mass was then compartmentalized into bone mass, skeletal mass, and residual mass, with the latter includingvisceral organs which have higher rates of metabolic activity compared to fat, bone, and skeletal muscle.Skeletal mass was significantly higher in African American women compared to white women in kg, but lower relative to total body mass. There were no differences among groups for residual mass in kg, but African American women had a lower proportion of residual mass when expressed relative to total body mass.African American women had higher absolute bone mass, with no statistically significant difference when expressed relative to body mass. There was no difference in resting metabolic rate between groups of women when expressed as kcal/day, but when expressed relative to body mass (mL/kg/min),African American women were significantly lower than white women(**Table 2**). Peak oxygen consumption was also lower among African American women, both absolute and relative to body mass.

Compliance with theactivity monitor was excellent, with 23.2±0.75 hours of daily weartime and no significant difference between groups. There was no difference in total daily energy expenditure between the groups. African American women spent significantly more time in sedentary and light activity, and less in moderate-to-vigorous physical activity (**Table 3**). Energy intake and diet composition (percent of total kcals for each macronutrient) also did not differ between groups, except for percent of kcals from alcohol (Table 3), consistent with previous findings.[36]

Due to statistically significant differences in body compartments among groups, linear models were created to adjust resting metabolic rate (**Table 4**), includingthe covariates race and age, which have previously been shown to influence resting metabolic rate, and four body compartments (skeletal muscle mass, residual mass, fat mass, and bone mass)were added individually in subsequent models. Adjusted resting metabolic rate values were calculated for each group from each model. The initial model which included race, age, and skeletal muscle mass explained 51% of the variance in resting metabolic rate, andadding residual mass explained 52%. After the addition of fat mass 66% of resting metabolic ratevariability was explained, and the adjusted mean resting metabolic rate became significantly lower for African American women compared to white women (1299.8±18.9 kcal/day vs. 1400.3±9.1 kcal/day, P<.001). Adding bone mass to the model did not significantly improve the model. The differences in resting metabolic rate among groups after adjustment for differences in body compartments are displayed in **Figure 1.**

To determine the role of aerobic capacity, cardiorespiratory fitness (L/min) was added to the model andreduced the difference in adjusted mean resting metabolic rate between African American and white women by 25% (Table 4 model 4, difference between African American and white women= 101.0 kcals/day; model 5, difference between African American and white women= 76.2 kcals/day).This approach was repeated to determine the influence of activity on resting metabolic rate, with time spent in moderate-to-vigorous physical activity replacing cardiorespiratory fitness in the model, but was not statistically significant. The individual components of energy expenditure related to physical intensity (time spent in sedentary, light, moderate, and vigorous activity) were also entered into the model both separately and together, but none were statistically related to resting metabolic rate (results not shown). This process was repeated for dietary information, and neither energy intake nor any diet variables were statistically related to resting metabolic rate (results not shown).

Discussion

The primary finding of the present study is low cardiorespiratory fitness explains 25% of the difference in resting metabolic rate between African American and white young adult women. After statistically adjusting for lower amounts (relative to body mass) of skeletal mass and residual mass and higher amounts of fat mass, African American women had a lower resting metabolic ratethan white womenby 101 kcal/day. After additional adjustments for lower cardiorespiratory fitnessamongAfrican American women, this difference was reduced to 76 kcal/day. These findings emphasize the independent role of cardiorespiratory fitness on resting metabolic rate and partially explain the variances previously observed between African American women and white women. The differences in resting metabolic ratebetween groups are clinically significant and the role of low fitness in the etiology of this differencerepresentsa possible intervention point for public health obesity campaigns.

While differences in kcalsbetween groups (i.e., between≈100kcal/day) may seem trivial, they are clinically significant for several reasons. A joint task force including the American Society for Nutrition currently advocates for a ‘small-changes framework’ of obesity prevention, encouraging individuals to make small lifestyle changes to reduce energy intake and increase physical activity.[7] While these recommendations focus on lifestyle interventions and not physiological processes such as resting metabolic rate, they are based on the roleof small ‘energy gaps’ (approximately 50 kcals/day) in influencing obesity at a population level.[37] Second, there is known heterogeneity in response to weight loss[3] and physical activity interventions[29] between racial groups; by identifying differences in the physiological components of the energy balance equation, tailored interventions can be created to maximize clinical effectiveness.[38] Finally, low resting metabolic rate levels have been shown to be associated with low total daily energy expenditure[9] and with modulatory hormones such as adiponectin,[39-41] reinforcing the role of resting metabolic rate within a broader regulatory system of body weight.

African American womenin our studyhadlevels of cardiorespiratory fitnessin the bottom 20% of a widely cited fitness classification system[42] representing ‘low’ cardiorespiratory fitness, while white women possessed levels corresponding to the middle 20%, representing ‘moderate’ cardiorespiratory fitness. When cardiorespiratory fitness was entered into the linear regression model adjusted for differences in body composition, differences in resting metabolic rate between African American and white women were reduced by 25% (101.0 kcals/day vs. 76.2 kcals/day, Table 4). This suggests low levels of cardiorespiratory fitnesspartially explain the low resting metabolic rate observed in African American women, suggesting a positive relationship between cardiorespiratory fitness and resting metabolic rate.[43,44]The mechanisms are not well understood, but cardiorespiratory fitness likely influences regulation of the sympathetic nervous system,[45] changes in muscle cell structure,[46] and substrate cycling,[47,48] which may influence resting metabolic rate. Other variables thought to be responsible for low cardiorespiratory fitness levels in African American women compared to white women, such as plasma hemoglobin and muscle fiber type,[49,50] may also contribute to resting metabolic ratedifferences.

Low resting metabolic rate may be positively associated with obesity viareductions intotal daily energy expenditure,[9]resulting in a chronic, positive energy balance if EI levels are not actively or passively reduced by similar levels. Additionally, low cardiorespiratory fitnessis associated with higher levels of adiposity[51,52] and is predictive of weight gain over time.[53]While several studies have described a lower resting metabolic rate in African American women,[5,6]cardiorespiratory fitness is rarely explored as a potential mediator. Hunter et al. explored racial differences in resting metabolic rate and cardiorespiratory fitness between

African American (n=18) and white women (n=17) women and found a 7% lower resting metabolic ratein African American womenafter adjustment for fat free massand cardiorespiratory fitness.[54]Our resultsextend these findings, utilizing a larger sample size and participants possessing a broader range of body weights, body compositions, and cardiorespiratory fitness levels. We found no relationship between resting metabolic rate and minutes of moderate-to-vigorous physical activity. To our knowledge, this is the first study to explore the role of objectively measured physical activity on resting metabolic rate.

By using DXAwe were able to compartmentalize the body according to the metabolic activity of tissues: skeletal mass, residual mass, fat mass, and bone mass. Previous studies involving MRI-derived measurement of highly metabolic organs(liver, kidney, spleen, brain) found lower levels in African American womencompared to white women by 8.8% (0.3 kg), and this difference explained approximately half of the difference in resting metabolic rate between African American and white participants.[55]We did not directly measure specific organs, a limitation to our study, but estimated residual mass including the liver, kidney, and spleen in addition to other tissues, and found lower levels among African American women by 3.8% compared to white women(Table 1).

Despite the strengths of our study, there are limitations. Specifically, uncertainty exists regarding the role of resting metabolic rate levels on subsequent weight gain, in addition to the role of cardiorespiratory fitness on resting metabolic rate, and we cannot identify causality given the cross-sectional study design. Additionally, we did not statistically control for differences in menstrual cycle phase in the present study. However, findings in the existing literature are highly varied, with some studies observing elevated resting metabolic rate following ovulation,[56]though others have not,[18] including perhaps the most thorough examination which found no significant difference in resting metabolic rate between the follicular and luteal phases of the menstrual cycle.[57]

In summary, African American women had a lower resting metabolic rate than white womenafter adjustment for differences in body composition, includinga higher residual mass and lowerfat mass. Additionally, cardiorespiratory fitness was independently associated with resting metabolic rate after adjustment for body composition, but time spent in moderate-to-vigorous physical activity was not. The differences in resting metabolic rate on a daily timeframe could have clinically significant influences on body weight gain over time. Additionally, racial differences in variables associated with resting metabolic rate, such as cardiorespiratory fitness, represent possible points of tailored interventions designed to address the current obesity epidemic.

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Table 1. Participant anthropometric characteristics overall and by race.

	All (N=179) (mean±SD)	**White** (N=141) (mean±SD)	**African American** (N=38) (mean±SD)	***P* value** between group differences
Age (years)	27.7±3.8	27.3±3.4	29.0±4.8	.06
Body Mass Index (kg/m^2)	25.5±4.3	24.6±3.9	28.8±4.1	<.001
Height (cm)	165.8±6.2	166.2±5.8	164.6±7.3	.17
Total Body Mass (kg)	70.2±12.4	68.0±11.3	78.3±13.0	<.001
Fat mass (kg)	25.4±9.6	23.7±9.1	31.7±8.7	<.001
Fat mass (%)*	35.0±8.1	33.8±8.2	39.8±6.0	<.001
Fat free mass (kg)	45.0±5.6	44.5±5.1	47.0±6.9	.04
Skeletal mass (kg)	21.3±3.1	20.9±2.7	22.6±3.8	.01
Skeletal mass (%)*	30.7±4.3	31.1±4.4	28.9±3.4	.01
Residual mass (kg)	21.0±2.7	20.9±2.5	21.3±3.3	.48
Residual mass (%)*	30.4±4.2	31.2±4.0	27.4±3.2	<.001
Bone mass (kg)	2.7±0.4	2.7±0.4	3.0±0.5	<.001
Bone (%)*	3.9±0.5	4.0±0.5	3.9±0.6	.70

*Percentages (%) based as a fraction of total body weight

Table 2. Oxygen consumption at rest and peak exercise overall and by race.

	All (N=179) (mean±SD)	**White** (N=141) (mean±SD)	**African American** (N=38) (mean±SD)	***P* value** between group differences
Resting energy expenditure (kcals/day)	1378.9±178.4	1375.7±173.6	1390.8±197.5	.64
Resting metabolic rate (mL/kg/min)	2.87±0.36	2.95±0.33	2.59±0.30	<.001
Resting metabolic rate (mL/kg of fat free mass/min)	4.43±0.41	4.47±0.42	4.28±0.36	.01
Respiratory quotient	0.79±0.05	0.79±0.4	0.79±0.06	.79
Cardiorespiratory fitness (mL/kg/min)	33.4±7.8	35.3±7.4	26.2±4.2	<.001
Cardiorespiratory fitness (L/min)	2.30±0.48	2.37±0.48	2.05±0.41	.002

Table 3. Energy expended by physical activity intensity and energy intake by macronutrient.

	All (N=179) (mean±SD)	**White** (N=141) (mean±SD)	**African American** (N=38) (mean±SD)	***P* value** between group differences
Total daily energy expenditure (kcal/day)	2419.7±291.1	2413.6±296.0	2442.5±274.7	.59
Sedentary (min/day)	1086.0±80.7	1080.4±85.0	1106.7±58.7	.03
Light (min/day)	242.0±58.3	237.1±57.9	260.0±56.8	.03
MVPA (min/day)	110.7±62.8	121.5±110.6	70.6±25.7	<.001
Energy intake (kcal/day)	1801.9±457.3	1827.6±450.7	1706.6±475.0	.15
Carbohydrates (% of total kcals)	48.1±8.4	47.9±8.6	48.6±8.0	.66
Fat (% of total kcals)	32.7±6.7	32.3±6.8	33.9±6.3	.20
Protein (% of total kcals)	16.7±3.5	16.6±3.5	17.0±3.5	.50
Alcohol (% of total kcals)	2.7±4.3	3.3±4.6	0.5±1.1	<.001

MVPA= Moderate to vigorous activity

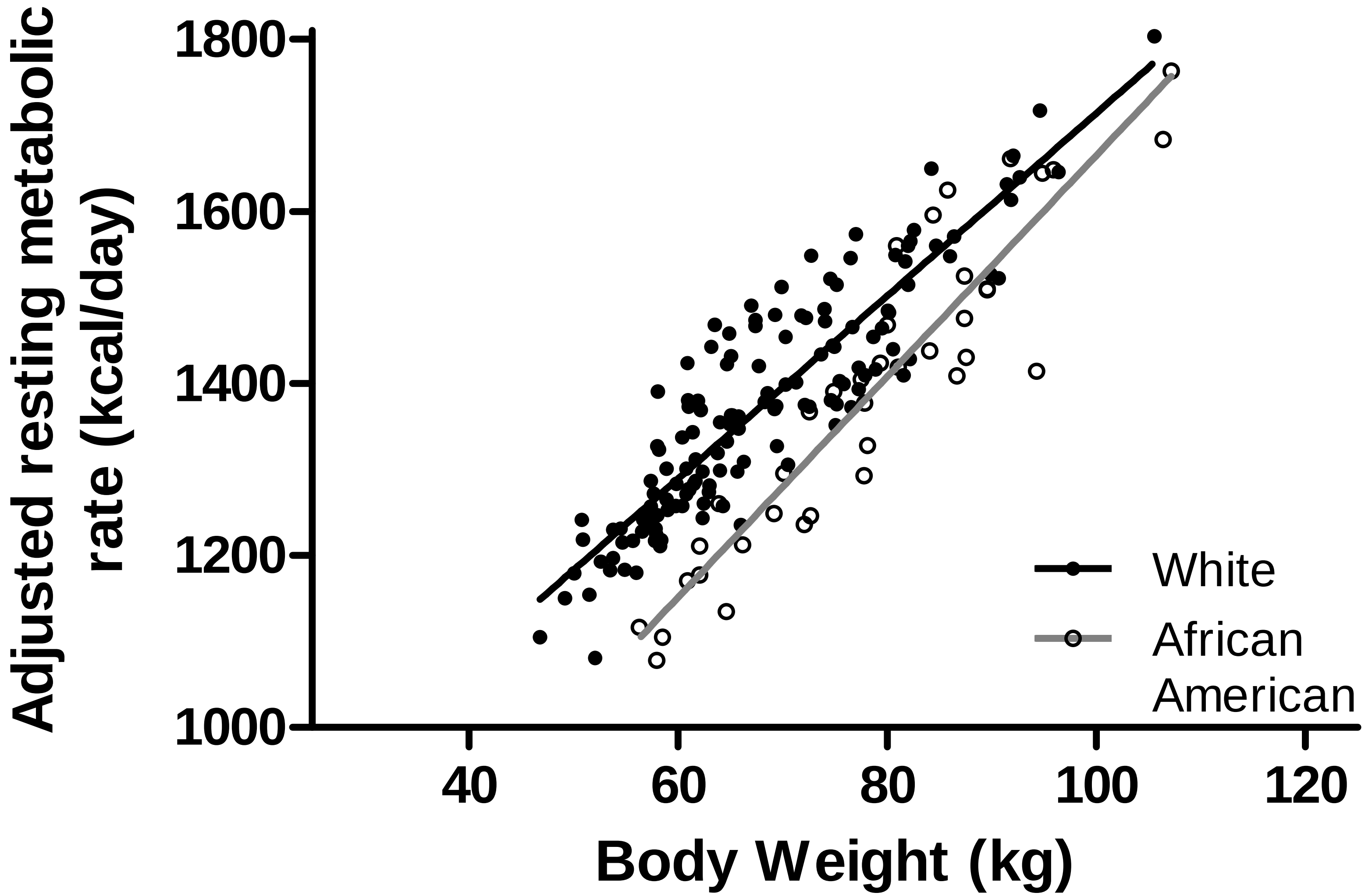
Table 4. Analysis of covariance comparing resting metabolic rate between races controlling for body compartments (kg), cardiorespiratory fitness (L/min) and time spent in physical activity (minutes/day) (mean±standard error).

	White	**African American**	**R^2**	***P* value***
Unadjusted (mean±sd)	1375.7±14.6	1390.8±32.0	NA	.64
1. Race + age + skeletal muscle	1391.5±10.8	1332.4±21.3	0.51	.16
2. Race + age + skeletal muscle + residual mass	1388.5±10.6	1343.5±21.2	0.52	.07
3. Race + age + skeletal muscle + residual mass + fat mass	1400.3±9.1	1299.8±18.9	0.66	<.001
4. Race + age + skeletal muscle + residual mass + fat mass + bone mass	1400.4±9.2	1299.4±19.2	0.66	<.001
5. Race + age + skeletal muscle + residual mass + fat mass + bone mass + cardiorespiratory fitness	1395.1±9.3	1318.9±20.3	0.67	.002
6. Race + age + skeletal muscle + residual mass + fat mass + bone mass + physical activity minutes	1399.9±9.2	1301.3±19.3	0.66	<.001

**P* value represents between group differences

Figure Legend

Figure. After adjustment for differences in body composition African American women had a significantly lower resting metabolic ratecompared to white women(difference for slopes P=0.014, difference for Y-intercept P=0.001)



Adjusted resting metabolic rate (kcal/day)
1800
1600
1400
1200
1000
40
60
80
100
120
Body Weight (kg)
White
African American

Full Title: Low cardiorespiratory fitness partially explains differences in resting metabolic rate between African American and white young adult women

Clinical significance

- African American young women have a lower resting metabolic rate than white young women.
- Low cardiorespiratory fitness levels among African American women explain approximately 25% of this difference in resting metabolic rate.
- Low levels of moderate to vigorous physical activity did not explain any additional difference in resting metabolic rate between groups.
- Variables associated with resting metabolic (E.g., CRF), represent possible points of tailored interventions designed to address the obesity epidemic.