Fatty acid oxidation in African-American and Caucasian women during physical activity

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Hickner, R. C., J. Privette, K. McIver, and H. Barakat. Fatty acid oxidation in African-American and Caucasian women during physical activity. J Appl Physiol 90: 2319–2324, 2001.—The goal of this study was to determine whether differences in physical activity-related fat oxidation exist between lean and obese African-American (LAA and OAA) and lean and obese Caucasian (LC and OC) premenopausal women. Lean AA (28.4 ± 2.8 yr, n = 7), LC (24.7 ± 1.8 yr, n = 9), OAA (30.9 ± 2.2 yr, n = 11), and OC (34.1 ± 2.5 yr, n = 9) women underwent preliminary assessment of peak aerobic capacity (V02peak). On a subsequent testing day, participants exercised after an 8-h fast on a cycle ergometer at 15 W (~40% V02peak) for 10 min and then for 10 min at ~65% V02peak. Fatty acid oxidation was determined using the average respiratory exchange ratio and O2 consumption during minutes 5–9 of the exercise session. Percent body fat and fat-free mass were lower (P < 0.05) in LAA (25.8 ± 2.8% and 48.3 kg) and LC (26.4 ± 2.0% and 45.8 ± 1.7 kg) than in OAA (41.2 ± 1.3% and 58.8 ± 3.3 kg) and OC (39.3 ± 2.7% and 58.6 kg) women. Fat oxidation among the groups was analyzed statistically using analysis of covariance with fat-free mass and V02peak as covariates. During exercise at 15 W, fat oxidation was as low in LAA (0.134 ± 0.024 g/min) as in OAA (0.144 ± 0.026 g/min) and OC (0.156 ± 0.020 g/min) women: all these rates of fat oxidation were lower than in LC women (0.200 ± 0.021 g/min, P < 0.05, LC vs. all other groups). Fatty acid oxidation during higher-intensity exercise (65% V02peak) was higher in LC than in OC women but was not statistically different between African-American and Caucasian groups. Fatty acid oxidation was therefore lower during low-intensity physical activity in OAA, LAA, and OC than in LC women.

body composition; obesity; respiratory exchange ratio

THE PREVALENCE OF OBESITY in the United States is greater in African-American than in Caucasian individuals (22, 23). Obese African-American women also suffer from higher incidences of hypertension, Type 2 diabetes, and morbidity than obese Caucasian women (12). Although environmental factors such as socioeconomic status and diet may influence the greater prevalence of obesity in African-American women, the higher incidence of obesity and subsequent adverse outcomes are not entirely due to environmental factors (5, 20, 25, 31, 32). This suggests that inherent physio-

logical and biochemical differences underlie the increased obesity in African-Americans.

Resting energy expenditure and resting fat oxidation have been shown to be depressed with obesity and may be lower in African-American than in Caucasian women (6, 7, 14, 15, 26, 27). This decreased resting energy expenditure could contribute to the increased rate of weight gain in African-American than in Caucasian women (5). In addition, there has been evidence of lower fat mobilization during weight loss in African-American than in Caucasian women. African-American women have been shown to have a slower rate and a smaller degree of weight loss, consistent with the hypothesis that there are inherent physiological and biochemical differences between the races (11, 24, 28). Although reduced resting energy expenditure or fat oxidation has been demonstrated in African-American compared with Caucasian individuals (14, 18, 27), there has been only one investigation of fat oxidation in these groups during exercise. Chitwood et al. (8) recently demonstrated that fat oxidation during treadmill exercise at 65% of maximal O2 uptake (V02) was lower in lean premenopausal African-American than in lean Caucasian women. However, there have been no investigations of fat oxidation in obese groups of African-American and Caucasian premenopausal women with the lower peak aerobic capacity (V02peak) in African-American than in Caucasian women taken into account (18). There have also been no investigations in these populations of fat oxidation during low-intensity exercise, which is more representative of normal daily activities.

We therefore investigated fat oxidation in groups of lean and obese African-American and Caucasian women. We analyzed the data using analysis of covariance to control for differences in our groups with respect to fat-free mass and V02peak per kilogram fat-free mass. The purpose of this investigation was to determine whether differences in fat oxidation exist in obese and lean African-American women compared with corresponding groups of Caucasian women.

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Exercise protocol. Within 1 wk of the VO$_2$ peak determination, participants exercised after an 8-h fast on a cycle ergometer at 15 W (~40% VO$_2$ peak) for ~10 min and then for 10 min at 65% VO$_2$ peak. Respiratory gases were analyzed continuously and averaged over 20-s intervals using a Sensormedics 2900 Metabolic Measurement Cart. Fat oxidation was determined using the average RER and VO$_2$ during minutes 5–9 of the exercise session. The day-to-day variation (coefficient of variation) for fat oxidation in these groups was 9.5%.

RESULTS

Body composition and aerobic capacity. Lean African-American and lean Caucasian groups had lower body weight, BMI, body fat, and fat-free mass than respective obese groups (Table 1). VO$_2$ peak was not different among any of the groups, although VO$_2$ peak per kilogram fat-free mass was higher in lean Caucasians than in both obese groups (P < 0.05).

Submaximal power output. The power output was set at 15 W for all groups for the low-intensity exercise. The power output for the higher intensity exercise (~65% VO$_2$ peak) was lower in obese African-American women (38.3 ± 5.2 W) than in lean African-American (56.0 ± 4.9 W), obese Caucasian (64.7 ± 7.7 W), and lean Caucasian (62.2 ± 3.2 W) women (P < 0.05, obese African-American vs. all other groups).

RER. RER was lower in lean Caucasian than all other groups of women during exercise at 15 W (Table 2; P < 0.05). RER was lower in lean Caucasian than in obese Caucasian and lean African-American women during exercise at ~65% VO$_2$ peak (Table 2; P < 0.05).

Submaximal VO$_2$. Submaximal VO$_2$ was higher in obese Caucasian and obese African-American women than in corresponding lean groups of women during exercise at 15 W (Table 3; P < 0.05). There were no differences in submaximal VO$_2$ during exercise at 65% VO$_2$ peak (Table 3).

Fat oxidation. The rate of fat oxidation in lean African-American women was 70% (P < 0.05) of that in lean Caucasian women during exercise at 15 W (Fig. 1A). During exercise at 65% VO$_2$ peak, there was an interaction (race × body composition) in the rates of fat oxidation intensity, 2) RER > 1.1, and 3) heart rate greater than age-predicted maximal heart rate.

Exercise intensity, 2) RER > 1.1, and 3) heart rate greater than age-predicted maximal heart rate.

Subjects. African-American (n = 18) and Caucasian (n = 18) premenopausal women participated in the study after giving informed consent according to the East Carolina University Institutional Review Board. African-Americans were individuals who self-reported only African-American parents and grandparents. Caucasians were individuals who self-reported only Caucasian parents and grandparents. All subjects were sedentary, in that they reported exercising less than one time per week over the previous 6 mo. Through personal history questionnaires, it was determined that the subjects were weight stable over the past 4 wk, had normal menses over the past year, were normotensive, had no prior history of cardiovascular or metabolic disease, and were not taking medications known to affect respiratory exchange rates. Additional exclusions included a history of cardiovascular or metabolic disease, and being pregnant or breast feeding. Once the initial selection had been performed, the remaining participants were further subdivided into lean African-American (n = 7) and lean Caucasian (n = 9, body mass index (BMI) ≤ 28 kg/m$^2$) women and obese African-American (n = 11) and obese Caucasian (n = 9, BMI > 28 kg/m$^2$) women. Subject characteristics are presented in Table 1.

Protocol. Participants underwent preliminary assessment of VO$_2$ peak on a cycle ergometer. On a subsequent testing day, participants exercised after an 8-h fast on a cycle ergometer at 15 W for 10 min and then for 10 min at ~65% VO$_2$ peak (not significant between groups). Fat oxidation (mean ± SE in g/min) was determined using the average RER and VO$_2$ during minutes 5–9 of the exercise session. The subjects were studied in their habitual state, in that diet was not controlled until they could no longer maintain a cadence of 40 rpm. Achievement of VO$_2$ peak was determined by attainment of two of the following criteria: 1) plateau in VO$_2$ with increased exercise intensity, 2) RER > 1.1, and 3) heart rate greater than age-predicted maximal heart rate.

Body composition and anthropometric determinations. Residual volume was determined by the O$_2$ dilution method as described by Wilmore (33). Body density was determined by hydrostatic weighing, with percent body fat calculated using residual volume and body density calculated using the equations of Brozek et al. (3).

Table 1. Subject characteristics

<table>
<thead>
<tr>
<th></th>
<th>OAA (n = 11)</th>
<th>LAA (n = 7)</th>
<th>OC (n = 9)</th>
<th>LC (n = 9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>30.9 ± 2.2</td>
<td>28.4 ± 2.8</td>
<td>34.1 ± 2.5</td>
<td>24.7 ± 1.8</td>
</tr>
<tr>
<td>Height, cm</td>
<td>163.9 ± 2.9</td>
<td>168.4 ± 3.5</td>
<td>164.3 ± 1.5</td>
<td>163.2 ± 1.8</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>103.2 ± 7.4</td>
<td>65.5 ± 2.6*</td>
<td>94.7 ± 3.2</td>
<td>63.0 ± 3.5*</td>
</tr>
<tr>
<td>BMI</td>
<td>38.0 ± 1.8</td>
<td>23.1 ± 1.2*</td>
<td>34.8 ± 0.9</td>
<td>23.5 ± 1.0*</td>
</tr>
<tr>
<td>Body fat, %</td>
<td>41.2 ± 1.3</td>
<td>25.8 ± 2.8*</td>
<td>39.3 ± 2.7</td>
<td>26.4 ± 2.0*</td>
</tr>
<tr>
<td>FFM, kg</td>
<td>58.8 ± 3.3</td>
<td>48.3 ± 0.8*</td>
<td>58.6 ± 2.1</td>
<td>45.8 ± 1.7*</td>
</tr>
<tr>
<td>VO$_2$peak</td>
<td>1.59 ± 0.11</td>
<td>1.51 ± 0.09</td>
<td>1.70 ± 0.09</td>
<td>1.65 ± 0.07</td>
</tr>
<tr>
<td>ml/min</td>
<td>27.1 ± 1.5</td>
<td>31.2 ± 1.4</td>
<td>29.2 ± 1.8</td>
<td>36.1 ± 1.6†</td>
</tr>
<tr>
<td>FFM$^{-1}$</td>
<td>27.1 ± 1.5</td>
<td>31.2 ± 1.4</td>
<td>29.2 ± 1.8</td>
<td>36.1 ± 1.6†</td>
</tr>
</tbody>
</table>

Values are means ± SE; n, no. of subjects. OAA, obese African-American; LAA, lean African-American; OC, obese Caucasian; LC, lean Caucasian; BMI, body mass index; FFM, fat-free mass; VO$_2$peak, peak aerobic capacity. *Different from obese, P < 0.05; †different from OAA and OC, P < 0.05.

Body composition and aerobic capacity. Lean African-American and lean Caucasian groups had lower body weight, BMI, body fat, and fat-free mass than respective obese groups (Table 1). VO$_2$ peak was not different among any of the groups, although VO$_2$ peak per kilogram fat-free mass was higher in lean Caucasians than in both obese groups (P < 0.05).

Submaximal power output. The power output was set at 15 W for all groups for the low-intensity exercise. The power output for the higher intensity exercise (~65% VO$_2$ peak) was lower in obese African-American women (38.3 ± 5.2 W) than in lean African-American (56.0 ± 4.9 W), obese Caucasian (64.7 ± 7.7 W), and lean Caucasian (62.2 ± 3.2 W) women (P < 0.05, obese African-American vs. all other groups).

RER. RER was lower in lean Caucasian than all other groups of women during exercise at 15 W (Table 2; P < 0.05). RER was lower in lean Caucasian than in obese Caucasian and lean African-American women during exercise at ~65% VO$_2$ peak (Table 2; P < 0.05).

Submaximal VO$_2$. Submaximal VO$_2$ was higher in obese Caucasian and obese African-American women than in corresponding lean groups of women during exercise at 15 W (Table 3; P < 0.05). There were no differences in submaximal VO$_2$ during exercise at 65% VO$_2$ peak (Table 3).

Fat oxidation. The rate of fat oxidation in lean African-American women was 70% (P < 0.05) of that in lean Caucasian women during exercise at 15 W (Fig. 1A). During exercise at 65% VO$_2$ peak, there was an interaction (race × body composition) in the rates of fat oxidation intensity, 2) RER > 1.1, and 3) heart rate greater than age-predicted maximal heart rate.
oxidation (P < 0.05). The rate of fat oxidation in obese Caucasian women was 45% (P < 0.05) of that in lean Caucasian women during exercise at 65% \( \dot{V}O_2 \) peak, although there was no difference in lean and obese African-American women (Fig. 2A). Fat oxidation rate in lean African-American women was 50% of that in lean Caucasian women during exercise at 65% \( \dot{V}O_2 \) peak (P = 0.1; Fig. 2A). Similar results were obtained when fat oxidation rates were expressed per kilogram fat-free mass (Figs. 1B and 2B).

DISCUSSION

The data demonstrate higher rates of fat oxidation during exercise in lean premenopausal Caucasian than in lean African-American women, although no significant differences were observed between obese Caucasian and obese African-American women. During low-intensity physical activity (~40% \( \dot{V}O_2 \) peak), there was a higher rate of fat oxidation in lean Caucasian women than in all other groups (obese Caucasian as well as lean and obese African-American women; Fig. 1A). Although the data presented in Fig. 1A are expressed as rates of total fat oxidation per minute, covariance analysis was performed to control for differences in our groups with respect to fat-free mass and aerobic capacity. The findings of lower rates of fat oxidation during cycle ergometer exercise at low intensity in African-American than in Caucasian women were therefore not due to a lower \( \dot{V}O_2 \) peak per kilogram fat-free mass in the African-American women.

Fat oxidation provides the majority of energy production at rest and during exercise below ~65% \( \dot{V}O_2 \) peak and is therefore an important regulator of adipose mass (4, 10). Reduced fat oxidation results in increased fatty acid storage as triglyceride when diet and exercise level are held constant. The resultant excess storage of fat has been implicated in insulin

<table>
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<tr>
<th>OAA</th>
<th>LAA</th>
<th>OC</th>
<th>LC</th>
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<tr>
<td>15 W</td>
<td>0.811 ± 0.070</td>
<td>0.559 ± 0.014*</td>
<td>0.712 ± 0.035</td>
</tr>
<tr>
<td>65%</td>
<td>1.036 ± 0.067</td>
<td>0.954 ± 0.053</td>
<td>1.120 ± 0.080</td>
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</table>

Values are means ± SE. 65%, 65% \( \dot{V}O_2 \) peak. *Different from both obese groups, P < 0.05.
resistance, hypertension, and the increased risk of obesity-related diseases (2, 9, 16). The lower fat oxidation rate in African-American than in Caucasian women may be one of the underlying causes of the higher rates of obesity in this population. Although socioeconomic status, diet, physical activity, and other environmental factors have also been implicated in the higher rates of obesity in African-American than in Caucasian women, the rates of obesity remain higher when these factors are controlled (5, 20, 25, 31, 32).

Our findings of a 30% lower fat oxidation rate in lean African-American than in lean Caucasian women during low-intensity exercise (−40% VO₂peak) are in agreement with those of a previous publication (8) in which RER was higher (reflective of lower fat oxidation) in lean African-American than in lean Caucasian premenopausal women during higher-intensity treadmill exercise (65% maximum VO₂). We also have demonstrated a higher RER in lean African-American than in lean Caucasian women in the present study during exercise at 65% VO₂peak, although the calculation of fat oxidation from RER and VO₂ data did not yield a statistically significant difference in fat oxidation between these two groups. However, the mean fat oxidation rates in the present study were 65% lower in lean African-American than in lean Caucasian women during this higher intensity (−65% VO₂peak) cycle ergometry exercise (Fig. 2A; P = 0.1). These data suggest differences that are similar in magnitude to the −65% difference in fat oxidation rate between lean African-American and lean Caucasian women that can be calculated from RER data of Chitwood et al. (8). Our findings at the lower exercise intensity (15 W, −40% VO₂peak) extend the previous findings of Chitwood et al., in that this is the first study to document a lower fat oxidation in lean African-American than in lean Caucasian women during low-intensity physical activity. The 15-W exercise intensity elicits a VO₂ in these groups that would be comparable to a walking pace. This decreased lipid oxidative disposal at intensities of activity close to everyday physical activity levels would promote fat storage in African-American women.

Reduced fat oxidation has been shown by some (6, 19, 21), although not all (17, 29, 30), authors to be related to increased adiposity. Findings presented in the present study of lower rates of fat oxidation in obese than in lean Caucasian women are in line with previous reports demonstrating reduced fat oxidation with obesity from our group and others, although our present data may have been influenced by the age of the lean (24.7 yr) and obese (34.1 yr) Caucasian women (P = 0.05). The novelty of the present findings was that fat oxidation during low-intensity exercise was reduced to a similar extent in obese African-American, lean African-American, and obese Caucasian women (Fig. 1). There may therefore be a similar defect in fat oxidation in these groups. These results are striking, suggesting that fat oxidation is already reduced in lean African-American women to a level equal to that in obese Caucasian women and is not further reduced with increasing adiposity in this group. These findings support the hypothesis of a racial difference between African-American and Caucasian women that may have an underlying genetic component.

The reduced fat oxidation per se could lead to an increased partitioning of fat to storage. The energy requirement for converting carbohydrate to triglyceride for storage has been approximated to be 25% greater (13) than the energy requirement for direct incorporation of fatty acids into triglyceride. Reduced fatty acid oxidation would therefore favor the more efficient method of energy storage, thereby increasing the propensity for obesity. The difference in fat oxidation between lean Caucasian and African-American women in the present study was 3.7 g/h at −40% VO₂peak and 4.2 g/h at −65% VO₂peak. This reduced fat oxidation during physical activity, combined with the previously reported reduction in resting fat oxidation (14, 18, 27), could result in a substantial accumulation of body fat over the decades of life. With the assumption of only 1 h/day of activity $\geq 40\%$ VO₂peak, there would be a difference of $\sim 1.5$ kg of fat per year, or $15$ kg of fat per decade, more oxidized during physical activity in a Caucasian than in an African-American woman. It is not possible to determine the relative contribution of activity-related and resting fat oxidation from this study, because we did not measure the amount of time each day spent in physical activity, rather than at rest, in these subjects. Furthermore, additional studies are necessary to determine whether the defect resulting in reduced fat oxidation during physical activity is the same as that resulting in reduced resting fat oxidation in lean African-American compared with lean Caucasian women. The lack of difference in fat oxidation at the same absolute (15 W) and relative (−65% VO₂peak) exercise intensities in obese Caucasian and obese African-American women in the present study suggests that reduced fat oxidation is not responsible for the previously reported (11, 24, 28) slower rate of weight loss in obese African-American than in obese Caucasian women.

There was a surprising difference in power output between the obese African-American and the obese Caucasian women during the higher intensity exercise. The 42% lower power output in obese African-American than in obese Caucasian women is not consistent with the similar VO₂ in these groups at 65% VO₂peak. Efficiency was apparently lower in the obese African-American than in the obese Caucasian women and was also lower than in all other groups. This phenomenon was not apparent when the subjects exercised at the lower power output set at 15 W. The higher VO₂ at 15 W in obese than in lean women in this study was likely due the necessity of moving the larger leg mass of the obese women at this very low power output. There are, to our knowledge, no previously published data regarding efficiency in African-American compared with Caucasian individuals, although resting VO₂ has been
shown to be lower in African-American than in Caucasian women (8).

The lack of blood or muscle biopsy data in this study limits the findings to the data obtained using whole body indirect calorimetry. Previous authors (8) reported that plasma insulin remains higher in African-American than in Caucasian individuals during exercise, which may have suppressed fat oxidation in African-American women. The lower slow-twitch fiber distribution in African-American than in Caucasian individuals might also contribute to the lower fat oxidation in African-American women (1). There are numerous other potential sites of limitation in fat oxidation, including transport of fatty acids into the muscle cell (lipoprotein lipase and putative fatty acid transporters), transport and activation of the fatty acids within the muscle cell (fatty acid-binding proteins and fatty acyl-CoA synthase), or transport of fatty acids into the mitochondria (carnitine palmitoyl transferases and regulatory molecules such as malonyl-CoA). There are no reported data, to our knowledge, comparing African-American and Caucasian women with respect to any of these potential sites of limitation.

In summary, fatty acid oxidation rates are lower in lean African-American than in lean Caucasian premenopausal women. This difference is evident during low-intensity (40% \( \dot{V}_O^2 \) peak) physical activity, in addition to the previously reported difference in RER at 65% \( \dot{V}_O^2 \) peak in lean African-American and lean Caucasian women (8). Fatty acid oxidation during low-intensity physical activity is reduced to a similar degree in obese Caucasian, lean African-American, and obese African-American premenopausal women compared with lean Caucasian premenopausal women. These findings support the hypothesis of inherent physiological or biochemical differences between African-American and Caucasian women that may have an underlying genetic component.

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REFERENCES


