ABSTRACT

BODY FAT HAS NO APPARENT EFFECT ON THE MAXIMAL FAT OXIDATION RATE IN YOUNG FIT NORMAL TO OVERWEIGHT WOMEN

by Ashley Nicole Blaize

The purpose of this thesis is to determine whether body fat affects the maximal rate of fat oxidation in young women during a graded exercise test. Fourteen female subjects with body composition ranging from 18.6 to 30% fat underwent testing. On day 1 the subjects performed a VO₂max treadmill test. On day 2 subjects were measured for % fat and performed a maximal fat oxidation test. The rates of fat and carbohydrate oxidation were determined using gas exchange analysis. The results here were no significant differences (p>0.05) in maximal fat oxidation rates between the women in lower-fat and higher-fat groups. Fat oxidation occurred at an exercise intensity of 55.7 ± 11.1% and 59.1 ± 5.4% VO₂max for the lower-fat and higher-fat groups, respectively, with no significant difference between groups (p>0.05). In conclusion, fat mass does not significantly influence the maximal fat oxidation rates during a graded exercise test in young healthy normal and overweight women.
BODY FAT HAS NO APPARENT EFFECT ON THE MAXIMAL FAT OXIDATION RATE IN YOUNG FIT NORMAL TO OVERWEIGHT WOMEN

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Ashley Nicole Blaize
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Oxford, Ohio
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Advisor ______________________
Dr. Jeffrey Potteiger

Reader ______________________
Dr. Randal Claytor

Reader ______________________
Dr. Douglas Noe
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Figure 3. Relationship between body fat mass (kg) and maximal fat oxidation (g/min) for all subjects (n=14).
Introduction

The maximal rate of fat oxidation can be defined as the highest observed use of fat as an energy source during oxidative metabolism (Achten, Gleeson, & Jeukendrup, 2002). The maximal rate of fat oxidation can be determined during a graded exercise test to exhaustion (Achten et al., 2002; Achten, Venables, & Jeukendrup, 2003; Friedlander, Casazza, Horning, Buddinger, & Brooks, 1998). Information provided from this test can be used to monitor changes to fat oxidation rates during training and to develop effective exercise prescriptions.

To date, most research has focused mainly on determining the maximal fat oxidation rates of men (Friedlander, Casazza, Horning, Usaj, & Brooks, 1999; Coyle, Jeukendrup, Oseto, Hodgkinson, & Zderic, 2001; Achten et al., 2002; Achten et al., 2003; Romijn, Coyle, Sidossis, Zhang, & Wolfe, 1995) and there has been less research examining women and the maximal fat oxidation rate (Friedlander et al., 1998; Friedlander, Casazza, Horning, Huie, & Brooks, 1997). Friedlander et al. found that women do not increase their rate of fat oxidation at the same relative exercise intensities as men (Friedlander et al., 1998). Compared to previous research conducted on men, women had a higher fat oxidation rate at the same relative workload after training than men (Friedlander et al., 1998; Friedlander et al., 1997). These findings suggest that muscle and adipose tissue metabolism may be different in men and women (Friedlander et al., 1998). Consequently, the rates of fat oxidation and the corresponding exercise intensity determined from studies in men may not be generalizable to women.

Little is known about the contribution of body composition to the maximal fat oxidation rate. Elevated fat mass allows for increased fasting free fatty acid levels in the blood and increased uptake by the muscles, promoting higher rates of fat oxidation (Schutz, 1992). Due to the increase in fat oxidation, it can be assumed that in the long term maintenance of fat and energy balance this increase would serve as a significant lipostatic factor (Schutz, Tremblay, Weinsier, & Nelson, 1992). For example, a cross-sectional study of 106 obese women maintaining stable weight demonstrated that post-absorptive fat oxidation was positively correlated \(r = 0.56, p < 0.001\) with fat mass (Schutz et al., 1992). Schutz et al. also examined 24 obese women in an effort to clarify the long-term adaptation in fat oxidation resulting from body fat loss (Schutz et al.,
1992). The subjects lost an average of 12.7 kg of body weight and 9.8 kg of body fat. The reduction in fat oxidation was identical to the regression coefficient found in the cross-sectional study. The researchers concluded that changes in fat mass significantly affected fat oxidation and that this process may contribute to the long-term relationship between fat and energy balance in obese individuals (Schutz et al., 1992).

Additional research is needed to determine if differences in maximal fat oxidation rates occur in women with different body fat levels. If the rate of maximal fat oxidation is affected by body fat, this information can help health practitioners prescribe more effective exercise protocols to women desiring to prevent weight gain and/or promote body fat and body weight loss. This in turn may help women effectively decrease their risk for health disorders such as obesity, insulin resistance, diabetes, and cardiovascular disease. The purpose of this study was to determine whether body fat affects the maximal rate of fat oxidation in young women during a graded exercise test. Based on the belief that higher levels of fat mass will increase fat oxidation, we expected to find that higher body fat levels result in a higher maximal fat oxidation rate.

**Methods**

*Subjects.* Fourteen healthy young females (age range 21-31 y) participated in this study. All testing was performed after the subject signed an informed consent and completed a health history questionnaire in accordance with university guidelines on human experimentation. Women with greater than 25% body fat were placed in the higher-fat group and women with less than 25% body fat were placed in the lower-fat group. Subjects refrained from prior exercise on the days of testing. Inclusionary criteria were 15 to 35% body fat, weight stable (±2.3 kg) for at least 2 months prior to the start of the investigation, a normal menstrual cycle (≥ 8 cycles per year), pre-menopausal, and physically active as defined by participating in at least 3 aerobic exercise training sessions per week for at least 2 months prior to the start of the study. Potential subjects were excluded from the study if they had 2 or more risk factors on the health history questionnaire, were using any medications that could affect exercise or metabolism, were a current smoker, or consumed a vegetarian diet.

*Research Design.* All subjects were tested on two separate occasions, at least 48 h apart. The subjects were instructed to refrain from vigorous exercise 24 h prior to testing. In
order to reduce the influence of prior food consumption on the substrate response during exercise the subjects were shown food samples and given detailed instructions for the accurate recording of food content and quantity. Subjects were instructed to maintain their normal diet throughout the study. All subjects were tested after a 4 h fast. On the first day of testing, the subjects reported to the Human Performance Laboratory where they were measured for height and weight. The subjects then performed a graded exercise test to exhaustion. On the second day of testing the subject reported to the laboratory where they were assessed for body mass and body composition. Immediately thereafter, subjects performed a treadmill fat oxidation test to determine the exercise intensity that elicits maximal fat oxidation. The test was stopped when the subjects reached a respiratory exchange ratio (RER) of 1.0 (Achten et al., 2003).

**Body mass and composition.** Height was determined using a stadiometer and body mass was measured using a calibrated electronic scale. Body composition was assessed using air displacement plethysmography (Bod Pod, Life Measurement Inc.) according to the manufacturer’s instructions. All subjects voided prior to testing and were measured wearing only a one piece nylon swimsuit and cap. Percent body fat (% fat) and body mass were used to calculate the amount of fat mass (FM) and fat-free mass (FFM) for each subject.

**Maximal oxygen consumption test.** Each participant performed a graded exercise test to exhaustion in order to determine maximal oxygen consumption (VO\(_{2}\)max). The subjects walked at 5.6 km/h and 0% grade for 2 min. The treadmill was then increased to the subject’s desired running speed (range 8.0 to 10.8 km/h) at a 0% grade. The grade of the treadmill was then increased by 2% every 2 min until the subjects reached volitional exhaustion. Expired air was measured for oxygen and carbon dioxide concentrations at one minute intervals using a Parvo Medics metabolic measurement cart. This system was calibrated before each test according to the manufacturer’s instructions. A test was considered maximal if the subject achieved any three of the four following criteria: a plateau in oxygen consumption (< 2.0 ml/kg/min) with an increase in exercise intensity, respiratory exchange ratio \(\geq 1.10\), a maximal heart rate within ±10 beats per minute of age-predicted values, and volitional exhaustion (Duncan, Howley, & Johnson, 1997). All subjects reached at least three of the four criteria during testing.
Maximal fat oxidation test. The participants performed a graded exercise test on the treadmill to determine individual maximal fat oxidation rates. The treadmill protocol used in this study was modified from previous research (Achten et al., 2003). Briefly, the participants walked at 3.5 km/h at a 1% grade for 3 minutes. The speed of the treadmill was increased by 0.9 km/h every 3 minutes until the subjects reached 9.3 km/h. Thereafter, the grade of the treadmill was increased by 2% every 3 minutes until the participants respiratory exchange ratio (RER) reached 1.0 and the test was stopped.

Heart rate (HR), RER, volume of oxygen consumed (VO2), and volume of carbon dioxide expired (VCO2) were recorded every minute using a Parvo Medics metabolic measurement cart. The metabolic cart was calibrated before each test according to the manufacturer’s instructions. After the completion of testing, the VO2 and VCO2 values were averaged for the last 2 minutes of every stage (Achten et al., 2002; Stisen et al., 2006). The values for fat and carbohydrate oxidation were determined using stoichiometric equations and appropriate energy equivalents (Achten et al., 2003; Frayn, 1983). The results of the maximal fat oxidation test were used to construct a curve of fat oxidation (g/min; mg/kg body mass/min; mg/kg FFM/min) versus exercise intensity, expressed as a percent of VO2 max. The curves were used to determine maximal fat oxidation and the exercise intensity at which the maximal rate of fat oxidation was observed.

Statistical Analysis. Experimental data are presented as means ± SD unless stated otherwise. A series of ANOVAs were used to identify differences between the lower-fat and higher-fat groups for maximal fat oxidation rates and the exercise intensity that elicited the maximal fat oxidation rate. Pearson correlations were used to identify significant relationships between percent body fat, fat-mass, fat-free-mass, VO2 max (absolute and relative) and maximal fat oxidation rates. A linear regression was run to determine if % fat, fat mass, fat-free mass, or VO2 max significantly predicted the maximal rate of fat oxidation during testing. The relationship between fat oxidation rates and relative exercise intensities for the lower-fat and higher-fat groups was estimated using a linear mixed effects model with a random intercept for each individual (Laird & Ware, 1982). Curves were fitted using the lme function within the nlme package in the
statistical software R (Pinheiro, Bates, Debroy, & Sarkar, 2009; R Development Core Team, 2010). For all analyses, statistical significance was accepted at p < .05.

Results

Physical characteristics

Physical characteristics of the fourteen subjects who completed the study are shown in Table 1. There were no significant differences between the lower-fat and higher-fat women in most of the anthropometrical variables (height, mass, fat-free mass, or VO₂max). There were significant differences in the % fat and fat-mass (p < 0.05) between the lower-fat and higher-fat groups.

Maximal Fat Oxidation Rates

There was no significant difference in maximal fat oxidation rates between the lower-fat group (0.39 ± 0.10 g/min, 8.52 ± 2.69 mg/kg FFM/min) and the higher fat group (0.49 ± 0.13 g/min, 10.81 ± 2.80 mg/kg FFM/min) (Table 2). Maximal fat oxidation occurred at an exercise intensity of 55.7 ± 11.1% and 59.1 ± 5.4% VO₂max for the lower-fat and higher-fat groups, respectively (Figure 1). There was no significant difference between the exercise intensity that elicited the maximal fat oxidation between the lower-fat and higher-fat groups (p<0.05). No significant differences were observed in fat oxidation rates at various exercise intensities for the lower-fat and higher-fat groups (Figure 2).

Since there were no significant differences in fat oxidation and carbohydrate oxidation between the two groups, the groups were collapsed for the correlation analysis. The maximal fat oxidation rate (absolute) was not significantly correlated with any of the descriptive variables (fat-free mass, % fat, fat-mass, or absolute and relative VO₂max). Fat-free-mass was significantly and positively related to the absolute (r (13) = .73, p<.01) and relative maximal rate of carbohydrate oxidation (r (13) = .58, p<.05). There was no significant relationship between fat mass and the maximal rate of fat oxidation (Figure 3).

Discussion

An important finding from this research is there were no significant differences in the maximal fat oxidation rate and the exercise intensity that elicited that rate between the lower-fat and higher-fat groups of women. Another key result is that fat-mass, fat-free-
mass, % fat, and absolute and relative VO$_2$max were not significantly correlated to maximal fat oxidation rates. These results indicate that maximal fat oxidation rates, as determined during a graded exercise test, are not affected by body fat levels in young physically active women with different % fat (range 18.6 to 30%).

Substrate supply can affect whole body substrate oxidation rates both during rest and exercise. Several investigations have demonstrated that body fat levels can specifically affect fat and carbohydrate oxidation. For example, Schutz et al. investigated obese women maintaining stable weight and obese women losing weight and demonstrated that post-absorptive resting fat oxidation was positively correlated with fat mass, which led to the conclusion that fat mass significantly affected fat oxidation (Schutz et al., 1992). Additionally, Astrup et al. (Astrup et al., 1992) examined 24 hour energy expenditure (EE) and fat oxidation rates in women who were classified as obese (BMI > 30 kg/m$^2$) and women who were classified as normal weight (BMI < 25 kg/m$^2$). The authors found that obese women had higher levels of lipid oxidation compared to the normal weight women, and these differences could be explained by body composition and body size (Astrup et al., 1992). When comparing the obese and normal weight subgroups, the obese women had significantly higher 24 h EE, lipid oxidation, and carbohydrate oxidation. These results led the researchers to believe that higher fat availability increases substrate supply and can lead to increased fat oxidation (Astrup et al., 1992; Friedlander et al., 1998).

It is important to note the fat mass, body mass, and % fat ranges were different for the current study when compared to the aforementioned research. Schutz et al. examined women who ranged from 62.0 to 111.7 kg with percent body fat ranges from 31.0 to 44.7 % (Schutz et al., 1992), while Astrup et al. examined obese women with an average mass of 93.2 kg and fat mass of 40.8 kg and normal weight women with an average mass of 61.0 kg and 17.4 kg of fat mass (Astrup et al., 1992). In the present study, women had an average mass of 61.2 (range 51.6 to 69.9 kg), an average fat mass of 15.4 kg (range 10 to 20 kg), and an average percent body fat of 24.9 % (range 18.6 to 30 %). The women in the current study fall into one of two body weight categories, normal or overweight, with none of the women being classified as obese. The influence of increased fat mass on substrate oxidation is thought to be mediated by increased levels of free fatty acids.
Since free fatty acid levels are mainly controlled by substrate availability increases in fat mass tend to promote fat mobilization and ultimately increase fat oxidation (Astrup et al., 1992; Schutz et al., 1992). Because none of the women in the present study were obese, this could serve as a potential explanation why the higher-fat women in the present study did not have higher maximal fat oxidation rates than the lower-fat women.

Several prior investigations have found significant positive correlations between fat mass and fat oxidation rates. The results of the present study showed no statistically significant correlation between fat oxidation rates and fat-mass, fat-free-mass, % fat, and VO$_2$max (in both absolute and relative values). The fact that all of the women in the present study were either normal weight or overweight could explain why there are no significant correlations between these variables and maximal fat oxidation rates. When comparing obese women to their post obese state Schutz et al. found that fat oxidation fell 42% (2.00 ± 0.95 to 1.17 ± 1.08 g/h) with weight loss (Schutz et al., 1992). This shows there is a relationship between fat mass and fat oxidation when comparing obese women to normal weight women who have had significant weight loss. A possible explanation for the lack of a significant difference could lie in the level of plasma free fatty acids. It is known that obese women have higher resting levels of fatty acids in the blood compared to normal weight individuals (Horowitz, 2001) and this could likely contribute to higher fat oxidation rates. Once again, the fact that none of the subjects in the higher-fat group were obese could mean that plasma fatty acid levels were normal in all subjects. This would mean that substrate supply was similar in both groups. It is unfortunate that plasma fatty acid levels were not measured in the current study and this remains an area for future investigation.

The range of exercise intensity that elicited the maximal fat oxidation rate has been shown to be between 59.2 to 64.0 % of VO$_2$max (Achten et al., 2003; Achten et al., 2002) and these values are similar to the current study. Research has shown that one of the benefits of high physical fitness is a higher rate of fat oxidation during exercise (Kriketos, Sharp, Seagle, Peters, & Hill, 2000). However, in a study by Krieketos et al. that examined the effects of aerobic fitness on fat oxidation and body fatness it was observed that VO$_2$max and fat oxidation were significantly related in men, however in the
women they were not (Kriketos et al., 2000). These findings suggest that physical fitness in women may contribute to substrate oxidation differently than men (Kriketos et al., 2000). This could be due to the fact that women have other factors that influence substrate oxidation other than body composition, such as fat oxidation capacity (fat free mass) or different hormonal levels (Kriketos et al., 2000). Further research in the difference between men and women and the regulation of fat oxidation is still needed.

The present study has some potential limitations. The study participants were all young women (21-31 y), non-obese (avg. % fat was 24.9 %, range 18.6 to 30 %), and all physically fit (mean VO$_2$max 63.2 ml/kg FFM/min, range 57.5 to 68.9 ml/kg FFM/min). These factors make it difficult to generalize the findings to women who are not classified as normal or overweight with good levels of cardiovascular fitness. The range we used for categorizing the lower-fat and higher-fat groups could also have been a limitation. The cutoff point for separating the women into lower-fat and higher-fat groups was 25%. Some of the subjects had body fat percentages that put them on the border for each group (ex. 24.5 and 25.5 % fat). This small variability between some of the lower-fat and higher-fat women could also partially explain why there are no significant differences between the two group’s maximal fat oxidation rates.

In conclusion, the findings of the present study suggest that body fat does not affect the maximal fat oxidation rate or the exercise intensity that elicits that rate in young, physically active, healthy women of normal and overweight status. These findings indicate that the substrate oxidation results derived from a maximal fat oxidation test may be used to accurately prescribe an exercise intensity that will maximize the utilization of fat as an energy source if the women tested are of normal or overweight status.
Table 1. *Physical characteristics (mean±SD) of 14 female subjects.*

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<th>Low-Fat Group</th>
<th>High-Fat Group</th>
<th>Combined Group</th>
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<td>N</td>
<td>7</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>23.6 ± 3.7</td>
<td>22.3 ± 2.6</td>
<td>22.9 ± 3.1</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>165.6 ± 5.7</td>
<td>164.7 ± 6.6</td>
<td>165.1 ± 5.9</td>
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<tr>
<td>Body mass (kg)</td>
<td>58.8 ± 7.2</td>
<td>63.7 ± 6.2</td>
<td>61.2 ± 6.9</td>
</tr>
<tr>
<td>% fat</td>
<td>21.7 ± 3.1</td>
<td>28.1 ± 1.9*</td>
<td>24.9 ± 4.1</td>
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<tr>
<td>Fat free mass (kg)</td>
<td>46.0 ± 4.9</td>
<td>45.8 ± 4.6</td>
<td>45.9 ± 4.6</td>
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<tr>
<td>Fat mass (kg)</td>
<td>12.9 ± 2.9</td>
<td>17.9 ± 2.1*</td>
<td>15.4 ± 3.6</td>
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<td>VO$_2$ max (L/min)</td>
<td>2.8 ± 0.6</td>
<td>3.0 ± 0.4</td>
<td>2.9 ± 0.5</td>
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<tr>
<td>VO$_2$ max (ml/kg FFM/min)</td>
<td>61.3 ± 7.0</td>
<td>65.1 ± 3.6</td>
<td>63.2 ± 5.7</td>
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*Significantly different from low-fat group, p < 0.05*
Table 2. Maximal fat oxidation rate and maximal carbohydrate oxidation rate during the maximal fat oxidation test (mean±SD).

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<th>Combined Group</th>
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</thead>
<tbody>
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<td>N</td>
<td>7</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>FAT-OX (g/min)</td>
<td>0.39 ± 0.1</td>
<td>0.49 ± 0.1</td>
<td>0.44 ± 0.1</td>
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<td>CHO-OX (g/min)</td>
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<td>FAT-OX (mg/kg FFM/min)</td>
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<td>9.7 ± 3.0</td>
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<tr>
<td>CHO-OX (mg/kg FFM/min)</td>
<td>23.7 ± 8.3</td>
<td>22.6 ± 9.6</td>
<td>23.1 ± 8.7</td>
</tr>
</tbody>
</table>
Figure 1. Percent VO$_2$max at maximal fat oxidation rate in lower-fat (n=7) and higher-fat (n = 7) young women (mean±SD).
Figure 2. Fat oxidation (ml/kg FFM/min) versus relative exercise intensities (% VO₂max) for lower-fat and higher-fat young women. Values are group means ± SE estimated from a linear mixed effects model with a random intercept for each individual. No significant difference between groups was discernible ($p = 0.1810$).
**Figure 3.** Relationship between body fat mass (kg) and maximal fat oxidation (g/min) for all subjects (n=14).
Reference List


