Effects of carbohydrate ingestion during exercise on fat and carbohydrate utilization in women of different body composition levels

Nicole M. Mitchell
Jeffery A. Potteiger
Brittney Bernardoni
Randal P. Claytor
Center for Health Enhancement
Department of Kinesiology and Health
Miami University

Direct correspondence to:
Jeffery A. Potteiger, Ph.D., FACSM
Center for Health Enhancement
Department of Kinesiology and Health
106 Phillips Hall
Miami University
Oxford, Ohio 45056
Phone: 513-529-6522
Fax: 513-529-5006
Email: potteija@muohio.edu
Abstract

The effects of consuming a carbohydrate (CHO) beverage (6% CHO) during exercise on substrate oxidation was examined in 17 physically active, young women of high fat >25% (HF) and low fat <25% (LF) body composition. Women in the HF group (n=9) were 32.4±5.6% fat with a VO$_2$max of 53.6±8.2 ml/kg FFM/min and women in the LF group (n=8) were 20.0±3.0% fat with a VO$_2$max of 57.8±6.3 ml/kg FFM/min. Subjects completed 2 treatment sessions of 45 minutes of treadmill exercise at 55% of VO$_2$max and 2 hours post-exercise recovery. Prior to exercise and at 15 minute intervals during exercise, subjects consumed 25% of a total volume of either CHO beverage (1 g CHO/kg) or a placebo (PLC). During exercise and for 2 h post-exercise, expired gases were analyzed to determine oxidation rates for CHO (CHO-OX) and fat (FAT-OX). During exercise significant differences (p < 0.05) in CHO-OX (mg/kg FFM/min) were found between groups for the CHO trial (LF 35.4±4.7 vs. HF 29.8±3.6) and PLC trial (LF 33.7±6.4 vs. HF 26.3±4.3). CHO-OX was significantly higher during the 1st hour of recovery in both LF (CHO, 9.3±2.1 vs. PLC, 5.3±2.4) and HF (CHO, 8.7±2.0 vs. PLC 4.2±1.0) groups but during the 2nd hour of recovery only the HF group had a higher CHO-OX (CHO, 5.3±1.8 vs. PLC, 3.9±1.1). FAT-OX was significantly lower during the 1st hour of recovery in both LF (CHO, 0.6±0.4 vs. PLC, 1.0±0.4) and HF (CHO, 0.4±0.4 vs. PLC, 1.4±.4) groups as well as during the 2nd hour of recovery LF (CHO,0.8±0.4 vs. PLC, 1.3±0.5) and HF (CHO,0.9±0.6 vs. PLC, 1.6±0). CHO ingestion during exercise promotes carbohydrate oxidation and suppresses fat oxidation during and following exercise in women with low and high levels of body fat percentage.

Key words: RER, obesity, women, body fat, exercise, sports drink
Introduction

According to the 2006 National Health and Nutrition Examination Survey, 66.9% of American adults ages 20-74 y are either overweight or obese (27). This is a significant increase since data were first collected in the 1960’s. This rising level of overweight and obesity presents our nation with not only increased health care costs (14) but also an increased risk of diseases such as diabetes, heart disease, stroke, arthritis, and some cancers (15). Excess body weight and body fat can be reduced through lifestyle changes such as reducing caloric intake and/or increasing caloric expenditure through physical activity and exercise. Strategies that promote the use of fat as an energy source are critical for the achievement of weight loss and/or body fat loss (1; 10).

During aerobic exercise carbohydrates and fats are the primary energy sources. Anecdotal evidence suggests that individuals may often ingest carbohydrate (CHO) during their exercise session in the form of sports drinks since well-known research has demonstrated that CHO ingestion increases endurance exercise capacity (32). The increase in exercise performance is generally attributed to an increased availability of blood glucose late in exercise (18). When CHO is ingested during exercise, blood glucose uptake and CHO oxidation by active skeletal muscle is increased (25) typically at the expense of fat oxidation. With these effects, individuals can generally exercise longer and/or at a higher intensity.

Individuals may not understand however the role that energy intake prior to and during exercise can have on substrate oxidation. CHO ingestion before and/or during exercise decreases the oxidation of fat as an energy source (25). After consumption of CHO, there is an increased uptake of the ingested glucose into the active muscle. If insulin concentration also increases there is a reduction of lipolysis and as a result of these two actions fat oxidation is decreased
This suppression of fat oxidation following CHO ingestion can last for several hours (26). Consequently, an individual consuming CHO before and/or during exercise will likely oxidize less fat and more CHO during and after the exercise session.

Individuals with varying levels of body composition use fat and CHO as energy sources to different extents (16). Current research suggests that obesity may be caused by altered fuel selection at either the dietary or metabolic level (16). High rates of CHO utilization during exercise may predispose a person to reduced fat oxidation and excess fat storage because they have lower rates of fat utilization. Excess body fat has been shown to have a significant effect on substrate utilization (4) with increased reliance on CHO oxidation and a decrease in fat oxidation during rest and exercise (7; 12; 13; 35). Conversely, several investigations have demonstrated a higher rate of fat oxidation in obese individuals during rest (3; 29). Possible mechanisms for the altered fat oxidation include alterations in fatty acid availability, oxidative capacity of skeletal muscle, the rate of glycolytic flux within muscle, and hormonal and neural factors (4). Metabolic differences between overweight and obese individuals compared to normal weight individuals necessitates additional research to determine what exercise and nutrition prescriptions would be most effective for promoting fat oxidation during and following exercise in the overweight and obese population.

Research on the effects of CHO ingestion before and during exercise on fat and CHO oxidation has focused primarily on metabolic responses in well-trained and lean individuals. Little is known about how CHO ingestion before and during exercise influences substrate oxidation during and after exercise in overweight and obese females. Often individuals consume CHO prior to exercise believing that the extra energy will help them complete the exercise session. Consumption of CHO prior to and during exercise may, however, alter substrate
oxidation by reducing fat oxidation and increasing CHO oxidation, resulting in hindered body weight and fat loss. The purpose of this investigation was to examine the effects of consuming a CHO beverage (6% CHO solution) prior to and during exercise on fat and CHO oxidation levels in women of high fat >25% (HF) and low fat <25% (LF) body composition. We hypothesize that women with a higher percent body fat will respond to CHO ingestion with a higher fat oxidation and lower CHO oxidation during and after exercise than women with a lower percent body fat.

Methodology

Subjects. Seventeen healthy, physically active young females participated in this experiment and were divided into two groups based on measured percent body fat. Women with greater than 25% body fat were placed in the HF group (mean ± SD; age = 21.4±2.3 y; weight = 71.6±14 kg; height = 165±10 cm; VO₂max = 53.6±8.2 ml/kg FFM/min). Women with less than 25% body fat were placed in the LF group (mean ± SD; age = 21.4±2.6 y; weight = 63.4±9.1 kg; height = 171±9.4 cm; VO₂max = 57.8±6.3 ml/kg FFM/min). All subjects read and voluntarily signed an informed consent form and completed a health history questionnaire in accordance with guidelines set forth by the Human Subjects Institutional Review Board at Miami University. Inclusionary criteria were as follows: participation in at least 3 aerobic exercise training sessions per week (≥ 30 min duration each) for at least 2 months prior to testing, weight stable (± 2.27 kg) for at least 2 months prior to testing, body composition (% fat) between 10-40%, and a normal menstrual cycle as defined by ≥ 8 cycles per year. Women were excluded from the study if they consumed any medications or had any metabolic disease that might affect metabolism or exercise performance, were a current smoker or vegetarian, or had any diagnosed eating
disorders. Subjects refrained from exercise on testing days and from consuming caffeine and alcohol for 24 h prior to testing.

Research Design. All subjects were tested on three occasions. During the initial testing session maximal oxygen consumption (VO₂\text{max}) and body composition were measured. Testing sessions two and three were treatment conditions during which subjects exercised for 45 minutes on a treadmill at 55% of VO₂\text{max} and underwent 2 hours of post-exercise recovery. A carbohydrate beverage (CHO, Gatorade®) or placebo (PLC, distilled water) was consumed immediately prior to and during exercise at 15 minute intervals. The dose of CHO (17.1 ml/kg body mass; 1 g CHO/kg) was based on data from previous research (17). During exercise and for 2 hours post-exercise expired air was collected to determine fat and CHO oxidation rates. Each subject participated in each condition with the conditions randomly assigned in a counterbalanced design. All testing sessions were performed during the same time of day and with each session separated by at least 48 h. Treatment sessions were performed between days 3-11 of the subject’s menstrual cycle as determined by calendar day estimation (31).

Body Composition and Exercise Testing. Subjects reported to the laboratory for preliminary testing following a 2 hour fast and a 24 h period of no exercise. Height was determined using a stadiometer and body mass was measured using a calibrated electronic scale. Percent body fat (%fat) was assessed using air displacement plethysmography (Bod Pod) according to the manufacturer’s instructions. Fat free mass (FFM) and fat mass (FM) were calculated from the %fat and body mass data. Waist circumference was measured at the level of the umbilicus and thigh circumference was measured at the gluteal fold using a Gulick II tape measure. These data were then used to calculate 24 h energy expenditure (24 h-EE) using the equation of Weyer et. al. (34).

VO₂\text{max} was determined using a graded exercise test (GXT) on a treadmill ergometer. The initial exercise intensity was set at a level that subjects could easily accomplish and then the
speed and/or grade were increased every 2 minutes until the subjects reached volitional exhaustion. Heart rate was recorded during each stage of testing with a Polar heart rate monitor. Expired air was measured for oxygen and carbon dioxide concentrations at 1 min intervals using a Parvomedics TrueOne 2400 metabolic measurement cart. The system was calibrated before each test according to the specifications of the manufacturer. A test was considered maximal if any three of the four following criteria were achieved: a plateau in oxygen consumption ($< 2.0 \text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) with an increase in exercise intensity, a respiratory exchange ratio (RER) $\geq 1.10$, a maximal heart rate within $\pm 10$ beats per minute of age-predicted maximum, and the subject reached exhaustion as determined by a rating of perceived exertion (RPE) $> 18$ (22). VO$_2$max was considered as the highest observed value of oxygen consumption during the GXT. Due to differences in body weight and %fat between the HF and LF groups, VO$_2$max was expressed as ml/kg FFM/min.

**Dietary Control.** Studies have shown that muscle glycogen availability may affect substrate oxidation and the respiratory exchange ratio (8). We used two procedures in an attempt to ensure similar muscle glycogen levels prior to exercise. First, subjects were asked to record their food and fluid intake for the 3 days prior to each treatment session and to maintain a similar food and fluid intake before each treatment session to ensure a consistent diet, both in terms of energy content and macronutrient intake. We have shown this procedure to be a valid method for producing similar muscle glycogen levels prior to exercise (20). Prior to beginning the recording of food intake subjects were shown food samples and given detailed instructions for recording the diet diary. Dietary analyses were performed using commercially available software (Food Processor, version 11.0, EHSA Research, Salem, OR). Second, 2 hours prior to each treatment sessions, the subjects consumed a pre-testing snack consisting of a commercially available...
granola bar (Chocolate Chip Clif Bar, 69% CHO, 17% fat, 14% protein) equal to 25% of their calculated 24 h-EE (34).

Treatment sessions. Upon reporting to the laboratory, each subject underwent the same experimental conditions. Subjects were asked to void and then were measured for body mass in shorts and t-shirt. The volume of fluid to be consumed (either CHO or PLC) was calculated, measured, and divided into 4 separate containers. The subject then consumed the initial fluid volume of beverage and was connected to the metabolic cart. After 5 minutes of rest, the subject began 45 min of treadmill exercise at 55% of her measured VO\textsubscript{2}max. At 15 minute intervals during exercise, the treadmill was stopped and data collection on the metabolic cart was paused while the subject consumed the beverage. Subjects were given 1 minute to consume the fluid. The subject resumed treadmill exercise, and data collection by the metabolic cart was resumed after 1 minute of exercise. Following the completion of exercise, data collection was paused, and the subject consumed the remaining fluid volume and was given a 5 minute bathroom break. Data collection on the metabolic cart was resumed, and the subject rested in a lounge chair keeping movement to a minimum. After 1 hour, data collection on the metabolic cart was paused, the subject was given another 5 minute bathroom break, and then she rested in the lounge chair for the final hour while data were collected. Figure 1 illustrates the treatment session timeline.

During the exercise and post-exercise periods expired gases were collected using a Parvomedics TrueOne 2400 metabolic measurement cart. The system was calibrated before each test according to the specifications of the manufacturer. After completion of the testing session the oxidation rates were calculated for CHO (CHO-OX) and fat (FAT-OX) using the Table of nonprotein respiratory quotient (28). Substrate oxidation rates were normalized to FFM to
account for body mass differences between individuals and because FFM is the tissue most responsible for the oxidation of carbohydrates and fats. Substrate oxidation rates (g/kg FFM/min) and the percent of total energy from CHO and fat were calculated for the following time periods of exercise, 1st h post-exercise, and 2nd h post-exercise.

**Statistical analyses.** Means and standard deviations were calculated for all dependent variables. Unpaired t-tests were performed on the physical characteristics to identify differences between the groups. A group (LF, HF) x treatment (CHO, PLC) analysis of variance (ANOVA) was performed on energy and macronutrient intake. A group (LF, HF) x treatment (CHO, PLC) x time (exercise, 1st h post-exercise, 2nd h post-exercise) ANOVA with repeated measures on time was performed on the dependent variables associated with substrate oxidation. Statistical significance was set as p < 0.05.

**Results**

**Subject Characteristics.** The physical characteristics of each group are listed in Table 1. Subjects were young, healthy, physically active females. There were no significant differences between the groups for age, height, weight, FFM, and VO2 max (in either L/min or ml/kg FFM/min). A significant difference between groups was observed for %fat and FM, with the HF group having a higher %fat and higher total FM (p<0.05).

**Nutritional intake.** Analysis of the food intake records showed that the subjects consumed similar amounts of carbohydrate, fat, and protein before each treatment session with no significant differences between groups or between treatment conditions. Those data are not reported.

**Exercise substrate oxidation.** There were no significant differences in oxygen consumption during exercise between the groups for either the CHO trial (LF, 1.58 ± 0.32 vs. HF 1.45 ± 0.34
L/min) or the PLC trial (1.59 ± 0.31 vs. HF 1.44 ± 0.33 L/min). Figure 2A illustrates the substrate oxidation rates during exercise. CHO-OX rates (mg/kg FFM/min) were significantly higher in the LF group compared to the HF group for both the CHO and PLC trials. There was a significant difference between the CHO and PLC trials for the HF group with a 13.3% increase in CHO-OX during the CHO trial compared to the PLC trial. While there were no statistically significant differences in FAT-OX between groups or within treatments, it is worth pointing out that fat oxidation showed a reciprocal relationship to CHO-OX and was higher in the HF group compared to the LF group for both the CHO and PLC trials. The percentage of total energy derived from CHO-OX and FAT-OX during exercise is shown in Figure 2B. The LF group derived a higher percentage of total energy expenditure from CHO oxidation during both trials (CHO, PLC) compared to the HF group. Conversely, the HF group derived a higher percentage of total energy from FAT oxidation compared to the LF group. For both groups, the CHO trial resulted in a higher percentage of total energy from CHO-OX, while the PLC trial resulted in a higher percentage of total energy from FAT-OX.

Post-exercise substrate oxidation. Figure 3A illustrates the substrate oxidation rates during the 1st h of recovery after exercise. There were no significant differences between the LF and HF groups for CHO-OX in either the CHO or PLC trial. CHO-OX rates were significantly higher in both groups for the CHO trial compared to the PLC trial. Conversely, FAT-OX rates were significantly higher in the PLC trial compared to the CHO trial for both the HF and LF groups. The percentage of total energy derived from CHO and FAT oxidation during the 1st hour of recovery is shown in Figure 3B. The LF group derived a higher percentage of total energy expenditure from CHO oxidation during both trials (CHO, PLC) compared to the HF women. Conversely, the HF group derived a higher percentage of total energy from FAT oxidation
compared to the LF group. For both groups, the CHO trial resulted in a higher percentage of total energy from CHO-OX, while the PLC trial resulted in a higher percentage of total energy from FAT-OX.

Figure 4A illustrates the substrate oxidation rates during the 2nd h of recovery after exercise. There were no significant differences between the LF and HF groups for CHO-OX in either the CHO or PLC trial. CHO-OX rates were significantly higher (35.9%) in the HF group during the CHO trial compared to the PLC trial. Conversely, FAT-OX rates were significantly higher in the PLC trial compared to the CHO trial for both the LF and HF groups. The percentage of total energy derived from CHO and FAT oxidation during the 2nd hour of recovery is shown in Figure 4B. There were no significant differences between the LF and HF groups for the percentage of energy derived from CHO-OX or FAT-OX for either the CHO or PLC trial. For the HF group there was a significant difference between the trials with more energy derived from CHO-OX during the CHO trial.

Table 2 illustrates the within trial differences for CHO-OX and FAT-OX for both the LF and HF groups. During the CHO trial CHO-OX and FAT-OX rates were significantly higher for both LF and HF groups during exercise compared to the 1st hour and 2nd hour of recovery. The percentage of CHO-OX was highest and the percentage of FAT-OX was lowest during the 1st hour of recovery compared to exercise and the 2nd hour of recovery. During the PLC trial CHO-OX and FAT-OX rates were significantly higher for both LF and HF groups during exercise compared to the 1st hour and 2nd hour of recovery. The percentage of CHO-OX and FAT-OX was not significantly different for the LF group across the exercise, 1st hour of recovery and 2nd hour of recovery. For the HF group the percentage of CHO-OX was highest and the percentage of FAT-OX was lowest during exercise compared to the 1st hour and the 2nd hour of recovery.
Discussion

It is well-established that carbohydrate ingestion prior to and during exercise alters substrate oxidation so there is an increase in carbohydrate oxidation and a decrease in fat oxidation when compared to fasting or placebo conditions. This change occurs during low intensity (2; 21) and moderate intensity (5; 6) exercise and can last for several hours following a meal (26). The proposed mechanisms behind these changes include an increase in glucose uptake by active skeletal muscle and an inhibition of lipolysis from adipose tissue which reduces fat oxidation (21). For example, Coyle et al demonstrated that glucose ingestion prior to exercise caused a hyperinsulinemia and elevated blood glucose levels that resulted in a 36% reduction in the plasma free fatty acid appearance that was accompanied by a 34% reduction in fat oxidation (9).

It has also been demonstrated that individuals with excess body weight and body fat have altered substrate utilization (4) however the various factors creating the alteration are not completely understood. For example, Schutz et al demonstrated in a study of 106 obese women that subjects in the upper half of the subject pool (i.e. highest body fat levels) had a significantly lower respiratory quotient and significantly high level of fat oxidation compared to subjects in the lower half of the subject pool (i.e. lower body fat levels) (29). Furthermore, Schutz et al demonstrated that a reduction of body weight, percent body fat, and fat mass in the prospective component of the study resulted in a higher overall respiratory quotient and a significantly lower level of fat oxidation (29). Additionally, Astrup et al. found that women who were classified as obese (BMI > 30 kg/m²) had a higher 24 hour fat oxidation rate than women who were classified as normal weight (BMI < 25 kg/m²) (3). The researchers proposed that the higher amount of fat availability in the abdomen in the obese women contributed to the higher fat oxidation rate.
Conversely, other investigations have demonstrated a reduction in fat oxidation within individuals who are obese (23; 24), experienced weight loss (23), and with Type 2 diabetes (30). The potential interactions between carbohydrate ingestion and altered substrate oxidation within individuals with excess body fat led us to conduct this experiment with our primary intent to examine substrate oxidation in response to consumption of a carbohydrate beverage prior to and during exercise in women with low and high levels of body fat.

*Exercise Substrate Oxidation.* As expected consumption of a carbohydrate beverage resulted in an increase in CHO-OX during exercise in both the LF and HF women when compared to placebo ingestion. We also found that the LF women had a higher CHO-OX compared to the HF women despite both groups performing exercise at the same relative exercise intensity (55% VO$_2$ max) during the CHO and PLC trials. The increased rate of CHO-OX and reduced rate of FAT-OX observed during the CHO trial is likely due to the increased availability of glucose from the CHO solution for uptake by skeletal muscle and the suppressive effects of insulin on lipolysis in adipose tissue (21). Even small increases in insulin concentration can have a significant suppressant effect on lipolysis. Insulin concentration has been shown to increase during low and moderate intensity exercise to a level that will reduce lipolysis and impair fat oxidation (21).

The difference in CHO-OX between the two groups for both the CHO and PLC trial has several possible explanations. First, the lower CHO-OX observed in the HF group could be due to the development of insulin insensitivity in the women with higher levels of body weight and body fat and elevations in abdominal fat levels. For example, Erdmann (11) demonstrated that insulin resistance develops during weight gain within the normal weight range. Additionally, it has been demonstrated that higher levels of waist circumference are related to the development
of insulin resistance. In the current study, the HF group had significantly higher body mass and waist circumference than the LF group. This could indicate the onset of the development of insulin resistance in this group and a reduction in CHO-OX. Second, the possibility exists that the HF group has a greater supply of fatty acids available for oxidation and this in turn results in a higher rate of fat oxidation. This is supported by work from Schutz et al. (29) and Astrup et al. (3) who have demonstrated higher rates of fat oxidation in obese individuals compared to less obese and normal weight individuals, respectively.

*Recovery substrate oxidation.* Post-exercise metabolism can be significantly affected by the exercise duration and intensity (33) as well as any nutrition strategy employed prior to and during exercise (19). The data from the current investigation illustrate the effect that consumption of a carbohydrate beverage during exercise can last well into the post-exercise recovery period. Figures 3 and 4 illustrate that the consumption of carbohydrate beverage will result in a higher carbohydrate oxidation and lower fat oxidation compared to a placebo in both the LF and HF groups. While we can only speculate on the mechanisms responsible for these responses it is likely that the higher blood glucose and insulin levels likely experienced following carbohydrate ingestion played a role in promoting a higher CHO-OX and lower FAT-OX (26). As the post-exercise period progressed from the 1<sup>st</sup> hour of recovery to the 2<sup>nd</sup> hour of recovery there was a reduction in CHO-OX and an increase in FAT-OX during the carbohydrate trial. This response was likely due to a removal of excess glucose from the blood in an effort to return levels to normal values. Both the CHO-OX and the FAT-OX responses were similar for the HF and LF groups suggesting that the level of body fat has a reduced influence on substrate oxidation in the post-exercise period.
Some possible limitations to the current study include the following. First, not all subjects in the high fat group were at the same level of body fat and obesity. This could confound the data by having subjects who were at different levels of insulin sensitivity, which in turn could affect the interaction of carbohydrate and fat oxidation. We also did not collect blood measures of glucose, FFA, or hormone levels. The use of the information from these measures could assist in the elucidation of the physiological mechanisms that contributed to the observed results.

In conclusion, elevated levels of body fat play a significant role in substrate oxidation during moderate intensity exercise both with and without CHO supplementation. This has important implications for the development of targeted exercise and nutritional strategies for individuals who are overweight or obese. Individuals desiring to lose body weight or body fat should be advised to not consume a carbohydrate beverage prior to or during exercise as this will decrease the amount and percentage of fat oxidized during and after exercise. This may then ultimately influence the amount of weight or fat loss during an exercise program.
**Figure 1** Treatment session timeline.
Figure 2A Substrate oxidation rates during exercise for the LF (n=8) and HF (n=9) groups during the CHO and PLC trials.
Figure 2B Percentage of total energy during exercise for the LF and HF groups during the CHO and PLC trials.
Figure 3A Substrate oxidation rates during the 1st h of recovery after exercise for the LF (n=8) and HF (n=9) groups during the CHO and PLC trials.
Figure 3B Percentage of total energy during the 1st hour of recovery after exercise for the LF and HF groups during the CHO and PLC trials.
Figure 4A Substrate oxidation rates during the 2$^{nd}$ h of recovery after exercise for the LF (n=8) and HF (n=9) groups during the CHO and PLC trials.
Figure 4B Percentage of total energy during the 2nd hour of recovery after exercise for the LF and HF groups during the CHO and PLC trials.
Table 1. Physical characteristics of the low fat (LF) and high fat (HF) women.

<table>
<thead>
<tr>
<th>Variable</th>
<th>LF (n=8)</th>
<th>HF (n=9)</th>
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</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>21.4 ± 2.6</td>
<td>21.4 ± 2.3</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>171 ± 9.4</td>
<td>165 ± 10</td>
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<tr>
<td>Weight (kg)</td>
<td>63.4 ± 9.1</td>
<td>71.6 ± 14</td>
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<tr>
<td>% fat</td>
<td>20.0 ± 3.0</td>
<td>32.4 ± 5.6*</td>
</tr>
<tr>
<td>Fat free mass (kg)</td>
<td>50.7 ± 7.3</td>
<td>48.0 ± 7.8</td>
</tr>
<tr>
<td>Fat mass (kg)</td>
<td>12.7 ± 3.0</td>
<td>23.8 ± 8.3*</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>74.3±4.6</td>
<td>85.3±11.4*</td>
</tr>
<tr>
<td>Thigh circumference (cm)</td>
<td>57.7±4.4</td>
<td>63.1±7.1</td>
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<tr>
<td>VO$_2$max (L/min)</td>
<td>2.9 ± 0.5</td>
<td>2.6 ± 0.7</td>
</tr>
<tr>
<td>VO$_2$max (ml/kg FFM/min)</td>
<td>57.8 ± 6.3</td>
<td>53.6 ± 8.2</td>
</tr>
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</table>

* = significant difference between groups (p<0.05)

Table 2. Substrate oxidation during and after exercise in low fat (LF, n=8) or high fat (HF, n=9) women consuming a carbohydrate drink (CHO) or placebo (PLC) immediately prior to and during exercise.

<table>
<thead>
<tr>
<th>CHO Trial</th>
<th>Exercise</th>
<th>1st hour post-exercise</th>
<th>2nd hour post-exercise</th>
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<tbody>
<tr>
<td></td>
<td>LF</td>
<td>HF</td>
<td>LF</td>
</tr>
<tr>
<td>CHO-OX</td>
<td>35.5±4.7$^a$</td>
<td>29.8±3.7$^a$</td>
<td>9.34±2.1$^b$</td>
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<tr>
<td>FAT-OX</td>
<td>2.5±1.3$^a$</td>
<td>3.7±1.5$^a$</td>
<td>0.6±0.5$^b$</td>
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<tr>
<td>CHO-OX %</td>
<td>83.1±8.6$^{ab}$</td>
<td>73.8±9.0$^{ab}$</td>
<td>91.8±10.6$^b$</td>
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<tr>
<td>FAT-OX %</td>
<td>16.9±8.6$^{ab}$</td>
<td>26.2±8.9$^{ab}$</td>
<td>8.2±10.6$^b$</td>
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</table>

CHO Trial

<table>
<thead>
<tr>
<th>PLC Trial</th>
<th>Exercise</th>
<th>1st hour post-exercise</th>
<th>2nd hour post-exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LF</td>
<td>HF</td>
<td>LF</td>
</tr>
<tr>
<td>CHO-OX</td>
<td>33.7±6.5$^a$</td>
<td>26.4±4.3$^a$</td>
<td>5.4±2.4$^b$</td>
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<tr>
<td>FAT-OX</td>
<td>3.4±1.42$^a$</td>
<td>4.5±1.3$^a$</td>
<td>1.0±0.6$^b$</td>
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<tr>
<td>CHO-OX %</td>
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<td>FAT-OX %</td>
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<td>33.1±8.6$^a$</td>
<td>36.3±22.1$^a$</td>
</tr>
</tbody>
</table>

Significant differences within trials (p<0.05). Means with the same superscript are not significantly different. CHO-OX is the carbohydrate oxidation rate in mg/kg fat free mass/min. FAT-OX is the fat oxidation rate in mg/kg fat free mass/min. CHO-OX % and FAT-OX % is the percentage of total energy that is derived from carbohydrate and fat oxidation respectively.
Reference List


