The Effect of Glycemic Indices and Timing of Meal on Exercise to Fatigue

Gyorkos
THE EFFECT OF GLYCEMIC INDICES AND TIMING OF MEAL ON EXERCISE TO FATIGUE

by

Amy Morrison Gyorkos

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
requirements for the
Degree of Master of Arts
Department of Health, Physical Education, and Recreation

Western Michigan University
Kalamazoo, Michigan
August 2005
ACKNOWLEDGEMENTS

I would like to begin by thanking my professors and colleagues that I have encountered throughout my graduate degree for all the support they have contributed, which resulted in the completion of my thesis. I am grateful to Dr. Cheatham for his willingness and patience to fix all the lab equipment, which prevented any major disruptions throughout the study. I am also appreciative to Dr. Ricard for his encouragement and backing to not stop short of researching a topic that truly took my interest. I give special thanks to Dr. Michael for his direction, support, and constructive feedback that helped this vague idea turn into a valid project.

Lastly, I would like to acknowledge the people that have helped me through all the projects in my life. I give thanks to my parents for giving me constant support, love, and encouragement through every twist and turn in my life. My brother Brian for his wisdom to help me think critically about a topic and his never ending support for whatever crazy idea his sister comes up with. I also give special thanks to my husband Andrew for being there to make me smile at the end of every endless day. Their support has kept me grounded through the latest of nights and longest of days.

Amy Morrison Gyorkos
THE EFFECT OF GLYCEMIC INDICES AND TIMING OF MEAL ON EXERCISE TO FATIGUE

Amy Morrison Gyorkos, M.A.
Western Michigan University, 2005

The purpose of this study was to investigate and describe the influence of pre-carbohydrate feedings prior to exercise to fatigue. Five individuals performed a peak bike test and four experimental trials, separated by 7 days. Upon arrival, subjects ingested 1g of carbohydrates (CHO) for every kilogram of body weight (BW) of a high glycemic index meal (HGI) or a low glycemic index meal (LGI) prior to exercise to fatigue. Subjects waited 30- or 60-minutes following each test meal, totaling four experimental trials. The exercise regiment was consistent following each meal; 90 minutes cycling at 70% peak oxygen consumption ($V_{O_2}$peak) followed by an all-out sprint until fatigue. The subjects for the 60 minute trial had blood draws taken at -30-, 0-, +10-, +30-, +60-, +90-min, and fatigue. One less blood sample was taken from the subjects waiting 30 minutes (0-, +10-, +30-, +60-, +90-min, and fatigue). Heart rate was taken at rest, every 10 minutes of exercise, and at fatigue. $V_{O_2}$ and respiratory exchange ratio (RER) measurements were taken for the first 30 minutes of exercise and at 10 minutes surrounding each blood draw. No significant statistical differences were found for any of the variables between trials, including blood glucose, blood lactate, ratings of perceived exertion (RPE), RER, $V_{O_2}$, and performance time. In conclusion, the pre-exercise meals used in this study consumed prior to exercise (-30-, -60-min) to fatigue does not increase time to fatigue.
# TABLE OF CONTENTS

ACKNOWLEDGMENTS ........................................................................................................ ii

LIST OF TABLES ............................................................................................................. v

LIST OF FIGURES ......................................................................................................... vi

INTRODUCTION ............................................................................................................. 1

METHODS ..................................................................................................................... 5

Subjects ...................................................................................................................... 5

Measurement of Peak Oxygen Consumption ($VO_{2\text{peak}}$)........................................ 5

Experimental Trial ..................................................................................................... 6

Pre-Exercise Conditions .......................................................................................... 7

Pre-Exercise Feedings ............................................................................................... 7

Blood Analyses ......................................................................................................... 8

Measurements ........................................................................................................... 8

Statistics .................................................................................................................... 9

RESULTS ..................................................................................................................... 9

Heart Rate and RPE .................................................................................................... 9

$VO_{2}$ and RER ........................................................................................................... 11

Blood Lactate and Blood Glucose ............................................................................. 12

Exercise Performance .............................................................................................. 13

DISCUSSION ................................................................................................................ 14
LIST OF TABLES

1. Descriptive characteristics of the subjects.............................. 5
LIST OF FIGURES

1. Heart Rate levels .......................................................................................... 10
2. Rate of Perceived Exertion (RPE) levels ..................................................... 10
3. VO₂ levels .................................................................................................... 11
4. Respiratory Exchange Ratio (RER) levels .................................................. 12
5. Blood Lactate levels ..................................................................................... 13
6. Blood Glucose levels ................................................................................... 13
7. Performance time ......................................................................................... 14
8. Blood Glucose levels for H60 and L60 ........................................................ 16
INTRODUCTION

The primary fuel source used for the working muscles during exercise depends highly on the intensity of exercise. At rest, approximately 60% of the energy is from lipid oxidation and the remainder is from carbohydrate (CHO) oxidation (approximately 35%). During submaximal exercise, 65-80% peak oxygen consumption (VO$_{2peak}$), fat oxidation only accounts for 10-45% of the energy expended and the remaining energy is taken from carbohydrates (Askew, 1984). Furthermore, during prolonged exercise, glycogen oxidation is even more of an essential fuel source for prolonging the time to fatigue. Therefore, during prolonged exercise, fatigue is associated with intramuscular glycogen depletion and hypoglycemia.

Carbohydrate pre-exercise ingestion has been found to increase time to fatigue due to a variety of factors such as; improving metabolic energy supply, maintaining blood glucose concentration (McConnell et al., 1999), preventing hypoglycemia (Schabort et al., 1999), increasing the rate of CHO oxidation (Sherman et al., 1991), reducing the rate of muscle glycogen utilization (Sherman et al., 1989; Hawley et al., 1992), contributing to hepatic energy reserves (Neuffer et al., 1987), and maintaining the concentration and availability of blood glucose (Bosch et al., 1993; Sherman et al., 1989). Bosch et al., (1993) found that during a cycle test of 180-minutes at 70% VO$_{2peak}$, all the subjects that ingested carbohydrates prior to exercise finished the 180-minute trial compared to only 50% finishing the trial in the group that did not pre-exercise carbohydrate load.

In addition to exploring pre-exercise carbohydrate ingestion on time to fatigue,
some researchers have gone further in exploring what types of carbohydrates are most beneficial for performance enhancement.

The glycemic index (GI) was introduced by Jenkins and his colleagues (Frail and Buke, 1994) as a measure of the blood glucose responses to CHO foods on the basis of the nature of the starch and saccharides, any cooking or processing of the food, and the physical form of the food (Burke et al., 1993; Wolever, 1990). The GI of food is determined using human subjects. A pre-determined amount of a given food is consumed by the subject after an overnight fast and several blood samples are taken at given time periods. The blood samples are then analyze to determine the foods GI value based on a 1-100 scale, with white bread rating 100.

Carbohydrates are broken down into glucose and released into the bloodstream, the faster the glucose enters the blood determines the subsequent insulin response (Moseldy et al, 2003). When a rapid amount of glucose is released into the blood, as in the case of high GI foods, insulin is released in large quantities to stimulate the cell’s uptake of glucose, amino acids, and fats. Rebound hypoglycemia is defined as when the glucose concentrations fall below 3.5 mmol·L⁻¹ (Decombaz, 1985), this is due to the insulin surge. Rebound hypoglycemia reduces the energy potential and therefore diminishes performance. In addition, foods that are labeled as high GI foods are digested and absorbed faster than foods that are labeled as low GI foods.

Many researchers have studied the effects of various GI levels before exercise and have produced contrasting results. Improvements in performance have been found when foods that have low GI levels are consumed prior to
exercise compared to foods that have high GI levels (Kirwan et al., 1998; DeMarco et al., 1999; Frail and Buke, 1994). Thomas et al. (1991) compared the exercise response after the ingestion of a low GI food (lentils), a high GI food (potatoes), and glucose and water one hour prior to exercising at 65-70% VO\textsubscript{2peak} until exhaustion. The group that ingested the low GI food showed statistically significant endurance time improvements of 20 minutes, along with less post-prandial hyperglycemia and hyperinsulinemia, and higher levels of plasma glucose and free fatty acids (FFA) during critical periods of exercise than the high GI group (Thomas et al., 1991). While these researchers claim that pre-exercise consumption of low GI foods improve performance (Kirwan et al., 1998; DeMarco et al., 1999; Thomas et al., 1991), many other researchers have shown contrary results indicating no statistically significant improvements (Wee et al., 1999; Febbraio and Stewart, 1996; Stannard et al., 2000; Sparks et al., 1998). These large discrepancies in the outcomes of the studies when using similar subject demographics may be due to variations in the methods used, such as; exercise intensity, meal composition, specific metabolic responses to the meals, exercise protocol, and timing of pre-exercise food ingestion.

In the previously mentioned studies, the timing of the pre-exercise food ingestions were given at 30 minutes (DeMarco et al., 1999), 45 minutes (Kirwan et al., 1998; Febbraio and Stewart, 1996; Sparks et al., 1998), 1 hour (Thomas et al., 1991), 65 minutes (Stannard et al., 2000), and 3 hours (Wee et al., 1999) prior to exercise. These differences may play a key role in the contradicting findings concerning exercise performance. Few researchers have evaluated time of
carbohydrate feedings prior to exercise (Moseldy et al., 2003). Hawley and Burke (1997) identified two metabolically significant stages of pre-exercise ingestion of carbohydrate: 2-4 hours and 30-60 minutes. The 2-4 hours are essential in the replenishing of muscle glycogen and hepatic stores that have been depleted from previous activity. Ingesting carbohydrates 4 hours before exercise has been shown to increase CHO oxidation (Coyle et al., 1985; Neuffer et al., 1987; Sherman et al., 1989). Flynn et al. (1989) observed no differences of substrate use and performance when increasing pre-exercise CHO ingestion time from 4 hours to 8 hours pre-exercise. The 30-60 minute stage prior to exercise is important in adding to the carbohydrate stores during prolonged exercise. In reviewing the literature, only one published study has examined the 30-60 minute pre-exercise carbohydrate ingestion on exercise performance (Moseley et al., 2003). Moseley et al., (2003) studied eight subjects in three trials ingesting carbohydrates 15-min, 45-min, and 75-min before starting exercise. The investigators concluded that there were no statistically significant improvements in performance when comparing the three different timings of ingestion prior to exercise. The subjects in this study consumed a drink containing 75g glucose, which would be considered a high GI food.

The aim of this study was to determine the effectiveness of consuming high and low GI foods at two time periods (-30,-60 min) prior to exercise. This study involved subjects participating in four experimental trials; consuming high and low glycemic foods at 30- and 60-minutes prior to exercise.
METHODS

Subjects

Five recreationally active men and women of college age volunteered to participate in the study approved by the Human Subject Institutional Review Board at Western Michigan University. Subject characteristics are listed in Table 1. Subjects provided their informed consent and completed a medical history questionnaire, a physical activity readiness questionnaire, and an inclusion/exclusion questionnaire to rule out any contraindications to participation. Subjects had to meet the following requirements; be between the ages of 18 and 35, exercise a minimum of 3 times a week, free of medication and/or complications with blood sugar, insulin, and blood clotting, free of pain when stretching, walking, or exercising, a BMI of <30, and a willingness to participate in blood collection and participation in four experimental trials.

<table>
<thead>
<tr>
<th>TABLE 1. Descriptive characteristics of the subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
</tr>
<tr>
<td>Body Weight (kg)</td>
</tr>
<tr>
<td>VO\textsubscript{2peak} (mL/kg\textsuperscript{-1}min\textsuperscript{-1})</td>
</tr>
<tr>
<td>BMI</td>
</tr>
<tr>
<td>20.6 ± 2.1</td>
</tr>
<tr>
<td>61.6 ± 3.1</td>
</tr>
<tr>
<td>43.4 ± 2.0</td>
</tr>
<tr>
<td>22.2 ± 1.2</td>
</tr>
</tbody>
</table>

Values are presented as mean ± SE (N=5)

Measurement of peak oxygen consumption (VO\textsubscript{2peak})

All subjects were asked to perform a peak bike test to determine their VO\textsubscript{2peak} and their tolerance to exercise. A Bosch cycle ergometer (model 551, Bosch, Berlin, Germany), was used for the peak bike test. The exercise test
protocol consisted of a 2-min warm-up stage at a light intensity (60 watts) after which exercise intensity was increased 20 watts every minute. The exercise test continued until the participant reached volitional fatigue or was unable to maintain a pedaling frequency of 50 revolutions per minute (RPM). \( \text{VO}_{2\text{peak}} \) was established when two of the following three conditions were observed; 1) a leveling off of \( \text{VO}_2 \) with increasing workload, 2) a heart rate within 10 beats\( \cdot \text{min}^{-1} \) of predicted maximum, and 3) a respiratory exchange ratio (RER) \( \geq 1.1 \). Exercise \( \text{O}_2 \) consumption, \( \text{CO}_2 \) production, and RER were determined by indirect calorimetry using a (Vmax 229, Sensor Medics, Yorba Linda, CA) metabolic measuring cart. All measurements were calculated breath-by-breath and averaged for 30 seconds. The subject’s heart rate and RPE were taken every minute and blood pressure was taken every three minutes of exercise. The results of the peak bike test were used to determine 70\% \( \text{VO}_{2\text{peak}} \) for subsequent experimental trials.

**Experimental Trial**

Subjects were asked to perform four experimental trials that were separated by 7 days. The subjects were asked to consume a carbohydrate meal, wait for a given amount of time (30- or 60-min) and then cycle at 70\% \( \text{VO}_{2\text{peak}} \) as calculated using ACSM Metabolic Equation (ACSM, 2000) for 90 minutes, followed by an all-out sprint until fatigued. Fatigue was defined as when the subject could not pedal any longer, needed to be prompted to cycle over 100 rpm three times or more, or if the subject experienced nausea or became lightheaded. All experimental trials were performed on the same Bosch cycle ergometer used for the peak bike testing.
Pre-Exercise Conditions

Subjects were instructed to avoid exercise or strenuous physical activity the day of and day before the tests and to get an adequate amount of sleep (6 to 8 hours) the night before each test. The subjects were also advised to drink plenty of water over the 24-h period preceding the test to ensure normal hydration and to avoid tobacco, alcohol, and caffeine for at least 24 hours prior to testing. Subjects were instructed to follow the food guide pyramid for two days prior to each testing in order to ensure proper energy consumption and testing consistency. The subjects recorded all foods and beverages consumed two days prior to each trial. Preceding each experimental test, subjects completed a yes/no worksheet to reveal if the above instructions were followed.

Pre-Exercise Feedings

The subjects arrived at the laboratory after a 12 hour fast and consumed either a high glycemic meal (HGI) or low glycemic meal (LGI) that was assigned in random order in accordance with the balanced Latin square for four treatment levels. The high glycemic meal consisted of Kellogg’s Cornflakes (GI: 81) and the low glycemic meal consisted of Kellogg’s All Bran (GI:42). Both meals provided 1.0gCHO/kgBW of carbohydrates and were consumed 30- and 60-minutes prior to exercise. Meals were supplemented with water to keep every meal volume composition at 1 Liter. Subjects were not blinded to the meals that they consumed, but were blinded to performance time during exercise and any hypothesized outcomes.
Blood Analyses

Approximately 1mL of blood was obtained from the subject for each trial. A total of eight blood draws were obtained for the subjects ingesting food 60 minutes prior to exercise (Baseline, -30-, 0-, +5-, +30-, +60-, +90-min, Fatigue). One less sample was taken for the subjects ingesting food 30 minutes prior to exercise (Baseline, 0-, +5-, +30-, +60-, +90-min, Fatigue).

A spring-loaded lancet device was used to puncture the fingertip quickly and a capillary tube containing heparin, fluoride, and nitrite was used for blood collection. A pipette was then used to transfer the blood from the pipette into the Analox Micro-Stat (model GM7/P-GM7, London, UK) to measure blood glucose and blood lactate levels. In the Analox Micro-Stat; Beta-D glucose reacts with oxygen in the presence of glucose oxidase to produce gluconic acid and hydrogen peroxide. The maximum rate of oxygen uptake is directly proportional to the amount of glucose in the sample. For blood lactate measurements, in the Analox Micro-Stat the L-lactate oxygen oxidoreductase (LOD) is highly specific for L-lactate, reacting with neither D-lactate nor pyruvate and is catalase free. Under appropriate conditions the maximum rate of oxygen consumption is directly related to lactate concentration. Blood glucose was analyzed immediately and blood lactate samples were put on ice for analysis immediately following the completion of the experimental trial.

Measurements

The RPE was recorded every 10 minutes, according to Borg’s 6-20 point category scale. Heart rates were continuously monitored using a Cardiosport
heart rate monitor to ensure that steady state heart rate (Healthcare Technology Ltd., Taiwan, China) was achieved. Exercise VO\textsubscript{2}, CO\textsubscript{2}, and RER were determined by indirect calorimetry using a Vmax 229 Sensor Medics metabolic measuring cart. All measurements were calculated breath-by-breath and averaged for 30 seconds. Measurements were taken for the first 30 minutes of exercise and for 5 minutes surrounding each blood draw.

**Statistics**

Data on the blood measurements and heart rate were analyzed using a three-way ANOVA with repeated measures. The three factors measured were feeding time (T-30min & T-60min), exercise time (-60-, -30-, 0-, +10-, +30-, +60-, +90-min, and fatigue), and carbohydrate feedings (high and low glycemic foods). The level of statistical significance was established *a priori* as P≤0.05. The SPSS statistical package (v12) was used for data analysis.

**RESULTS**

**Heart Rate and RPE**

Heart rate and RPE increased over exercise as expected (Fig.1). Heart rate increased the greatest over the first 10 minutes of exercise. Mean heart rate for the L60 trial remained higher than any other group, although there were no statistically significant differences among any of the four trials. There were no statistically significant differences between the RPE for any of the four trials.
Fig. 1. Heart Rate (means ± SE) levels at rest, during 90 minutes at 70% VO$_{2peak}$, and at a sprint until fatigue. No statistically significant differences among trials.

Fig. 2. Rate of Perceived Exertion (RPE) (means ± SE) levels at rest, during 90 minutes at 70% VO$_{2peak}$, and at a sprint until fatigue. RPE was assessed using Borg’s 6-20 category scale. No statistically significant differences among trials.
VO₂ and RER

VO₂ increased slightly throughout exercise and showed no statistically significant difference among trials (Fig. 2). The H30 and H60 trials showed an initial drop in oxygen consumption during the first 30 minutes. H30 trial increased at 30 minutes, passing all of the other three trials after 60 minutes until fatigue. There were no statistically significant differences among trials for the respiratory exchange ratio (RER). All trials, with the exception of H30 trial, declined from time 0 to 90 minutes (Fig. 3). H30 trial showed an initial drop, but began to increase thirty minutes into exercise until fatigue.

![Graph showing VO₂ and respiratory exchange ratio (RER) levels at 10-, 30-, 60-, 90-min, fatigue.](image)

Fig. 3. VO₂ (means ± SE) levels at 10-, 30-, 60-, 90-min, fatigue. No statistically significant differences among trials.
Blood Lactate and Blood Glucose

Blood lactate levels were not statistically different between any of the four trials (Fig. 5). The H60 trial showed the biggest elevation in blood lactate during the initial 10 minutes of exercise and also illustrated the greatest drop in blood lactate concentration from 10- to 60-minutes of exercise. All trials were similar at exhaustion. Blood glucose levels for the four trials can be seen in figure 6. The H30 trial showed levels above the other three trials from post-meal to fatigue. The L60 trial was the only trial that increased blood glucose from the post meal (4.4 ± 0.3) to fatigue (4.5 ± 0.6).
Fig. 5. Blood Lactate (means ± SE) levels measured at rest, 10-, 30-, 60-, 90-min, and fatigue. No statistically significant differences among trials.

Fig. 6. Blood Glucose (means ± SE) levels measured at rest, 10-, 30-, 60-, 90-min, and fatigue. No statistically significant differences among trials.

**Exercise Performance**

There were no statistically significant differences in the performance time to fatigue (Fig. 7). The L30 group performed the shortest time during the final sprint to fatigue, while the H30 group performed the longest.
Fig. 7. Performance time (means ± SE) from 90 minutes of exercise until fatigue. No statistically significant differences between trials.

DISCUSSION

The purpose of this study was to determine the effect of meal timing and meal GI prior to exercise. The two carbohydrate meals that were chosen were Kellogg’s Cornflakes Cereal (high GI of 81) and Kellogg’s All Bran Cereal (low GI of 42). The meals were consumed 30- and 60-minutes prior to exercise until fatigue. There have been several studies that indicate differing results when studying the GI and timing of carbohydrate feedings prior to exercise. This study supports those studies that found no statistically significant differences between trials regardless of timing or meal composition (Moseley et al., 2002; Wee et al., 1999; Febbraio and Stewart, 1996; Stannard et al., 2000; Sparks et al., 1998).

Moseley et al., (2002) found similar results indicating that no difference in performance existed between trials when ingesting 75g of carbohydrates 15-, 45-, and 75-minutes prior to exercise. Although this study did not measure muscle
glycogen, the data collected agrees with Febbraio and Stewart (1996) findings on performance. They found that when subjects ingested a high or low glycemic meal 45 minutes prior to exercise that there was no effect on muscle glycogen utilization or exercise performance. Sparks et al., (1998) found alterations in metabolism, but no affect on exercise performance following a high or low glycemic meal 45 minutes prior to exercise. In contrast, researchers have found increases in performance time during exercise with a low glycemic pre-exercise meal (Kirwan et al., 1998; DeMarco et al., 1999; Frail and Buke, 1994; Thomas et al., 1991). The reasons for the discrepancies between the studies are unknown, but it has been speculated that possible reasons for the disagreements between studies may be the inconsistencies in methodology. Many researchers have chosen to compare different meals (high glycemic v. low glycemic), but their methods are very different, ranging from cereal foods to carbohydrate solutions. In addition, exercise intensity, specific metabolic responses to the meals, exercise protocol, and timing of pre-exercise food ingestion are all inconsistent.

This study, along with other studies, (Hargreaves et al., 1985; Koivisto et al., 1981; Thomas et al., 1991; Febbraio and Stewart, 1996) found a hyperglycemic response after the ingestion of the high glycemic food (Cornflakes). Despite the differences between blood glucose elevations after the ingestion of the high and low glycemic meal; all trials had blood glucose levels that were similar after 10 minutes of exercise. Figure 8 illustrates the mean response to the high glycemic and low glycemic food consumed 60 minutes prior to exercise. Moseley et al. (2002) found similar results that blood glucose levels
were similar 10 minutes into exercise after subjects consumed 75g of glucose dissolved in 500 ml of water and resting for either 15, 45, or 75 minutes prior to the start of exercise. Subject’s blood glucose levels have also been shown to drop to near resting levels at 30 minutes of exercise (Kirwan et al., 2001), at 20 minutes of exercise (Febbraio et al., 2000), and at the onset of exercise (Sparks et al., 1998).

![Graph showing blood glucose levels](image)

**Fig. 8.** Blood Glucose (means ± SE) levels for H60 and L60 at 10-, 30-, 60-, 90-min, fatigue. No statistically significant difference among trials.

These findings are important because it is well known that blood glucose levels that are elevated results in an increased uptake of glucose due to an increase in insulin release. This reduces the amount of blood glucose available for working muscles during exercise and hinders performance. However, these findings may indicate that after 10 to 30 minutes of exercise, blood glucose levels have leveled off to near resting levels regardless of the meal composition (high or low glycemic indices) prior to exercise. This may indicate that after 10-30
minutes of exercise, the meal consumed prior to exercise has no real impact.
More studies would be useful to examine different meal compositions (fat, protein, and carbohydrate) prior to exercise and its effect on blood glucose levels.

Blood glucose for the H60 trial averaged higher throughout than any other trials, (not a statistically significant difference), which agrees with the results of Sparks et al., (1998). Surprisingly, however, that the blood glucose in the H60 trial experienced a great decline at the start of exercise (as expected), but leveled out at 10 minutes and levels remained above all other trials until fatigue (no statistically significant differences between trials). In contrast, several other studies demonstrate that blood glucose levels for a high glycemic group increase the greatest post-meal and decrease the greatest during exercise, while remaining suppressed under all other trials until fatigue (Sparks et al. 1998; DeMarco et al., 1999; and Thomas et al., 1991).

Hypoglycemia (blood glucose concentrations below 3.5 mmol L\(^{-1}\)) was not evident for any of the trials averaged blood glucose levels. Hypoglycemia, however, was experienced at some time point during the trials for certain individuals. Moseley et al., (2002) found that there was an occurrence of hypoglycemia related to the trial and related to the individual. Although there does not seem to be an occurrence related to the trials, this study exhibits a pattern related to the individuals. Two subjects experienced hypoglycemia during two separate trials and two subjects experienced hypoglycemia during every trial (four trials). This supports Moseley et al., (2002) suggestion that some individuals may have a threshold of insulin exposure that leaves them more susceptible to
experiencing hypoglycemia. This is an area of study that deserves more research to determine the reason(s) for occurrences and susceptibility of hypoglycemia.

CONCLUSION

In conclusion, the data from this study indicates that there are no statistically significant differences among trials in relation to blood glucose, blood lactate, RPE, RER, VO₂, and performance time when consuming a high glycemic meal or a low glycemic meal 30-or 60-minutes prior to exercise to fatigue. This study supports the idea that even though a greater increase in blood glucose is evident after ingesting a high glycemic meal, levels for all trials were normalized by 10 minutes into exercise. Hypoglycemia may be more prevalent in some individuals with a lower threshold and should be further researched. Most importantly, altering the timing of the meals (-30 & -60min) and the meal composition (high and low glycemic) does not increase exercise performance.
REFERENCES


Appendix A

DEMOGRAPHICS FORM

Research Code

Please fill in the information below to the best of your knowledge. This information will only be seen and utilized by the Principal and Student Investigators during the course of this research and will be destroyed upon completion of the study. In the result that the findings of this research become published in professional and medial journals only data will be published with no names of the subjects provided.

Age: __________

Weight: ________

Height: ________

BMI: ________

Exercise Activity Presently Involved In:

__________________________________________

Any Foods Allergic To:

__________________________________________

Days of the Week Most Available for Testing (only mornings):

__________________________________________
# Appendix B

## PAR-Q

Please read the questions carefully and answer each one honestly. Circle YES or NO.

<table>
<thead>
<tr>
<th>Question</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Do you feel pain in your chest when you engage in physical activity?</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>3. In the past month, have you had chest pain when you were not doing physical activity?</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>4. Do you lose your balance because of dizziness or do you ever lose consciousness?</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>6. Is your doctor currently prescribing drugs for a blood pressure or heart condition?</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>7. Do you know of any other reason you should not participate in physical activity</td>
<td>YES</td>
<td>NO</td>
</tr>
</tbody>
</table>

I have read, understood, and completed this questionnaire. Any questions I had were answered to my full satisfaction.

Name ___________________________ Date ___________________________
Signature ________________________ Witness ________________________
Appendix C

HEALTH HISTORY FORM

TABLE 2. AHA/ACSM Health/Fitness Facility Preparticipation Screening Questionnaire

Assess your health needs by marking all true statements.

History
You have had:

_____ a heart attack
_____ heart surgery
_____ cardiac catheterization
_____ coronary angioplasty (PTCA)
_____ pacemaker/implantable cardiac
defibrillator/rhythm disturbance
_____ heart valve disease
_____ heart failure
_____ heart transplantation
_____ congenital heart disease

If you marked any of the statements in this section, consult your healthcare provider before engaging in exercise. You may need to use a facility with a medically qualified staff.

Symptoms

_____ You experience chest discomfort with exertion.
_____ You experience unreasonable breathlessness.
_____ You experience dizziness, fainting, blackouts.
_____ You take heart medications.

Other health issues:

_____ You have musculoskeletal problems.
_____ You have concerns about the safety of exercise.
_____ You take prescription medication(s).
_____ You are pregnant.

Cardiovascular risk factors

_____ You are a man older than 45 years.
_____ You are a woman older than 55 years or you have had a hysterectomy or you are postmenopausal.
_____ You smoke.
_____ Your blood pressure is >140/90.
_____ You don’t know your blood pressure.
_____ You take blood pressure medication.
_____ Your blood cholesterol level is >240 mg/dL.
_____ You don’t know your cholesterol level.
_____ You have a close blood relative who had a heart attack before age 55 (father or brother) or age 65 (mother or sister).
_____ You are diabetic or take medicine to control your blood sugar.
_____ You are physically inactive (ie, you get <30 minutes of physical activity on at least 3 days per week).
_____ You are >20 pounds overweight.

If you marked 2 or more of the statements in this section, consult your healthcare provider before engaging in exercise. You might benefit by using a facility with a professionally qualified exercise staff to guide your exercise program.

_____ None of the above is true. You should be able to exercise safely without consulting your healthcare provider in almost any facility that meets your exercise program needs.

AHA/ACSM indicates American Heart Association/American College of Sports Medicine.
Appendix D

INCLUSION/EXCLUSION QUESTIONNAIRE

Please read the questions carefully and answer each one honestly.

Circle YES (Y) or NO (N).

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Are between the ages of 18-35?</td>
<td>Y</td>
</tr>
<tr>
<td>2.</td>
<td>Do you exercise on a regular basis? (At least three times a week)</td>
<td>Y</td>
</tr>
<tr>
<td>3.</td>
<td>Have you ever been diagnosed with diabetes, insulin, or blood clotting disorder?</td>
<td>Y</td>
</tr>
<tr>
<td>4.</td>
<td>Are you currently on any medication for blood sugar or blood clotting?</td>
<td>Y</td>
</tr>
<tr>
<td>5.</td>
<td>To your knowledge, do you have any blood sugar or insulin response problems?</td>
<td>Y</td>
</tr>
<tr>
<td>6.</td>
<td>Do you currently have pain when you stretch, walk, or exercise?</td>
<td>Y</td>
</tr>
<tr>
<td>7.</td>
<td>Are you available and willing to meet a total of six times for the study?</td>
<td>Y</td>
</tr>
<tr>
<td>8.</td>
<td>Are you willing to have blood drawn from your fingertips before, during, and after exercise?</td>
<td>Y</td>
</tr>
</tbody>
</table>

I have read, understood, and completed this questionnaire. Any questions I had were answered to my full satisfaction. I am aware that if I do not meet the inclusion criteria for this study I will not be permitted to participate. However, I understand I will receive no penalty, risk of loss of service I would otherwise receive or negative affects on me or my status in HPER classes if I do not meet the inclusion criteria.

Name ___________________________ Date ________________________

Signature _______________________ Witness _______________________
Appendix E

CONSENT FORM

Western Michigan University
Department of Health, Physical Education, and Recreation

Principal Investigator: Timothy J. Michael, Ph.D.
Student Investigator: Amy Gyorkos

You have been invited to participate in a research project entitled "Effect of Glycemic Indices and Timing of Meal on Exercise to Fatigue". This study is Amy Gyorkos’s thesis project. This consent document will explain the purpose of this research project and will go over all of the time commitments, the procedures used in the study, and the risks and benefits of participating in this research project.

Purpose of Study

The purpose of this study is to determine if high and low glycemic food ingestion prior to exercise, while consuming equal amounts of carbohydrates influence metabolic levels and performance time. In addition, this study will determine the optimal time of carbohydrate ingestion prior to exercise.

Qualifications to Participate in this Research

To be able to participate in this research project, you must meet the following criteria:
✓ Between ages 18-35
✓ Moderately active
✓ Free of diabetes
✓ Free of insulin, blood clotting, and blood glucose complications
✓ Able to stretch, walk, and exercise pain free
✓ Free of medications affecting blood glucose levels and blood clotting
✓ Willing to meet six total times
✓ Willing to get blood drawn from fingertip before, during, and after exercise

Duration of the Study

You will be asked to come to the Exercise Physiology Laboratory of Western Michigan University located on the first floor of the Student Recreation Center six separate times. The first visit will be an Orientation visit and the second visit will be for the Peak Bike Exercise Test. The final four visits will be for the Experimental Trials.
The initial orientation visit will last approximately 30-45 minutes. The visit for the peak bike test will last approximately 60 minutes. The four experimental trials will depend on your protocol; you will be asked to come to the lab 60 minutes (2X) and 30 minutes (2X) prior to exercise. In addition, you will be asked to exercise (cycling) for 90 minutes and then perform a time trial to fatigue. The minimum amount of time from the beginning of the study to the end of your commitment will be four weeks, however, due to scheduling; completion of the study for you may take upwards of six weeks. The requested length of approval for the entire study is one year although data collection should take considerably less time than the requested approval period.

It is necessary to have a 7-day break period between each of the experimental trials. The break period is so the effect of one experimental trial does not effect the next trial. Your participation in this study should last about six total weeks, but no more than eight weeks.

**Research Procedures**

You will be asked to meet with the student investigator, Amy Gyorkos, in the Exercise Physiology Laboratory in the Student Recreation Center on the campus of Western Michigan University. If you are willing to participate in the study will be asked to meet on six separate occasions; pre-screening meeting, peak bike test meeting, and six experimental trials.

**Orientation Visit**

When you arrive to the laboratory for the Orientation visit, one of the investigators will go over this consent form with you and explain the study and all of its procedures, risks, and benefits to you. You will be encouraged to ask any questions that you may have. If you decide to participate, one of the investigators will ask you to sign this consent form.

We will ask you to wear a t-shirt and shorts for this visit.

You will also complete a health history questionnaire. The investigators will use this information to classify your "risk level" for exercise based on guidelines established by the American College of Sports Medicine. You can participate in this study only if your "risk level" is "Low-Risk". This risk-level procedure will be explained to you.

You will also have your anthropometric measurements assessed. This means that we will measure your height, weight, and determine your body mass index.

**Pretest Instructions**

The following instructions will be asked to be adhered to before the peak bike test and all the experimental testing. You will be asked to drink plenty of water over the 24-h period before the test to make sure that you are at normal hydration levels
prior to the test. In addition, you will be asked to avoid tobacco, alcohol, and caffeine for at least 24 hours before the testing.

Please note that if you normally consume caffeine, that abstention from caffeine for the 24 hours prior to each experimental trial may produce some symptoms of caffeine withdrawal such as mild headache. Caffeine can increase heart rate and increase nervous system activity. Caffeine and alcohol can cause a person to become dehydrated which may also affect the responses to exercise.

You will also be asked to avoid exercise or strenuous physical activity the day of and the day before the tests and to get an adequate amount of sleep (6 to 8 hours) the night before each test. On each test day you will be asked to complete a worksheet that asks if you have followed the above instructions. If you answer "no" to any of the questions, testing may be terminated and we can reschedule your testing trial day if you would still like to be involved in the study.

**Pre-Exercise Feedings**

You will be asked to follow the United States Department of Agriculture (USDA) food guide pyramid for two days prior to experimental trials. The food guide pyramid includes 55% Carbohydrates, 30% Fat, and 15% Protein. A handout explaining the food groups and examples will be provided for you. In addition, you will be asked to record the foods consumed two days prior to trials in a diet journal that will also be provided. Researchers will collect that diet information and record it into the Nutrition CalcPlus program (McGraw Hill) to ensure that you are properly using the USDA information when making your diet decisions. In addition, you will be asked to fast for 12 hours prior to experimental trials (not peak bike test).

**Peak Bike Test**

The purpose of the peak bike test is to find out how well your body is able to use oxygen during exercise. To do this, you will exercise for about 15 to 20 minutes on a cycle ergometer. You will need to bring with you a set of exercise clothes (t-shirt, shorts, athletic/running shoes).

On the day of the peak bike test, you will be asked to come into the laboratory an hour early. Upon arrival, your weight will be measured and we will fit you comfortably with a polar heart rate monitor, which has a strap that fits around your chest. During the sixty-minute rest period, you can do any seated function, such as homework, study, read, write, or watch television or a movie.

After the sixty-minute rest period, we will take and record your blood pressure and your heart rate. We will then get you positioned on the cycle so that you are sitting upright, hands on the handlebars, and you have a 5-degree bend in the knees when you extend your leg. In addition, we will then hook you up to the metabolic measurement cart so that we can measure how much oxygen your body uses during exercise and how much carbon dioxide your body produces. To do this, you will
breathe through a clean, sanitized mouthpiece (similar to a snorkel mouthpiece) and you will wear a pair of noseclips so that you can only breathe through your mouth. The air you blow out during exercise goes into the metabolic measurement cart and the amount of oxygen and carbon dioxide is measured.

During the exercise test, your heart rate and your blood pressure will be measured at every 3 minutes and at every 1 to 2 minutes after exercise. We will explain how to use the Borg Ratings of Perceived Exertion Scale. This is a scale with numbers and words describing how hard the exercise is. To use the scale, you simply point to a number. During exercise, the resistance of the bike’s wheel will increase every minute by 20 watts. This will make the exercise harder for you and will cause you to get tired. You will do this until you can no longer pedal, you ask to stop, or we request you to stop. When you reach fatigue, you will continue to cycle at a light intensity, until your heart rate and blood pressure recovery to near resting levels.

Your appearance and symptoms, along with heart rate, blood pressure, and RPE will be monitored at all times throughout exercise. If at any time during the test you begin to experience adverse signs or symptoms, request to stop, or experience an emergency situation the test will be terminated. In addition, the investigators are trained in CPR techniques and emergency procedures. A spotter will be standing next to the cycle ergometer throughout the entire test if the participant becomes dizzy or disoriented.

**Experimental Trials**

For the experimental trials, we ask that you come to the laboratory wearing a t-shirt, shorts, and running/gym shoes. You will be asked to come to the exercise lab to consume a meal for breakfast after at least a 12 hour fast. Upon arrival, you will be weighed and then you will sit down and consume a meal. The time and/or the meal will change prior to each experimental trial. The following describes each of the four protocols for consuming food prior to exercise.

1) Protocol #1: Eat a high glycemic meal 30 minutes prior to exercise
2) Protocol #2: Eat a high glycemic meal 60 minutes prior to exercise
3) Protocol #3: Eat a low glycemic meal 30 minutes prior to exercise
4) Protocol #4: Eat a low glycemic meal 60 minutes prior to exercise

After you consume your meal we will fit you comfortably with a polar heart rate monitor, which has a strap that fits around your chest. You will then wait for 30 minutes or for 60 minutes in a resting state, depending on your protocol for that day. During the resting period, you can do any seated function, such as homework, study, read, write, or watch television or a movie. Blood samples will be taken prior to the exercise. Blood will be taken at different times depending on your protocol for that day (for more details on blood draws see “Blood Sampling”). The following describes the blood draws prior to exercise:
1) Protocol #1 & #3: You will have blood drawn at 30 minutes after you consume your meal
2) Protocol #2 & #4: You will have blood drawn at 30 minutes and at 60 minutes after you consume your meal

We will remind you how to use the Borg Ratings of Perceived Exertion Scale. This is a scale with numbers and words describing how hard the exercise is. To use the scale, you simply point to a number.

You will then sit on the stationary cycle ergometer and we will adjust the height of the seat so you are comfortable. And once again, you will be hooked up to the metabolic cart so that we can measure how much oxygen your body uses during exercise and how much carbon dioxide your body produces.

We will then begin the exercise trial.

The exercise protocol will be the same each trial. You will be asked to cycle at an intensity of 70% $\text{VO}_{2\text{peak}}$ for 90 minutes. After the 90 minutes of cycling, you will be asked to cycle at 100% $\text{VO}_{2\text{peak}}$. This means that you will be pedaling as fast as you can until you cannot exercise any longer, you ask to stop, or we request that you stop.

During the exercise test, we will measure your heart rate every ten minutes using the heart rate monitor and we will ask you how you feel using the Borg scale. Blood draws will be taken during the first 5 minutes and at every 30 minutes of exercise, and one final blood draw at fatigue (for more details on blood draws see “Blood Sampling”).

Your appearance and symptoms, along with heart rate and RPE will be monitored at all times throughout exercise. If at any time during the test you begin to experience adverse signs or symptoms, request to stop, or experience an emergency situation the test will be terminated. In addition, the investigators are trained in CPR techniques and emergency procedures. A spotter will be standing next to the cycle ergometer throughout the entire test if the participant becomes dizzy or disoriented.

When you are finished with the exercise test, we will take the mouthpiece and noseclips off and you will ride the bike for a few minutes at a very low level for a cool-down period. Once you finish on the cycle ergometer, we will remove the heart rate monitor.

**Blood Sampling Procedures**

Blood will be taken up to two times prior to exercise, three times during exercise, and once at fatigue. A small spring-loaded device will be used to puncture your fingertip quickly. This will create a tiny hole for blood to surface and blood will be taken for analysis.
The area of blood sampling (finger tips) will be cleaned prior to blood sampling using an alcohol swab. All supplies utilized for the blood collection will be new, sterile and only used once. At the end of each Experimental Trial, a band-aid will be applied over the collection site.

The total amount of blood that we are taking for each experimental trial will be approximately 1mL (1/5 teaspoon). The removal of this amount of blood has no negative impact on your body. Universal precautions will be taken during these procedures to ensure safety and sterilization and the investigators are qualified to perform the procedures.

**Possible Risks of Your Participation In This Study**

Risks and inconveniences associated with intense exercise include muscular fatigue and possibly muscle soreness on the following day. The exercise will be stressful but is generally easily tolerated by individuals and is not dangerous for healthy individuals. The investigators are trained in performing exercise tests and are familiar with emergency procedures.

The risks associated with the drawing of blood samples include soreness and possible bruising. These risks are minimized by observing proper sterile techniques. Also, the investigators are properly trained and have much experience in taking blood samples. Universal precautions will be taken during these procedures to ensure safety and sterilization, and the investigators are qualified to perform the procedures. The total volume of blood drawn during any single experimental trial will not exceed 1mL (1/5 teaspoon). The removal of this amount of blood poses no risk to a healthy subject.

The overall time commitment to be a subject for this study is significant, thus the time factor may be an inconvenience.

As in all research, there may be unforeseen risks to the participant. If an accidental injury occurs, appropriate emergency measures will be taken; however, no compensation or additional treatment will be made available to you except as otherwise stated in this consent form. You will NOT be compensated for participating in this study.

**Benefits of Your Participation in this Study**

The insight gained from this study, in combination with others, could help you in ingesting effective meals prior to exercise in order to prolong endurance trials and to provide an adequate energy source to help your blood glucose levels. In addition, you will get free results on your blood glucose and lactate responses before, during, and after exercise. In addition, a measurement of your peak oxygen uptake is obtained. Peak oxygen uptake is the single, best indicator of aerobic fitness. Therefore, that information will be provided for you and we will educate you as to how your value compared to population norms. In addition, you will gain exposure to the procedures involved in scientific research.
Conditions of Participation in the Study

There are conditions that must be met in order for you to participate in this study. One is being moderately active, defined at having a VO$_{2\text{peak}}$ between 50-60 ml·kg$^{-1}$·min$^{-1}$. This will be determined in your second meeting during the peak bike test. You must be between the ages of 18-35 years (male or female). You must be free of diabetes and blood clotting disorders and medications effecting blood glucose levels and/or blood clotting. In addition, you must be a low risk subject according to ACSM guidelines, including a Body Mass Index of <30 (determined at first meeting and highly confidential). You must also be willing to meet a total of six times for information, fitness testing, and carbohydrate feedings and experimental trials.

The following instructions will be asked to be adhered to before the peak bike test and all the experimental testing. You will be advised to drink plenty of water over the 24-h period preceding the test to ensure normal hydration prior to the test. In addition, you will be asked to avoid tobacco, alcohol, and caffeine for at least 24 hours before all the testing.

You will also be asked to follow the food guide pyramid strictly for two days prior to all experimental trials and to record your diet in a journal that will be provided for you.

Because the data collected could be affected if you do not follow these guidelines, we ask that you tell us if you did not follow any of the guidelines. You will not suffer any penalties from the investigators if you do not follow the guidelines, but it is important for us to know. You will be asked to fill out a pre-exercise questionnaire prior to all experimental trial asking if you adhered to each of the above guidelines. In this case, that you answer “no” we can reschedule one of your appointments or you can choose not to participate in the study any longer.

Confidentiality of Your Results

In order to maintain confidentiality the study will be focused on group data and an identification number (rather than the subject’s name) will be used to record data. Following the study, the primary investigator and the research committee will have access to the original data. The original data will be retained in a locked cabinet for a minimum of three years after the completion of the study in the department of Health, Physical Education, and Recreation at Western Michigan University and then destroyed.

If the results of the study are published in a journal or presented at a conference, no names will ever be used.
Withdrawal from the Study

You can choose to stop participating in the study at anytime for any reason. You will not suffer any prejudice or penalty by your decision to stop your participation. You will experience NO consequences either academically or personally if you choose to withdraw from this study.

The study investigators can also decide to stop your participation in the study without your consent.

Should you have any questions prior to or during the study, you can contact the student investigator, Amy Gyorkos, at 269-420-3933 or 269-387-2689 (campus GA office), or the primary investigator, Dr. Timothy Michael at 269-387-2691. You may also contact the Chair, Human Subjects Institutional Review Board at 269-387-8293 or the Vice President for Research at 269-387-8298 if questions arise during the course of the study.

This consent document has been approved for use for one year by the Human Subjects Institutional Review Board (HSIRB) as indicated by the stamped date and signature of the board chair in the upper right corner. Do not participate in this study if the stamped date is older than one year.

“I have read this informed consent. The risks and benefits have been explained to me. I agree to take part in this study.”

Please Print Your Name

________________________________________
Participant’s Signature

________________________________________
Permission obtained by:  

Signature of Investigator

Date
Appendix F

PROCEDURE SCRIPT

The following provides a description and instructions for the study

Pretesting Instructions
The following should be followed prior to testing days
1. 48 hours prior
   a. Follow food guide pyramid (55% CHO, 30% FAT, 15% PRO)
   b. Record all food and beverages in Diet Record Keeping sheet (2 days)
2. 24 hours prior
   a. Drink plenty of water
   b. Avoid tobacco
   c. Avoid alcohol
   d. Avoid caffeine
   e. Avoid any exercise or strenuous activity
   f. Get adequate amount of sleep (6-8 hours)
3. 12 hours prior
   a. Avoid any food except high or low glycemic food as specified

Peak Bike Test
The peak bike test will be used to determine the subjects VO$_{2peak}$ and their tolerance to exercise. It will be performed on a Monark cycle ergometer.
1. Procedure
   a. 2-3 minute warm-up and acquaintance with the cycle (60 Watts)
      i. 5-degree bend in knee at maximal leg extension
      ii. Hands proper position on handlebars
   b. Intensity increased 20 Watts every minute
   c. Until volitional fatigue: unable to pedal at 50 RPM
   d. 5 minute cool-down
2. Heart rate, blood pressure, rates of perceived exertion, expired air will be continually monitored

Meeting Times
Subjects will be expected to commute to the Student Recreation Center six separate times
1. Experimental Trials 3-6 will be performed in random order

<table>
<thead>
<tr>
<th>Session</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Session 1</td>
<td>Initial forms, explanation of study, basic fitness testing</td>
</tr>
<tr>
<td>Session 2</td>
<td>Peak Bike Test- determines exercise tolerance and VO$_{2peak}$</td>
</tr>
<tr>
<td>Session 3</td>
<td>Consume high glycemic food 30 minutes prior to exercise</td>
</tr>
<tr>
<td>Session 4</td>
<td>Consume low glycemic food 30 minutes prior to exercise</td>
</tr>
<tr>
<td>Session 5</td>
<td>Consume high glycemic food 60 minutes prior to exercise</td>
</tr>
<tr>
<td>Session 6</td>
<td>Consume low glycemic food 60 minutes prior to exercise</td>
</tr>
</tbody>
</table>
Exercise Trials Protocol
All exercise testing will also be performed on the Bosch cycle ergometer

1. Procedure
   a. 2-3 minute warm-up and acquaintance with the cycle
      i. 5-degree bend in knee at maximal leg extension
      ii. Hands proper position on handlebars
   b. Maintain a given intensity (70% VO\textsubscript{2peak}) for 90min and then maintain intensity at 100% VO\textsubscript{2peak} until fatigue
   c. Fatigue is defined as the following
      i. Unable to pedal any longer
      ii. Experiencing nausea
      iii. Lightheaded
   d. Cool-down/recovery until near resting levels are reached (HR, RPE)

2. Heart rate, rates of perceived exertion, expired air will be monitored
3. Report back to Exercise Physiology Lab in 7 days to perform next trial

Precautions
If at any time during the test subjects begin to experience adverse signs or symptoms, requests to stop, experiences an emergency situation, or experiences fatigue (defined above), exercise will be terminated.
Appendix G

SUBJECTS WANTED FLYER

This study will be used to examine the effect of different timing of carbohydrate feeding prior to exercise on blood glucose levels and performance. In addition, this study will examine the effect of high v low glycemic foods prior to exercise.

☐ Subjects-Adult Males and Females
  ✓ Between ages 18-35
  ✓ Moderately active
  ✓ Free of diabetes
  ✓ Free of insulin, blood clotting, and blood glucose complications
  ✓ Able to stretch, walk, and exercise pain free
  ✓ Free of medications affecting blood glucose levels and blood clotting
  ✓ Willing to meet six total times
  ✓ Willing to get blood drawn from fingertip

☐ During the Study
  2. Subjects will be expected to commute to the Student Recreation Center to participate in carbohydrate feedings and exercise testing
  3. Exercise includes cycling at 70% VO₂peak for 90 minutes and then cycling at 100% VO₂peak until fatigue
  4. Sessions 3-6 performed in random order

| Session 1 | Initial forms, explanation of study, basic fitness testing |
| Session 2 | Peak Bike Test- determines exercise tolerance and VO₂max |
| Session 3 | Consume high glycemic food 30 minutes prior to exercise |
| Session 4 | Consume low glycemic food 30 minutes prior to exercise |
| Session 5 | Consume high glycemic food 60 minutes prior to exercise |
| Session 6 | Consume low glycemic food 60 minutes prior to exercise |

☐ Benefits
  ➢ The research may be of benefit to you by learning when to consume carbohydrates prior to exercise to improve your time to fatigue
  ➢ The results may also benefit in producing effective protocols for all individuals who wish to improve blood glucose levels and performance

☐ Confidentiality
  ➢ All data collected during experiment will remain confidential

☐ If Interested...
  ➢ If you are interested in hearing more, please contact Amy Gyorkos at 269-420-3933
Appendix H

FOOD GUIDELINES

- US Department of Agriculture Food Guidelines will be used as a reference for appropriate meal consumption two days prior to exercise testing
- All food and beverage intake should be recorded for the two days prior to testing using the attached recording sheets
- Additional information regarding nutrition can be found at http://www.cfsan.fda.gov/~dms/nutrlist.html
Diet Record Keeping

* Please record all foods and beverages consumed two days prior to all testing dates

<table>
<thead>
<tr>
<th>Date</th>
<th>Food Description</th>
<th>Amount (ounces)</th>
<th>Beverage Description</th>
<th>Amount (ounces)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Remember: 55% Carbohydrates, 30% Fat, 15% Protein
- Be as specific as possible with descriptions
- All information will be entered in Nutritional CalcPlus Program
- Additional diet recording sheets can be picked up in the Exercise Physiology Lab
Appendix I

PRE-EXERCISE QUESTIONNAIRE

Please read the questions carefully and answer each one honestly.

Circle YES (Y) or NO (N).

<table>
<thead>
<tr>
<th>Question</th>
<th>Y</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Have you consumed plenty of water in the past 24 hours?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Have you followed the food guide pyramid for the past two days?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Have you refrained from using any tobacco in the past 24 hours?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Have you refrained from consuming any alcoholic beverages in the past 24 hours?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Have you refrained from consuming any caffeine in the past 24 hours?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Have you avoided exercise and strenuous activity in the past 24 hours?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Did you receive an adequate amount of sleep last night? (6-8 hours)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Have you fasted for at least 12 hours before this test time?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

I have read, understood, and completed this questionnaire. Any questions I had were answered to my full satisfaction.

Name ___________________________ Date ___________________________
### Appendix J

**GLYCEMIC INDEX**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose 100</td>
<td>Orange Juice 57</td>
<td>All Bran 42</td>
</tr>
<tr>
<td>Baked Potato 85</td>
<td>White Rice 56</td>
<td>Apple 36</td>
</tr>
<tr>
<td>Corn Flakes 81</td>
<td>Popcorn 55</td>
<td>Pear 36</td>
</tr>
<tr>
<td>Cheerios 74</td>
<td>Corn 55</td>
<td>Skim Milk 32</td>
</tr>
<tr>
<td>Graham Crackers 74</td>
<td>Brown Rice 55</td>
<td>Green Beans 30</td>
</tr>
<tr>
<td>Honey 73</td>
<td>Sweet Potato 54</td>
<td>Lentils 29</td>
</tr>
<tr>
<td>Watermelon 72</td>
<td>(Ripe) Banana 50</td>
<td>Kidney Beans 27</td>
</tr>
<tr>
<td>White Bread/Bagel 70-72</td>
<td>Orange 43</td>
<td>Grapefruit 25</td>
</tr>
<tr>
<td>Table Sugar 65</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix K

BORG SCALE OF PERCEIVED EXERTION

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Very, Very Light</td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Very Light</td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Fairly Light</td>
</tr>
<tr>
<td>12</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Somewhat Hard</td>
</tr>
<tr>
<td>14</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Hard</td>
</tr>
<tr>
<td>16</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Very Hard</td>
</tr>
<tr>
<td>18</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Very, Very Hard</td>
</tr>
<tr>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>
Appendix L

COLLECTION OF THE BLOOD PRODUCT

1. Blood collection procedures will take place in the Exercise Science Laboratory on the campus of Western Michigan University. The student investigator will perform the fingerpricks, blood collection, analysis, and disposal of blood samples.

2. A spring loaded lancet device is used to puncture the fingertip quickly. A capillary tube containing nitrate, fluoride, and heparin is used to collect the blood. Approximately 1mL (1/5 teaspoon) of blood will be obtained from the subjects each experimental trial. Two samples will be taken prior to exercise (T-30 & T-60) for the group that will ingest food 60 minutes prior to exercise, five samples will be taken during exercise (T+5, T+30, T+60, T+90), and one at fatigue. One less sample will be taken for the subjects ingesting food 30 minutes prior to exercise (T-30).

3. The area of fingertip puncturing will be cleaned using an alcohol pad.

4. Lab coats, gloves, and any other personal protective equipment deemed necessary will be used when handling samples. OSHA guidelines and Universal Precautions will be implemented when collecting and disposing of the blood.

5. Medical history forms will be filled out by each subject. Any subject with history of blood disorders will be excluded from the study.

6. The principal and student investigator have both been vaccinated for Hepatitis B.

7. The Sindecuse Medical Laboratory Director will be made aware of any accidental contact with blood samples, as well as Dr. Robert Baker, WMU team physician. Complications arising from the blood sampling will be referred to Sindecuse Health Center for medical attention.

8. Blood samples for each subject will be analyzed after completion of each Experimental Trial.

9. Extra blood will be stored in a freezer in the laboratory in case some sample need to be re-run at the conclusion of the study.

TREATMENT OF THE MATERIAL USED TO DRAW THE BLOOD SAMPLE

1. Instruments used to collect the blood sample will be disposed of in their respective biohazard waste containers. Capillary tubes and spring loaded lancet devices will be disposed of in a Sharps container. Gauze will be disposed of in a biohazard container.

2. Instruments used to analyze the blood samples are not disposable. The instruments have their own decontamination system built in to flush antiseptic fluids through the instrument.

3. Any materials that may have come in contact with the blood sample that are disposable will be disposed of in biohazardous containers. Bloodborne Pathogens Training as well as OSHA guidelines already established at Western Michigan University within the HPER department will be followed.

STORAGE AND DISPOSITION OF THE BLOOD SAMPLE:

1. Blood samples contained in storage tubes (cryovials) will be stored in a freezer.

2. Bloodborne Pathogen Training procedures already established at Western Michigan University within the HPER department will be followed.

3. When analysis is complete, blood samples will be disposed of in biohazardous waste containers.
Appendix M

DATA COLLECTION FORM

Subject Information for ____/____/2005

<table>
<thead>
<tr>
<th>Subject ID #:</th>
<th>Trial #:</th>
<th>Weight:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glycemic Index</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Food Consumption Prior to Exercise</td>
<td>30 minutes</td>
<td>60 minutes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>0</th>
<th>20</th>
<th>0</th>
<th>30</th>
<th>0</th>
<th>40</th>
<th>0</th>
<th>50</th>
<th>0</th>
<th>60</th>
<th>0</th>
<th>70</th>
<th>0</th>
<th>80</th>
<th>0</th>
<th>90</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RPE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VO2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VCO2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RER</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood Lactate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood Glucose</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix N

HSIRB APPROVAL LETTER

Date: December 7, 2004

To: Timothy Michael, Principal Investigator
Amy Morrison, Student Investigator for thesis

From: Amy Naugle, Ph.D., Interim Chair

Re: HSIRB Project Number: 04-11-14

This letter will serve as confirmation that your research project entitled "Effect of Glycemic Index and Timing Variations Prior to Exercise" has been approved under the full category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you may only conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: November 17, 2005
Appendix O

REVIEW OF RELATED LITERATURE

Metabolism

Metabolism is defined as the rate of heat production. A calorie is the basic unit of heat measurement and is the heat required to raise the temperature of 1 gram of water 1 degree Celsius. Oxygen and heat production have a relationship in that when we breathe, we give off heat, therefore oxygen can be used to measure metabolic rate. Indirect calorimetry measures the amount of oxygen and/or carbon dioxide produced to estimate the rate of heat production (metabolic rate). Indirect calorimetry can give important information concerning the metabolism during exercise such as; oxygen and carbon dioxide consumption, VO2max and Respiratory Exchange Ratios (RER) (Brooks et al., 2000).

Submaximal and Maximal Exercise

Moderately vigorous exercise exists around 55-70% VO2max. At these moderately high intensities, subjects are not subjected to a maximum level of physical stress. Maximal exercise is high intensity aerobic workout with intensities that reach 100% VO2max. Intensity can be measured by maximum heart rate or VO2max (see below) (Brooks et al., 2000). With knowledge of HRmax or VO2max, a percentage can be taken to implement in a variety of exercise modalities to elicit a submaximal or maximal intensity workout.

Responses to Submaximal and Maximal Exercise

Cardiac Output & Heart Rate:
It is essential to provide the body with adequate oxygen flow at all times and during exercise a greater demand is placed on the body to maintain the homeostasis of the body. During exercise, the body works to provide adequate blood flow to active areas and reduce or redirect it from inactive areas. In order for this demand to be met, one response is the increase in cardiac output (heart rate * stroke volume) during exercise, which increases oxygen and substrate delivery to active tissues. Heart rate increases incrementally with the intensity of exercise, therefore, during submaximal exercise (steady state), the heart rate rises and levels off as the oxygen requirements of the activity have been satisfied. If the activity is prolonged, heart rate may increase slightly (cardiovascular drift) to maintain cardiac output and blood pressure. As exercise is increased to maximal effort, heart rate levels off at VO2max. A normal range for heart rate is approximately 70 beats per minute at rest to 180-200 beats per minute at maximal exercise (Brooks et al., 2000).

**Oxygen Consumption:**

Similar to heart rate, oxygen consumption also increases in proportion to exercise intensity. It is the rate at which oxygen is transported and extracted from blood and is measured by indirect calorimetry. During submaximal (steady state) exercise, oxygen consumption remains steady until intensity increases. As intensity increases to maximal effort, a VO2max is reached, which indicates a point in which no further increases in oxygen consumption can be achieved (Brooks et al., 2000).

VO2max is the product of maximum cardiac output and maximum arteriovenous oxygen difference. This measurement has been respected to be the best indicator of one’s fitness level. A high VO2max indicates the body’s ability to
exercise at high intensities before it can no longer keep up with the metabolism
demands of that bout of exercise (Brooks et al., 2000).

Respiratory Exchange Ratio:

The respiratory exchange ratio (RER) can be determined by indirect
calorimetry by dividing the amount of carbon dioxide produced by the amount of
oxygen consumed. This ratio usually ranges from 0.7 (aerobic)-1.0 (anaerobic), with
the exception of hyperventilation where the ratio can be more than 1.0 (R).

Carbohydrates are 100% of what is being burning at a RQ of 1.0 and fats are 100% of
what is being burned at a RQ of 0.7. During prolonged exercise in a trained person,
the RQ value will begin to decrease, indicating the burning of fats because glycogen
supply can be a limiting factor and fat broken down gives off 2.3 times as much
energy as carbohydrates (Brooks et al., 2000).

Rates of Perceived Exertion:

Borg’s rates of perceived exertion (RPE) category scale is used as a means
to measure progress during exercise to fatigue. This scale represents the individual’s
exercise tolerance and is highly correlated with exercise heart rates and work rates. A
high correlation exists between the perception of exhaustion and VO2max. This scale
allows the researchers to monitor progress toward maximal exertion during exercise
and to know when the subject is reaching ratings of 18-19 that fatigue has been
reached (Brooks et al., 2000).

Fatigue:

Exercise fatigue is a point in which exercise intensity can no longer be
sustained. At this point, the body is unable to keep up with the metabolic demands of
the exercise. This could include depletion of essential metabolites, or increased amount of particular metabolites that hinder performance, overheating, muscular fatigue, boredom, etc. It is hard to pinpoint the exact cause of fatigue because so many factors are involved. During exercise, VO2max is defined as 1) a leveling off of VO2 with increasing workload, 2) a heart rate within 10 beats*min\(^{-1}\) of predicted maximum, and 3) a respiratory exchange ratio \(\geq 1.1\) (Brooks et al., 2000).

**Fuel Utilization During Exercise**

The primary fuel source used for the working muscles during exercise depends highly on the intensity of exercise. As exercise begins to increase from moderate to hard intensities, the working muscles begin to rely heavily on carbohydrates (CHO) as the primary fuel source. Therefore, during prolonged exercise, fatigue is associated with intramuscular glycogen depletion and hypoglycemia (Brooks et al., 2000).

Amino acids and fats serve as an alternative fuel source and subsequently help to maintain blood glucose levels and prolong exercise. In addition, fats provide far more energy than any other system; therefore it becomes an essential fuel during prolonged work. Thus, the process of changing fuel sources becomes an important component during exercise (Brooks et al., 2000).

This change identifies the “crossover concept” from lipids to carbohydrates during exercise. At rest, approximately 60% of the energy is from lipid oxidation and the remainder is from carbohydrate oxidation (approximately 35%). During submaximal exercise (65-80% VO2max) fat oxidation only accounts for 10-45% of the energy expended and the remaining energy is taken from carbohydrates (Askew,
Furthermore, as exercise intensities advance, lipid oxidation continues to decline and carbohydrate oxidation further increases. This crossover effect takes place because as muscle contractions increase, more GLUT-4, insulin regulatable glucose transporter protein, is released to the cell’s surface in order to take up glucose for glycolysis. This process produces more blood lactate, which decreases pH values and inhibits lipolysis and increases esterification of free fatty acids to triglyceride (Brooks et al., 2000). Therefore, during hard exercise, lipid oxidation is decreased as carbohydrate oxidation is increased.

The three main energy systems all provide energy for the working muscles, but produce very different power and capacities. Glucose combines with oxygen and produces 36 ATP’s, carbon dioxide, and water. Oxidative energy source provides for more energy than any of the other sources. Fats, when oxidized, produce 129 ATP’s, carbon dioxide, and water (Brooks et al., 2000). This produces, by far, the most energy of the other systems, including oxidative glycolysis. Therefore, it is not surprising that a goal of endurance training is to increase fat oxidation for more energy and to maintain blood glucose levels.

**Glucose and Lactate Role During Exercise**

Ingesting carbohydrates provides the first step in a process of digesting, releasing, using, and storing glucose. Glucose is the main product of digesting carbohydrates (dietary sugar and starches). The glucose is released into the systemic circulation and is either used immediately (glycolysis) or stored and used later in a process called glucogenolysis. Glycolysis and glucogenolysis provides energy to the working muscles in order for a powerful contraction to occur (Brooks et al., 2000).
Maintaining blood glucose levels is essential in providing fuel to the brain, other CNS tissues, and to other working muscles for continued exercise. The body has two primary systems to maintain glucose levels in the range of 4-5mM (90-100mg*d1), the autonomic nervous system (ANS), and the endocrine (hormonal) system. During exercise, tissues begin to take up an increased amount of blood glucose; therefore glucose production must be increased to ensure homeostasis. Ways in which the body accomplished this is by making new glucose from precursor molecules (gluconeogenesis), by increasing release of glucose and alternative substances into the blood from gut, liver, and kidneys for primarily the working muscles (Brooks et al., 2000).

Glycolysis is the metabolic pathway in mammalian cells and is the first stage of cellular glucose catabolism. Glycolysis is an 11 or 12 step process responsible for the initial catabolism of glucose for ATP and it results in the production of lactate (anaerobic glycolysis) or pyruvate (aerobic glycolysis). When glucose molecules do not undergo glycolysis, it results in the storage of glucose (glycogen). Glycogen is essential in providing energy to working muscles. In fact, glycogen, in the muscle, provides 80% or more of the carbon used for glycolysis. The breakdown of glycogen is made possible by the process of glucogenolysis (Brooks et al., 2000).

Rapid glycolysis provides energy for the working muscles for a period of a few seconds to a couple of minutes. The mitochondria require 1-2 minutes, during the transition from rest to steady-state exercise, to produce energy from oxidative phosphorylation to fully supply the required energy from muscular contractions (Watt
et al., 2002). Slow glycolysis can provide energy during exercise, especially in pale or white skeletal muscles, which contain large quantities of glycolytic enzymes.

Mitochondria are abundant in the slow oxidizing fibers, such as those found in white skeletal muscles. Mitochondrion consumes and oxidizes both pyruvate and lactate. In some muscle fibers (red and type IIb) mitochondria are not abundant enough to consume the increasing amounts of pyruvate due to an increase in glycolysis. Therefore, an increase in lactate is visible in these areas. Lactate acid is formed when a hydrogen ion is reduced (added) to the pyruvate. The hydrogen ion is carried by NADH+ into the mitochondria for oxidization unless there are not enough available mitochondria in the cell, then the NADH+ is oxidized (looses the H+) and pyruvate gets reduced (H+ added), forming lactate in the cytoplasm. Pyruvate always favors conversion to lactate, which will allow its transport into mitochondria. In the mitochondria, the lactate is oxidized to pyruvate by LDH and then oxidized by the tricarboxylic acid cycle (TCA cycle), which is another step toward the complete breakdown of glucose, producing ATP and NADH+. This complete process is referred to as the intracellular lactate shuttle (Brooks et al., 2000).

When removal of lactic acid is slower than its production, it results in H+ accumulation in the blood and muscles, which causes acidosis and inhibits phosphofructokinase and slows glycolysis. This indicates that the body’s system is failing to cope with metabolic demands and exercise will cease in order to regain homeostasis. Therefore, maintaining muscle glycogen levels and availability, increasing oxidation, and maintaining levels of metabolic bi-products (lactic acid) from accumulating is essential in exercise. Carbohydrate feedings prior to exercise
has shown to maintain these levels for an extended amount of time during exercise (Brooks et al., 2000).

Pre-Carbohydrate Feedings

The primary fuel source used for the working muscles during exercise depends highly on the intensity of exercise. At rest, approximately 60% of the energy is from lipid oxidation and the remainder is from carbohydrate oxidation (approximately 35%). During submaximal exercise (65-80% VO2max) fat oxidation only accounts for 10-45% of the energy expended and the remaining energy is taken from carbohydrates (Askew, 1984). Furthermore, during prolonged exercise, glycogen oxidation is even more of an essential fuel source for prolonging the time to fatigue. Therefore, during prolonged exercise, fatigue is associated with intramuscular glycogen depletion and hypoglycemia.

Carbohydrate pre-exercise ingestion has been found to increase time to fatigue due to a variety of factors such as; improving metabolic energy supply, maintaining blood glucose concentration (McConnell et al., 1999), preventing hypoglycemia (Schabort et al., 1999), increasing the rate of CHO oxidation (Sherman et al., 1991), reducing the rate of muscle glycogen utilization (Sherman et al., 1989; Hawley et al., 1992), contributing to hepatic energy reserves (Neuffer et al., 1987), and maintaining the concentration and availability of blood glucose (Bosch et al., 1993; Sherman et al., 1989). Bosch et al., (1993) found that during a cycle test of 180-minutes at 70% VO2max, all the subjects that ingested carbohydrates prior to exercising finished the 180-minute trial compared to only 50% finishing the trial in the group that did not pre-exercise carbohydrate load. In addition to exploring pre-exercise carbohydrate
ingestion on time to fatigue, some researchers have gone further in exploring what types of carbohydrates are most beneficial for performance enhancement.

**Glycemic Index and its Performance Effect**

The glycemic index (GI) was introduced by Jenkins and his colleagues (Frail and Buke, 1994) as a measure of the blood glucose responses to CHO foods on the basis of the nature of the starch and saccharides, any cooking or processing of the food, and the physical form of the food (Burke et al., 1993; Wolever, 1990). Carbohydrates are broken down into glucose and released into the bloodstream, the faster the glucose enters the blood determines the subsequent insulin response (Moseldy et al, 2003). When a rapid amount of glucose is released in the blood, as in the case of high GI foods, insulin is released in large quantities to stimulate the cell’s uptake of glucose, amino acids, and fats. When glucose concentrations falls below 3.5 mmol*1^-1 it is called rebound hypoglycemia (Decombaz, 1985). Rebound hypoglycemia reduces the energy potential and therefore diminishes performance. In addition, foods that are labeled as high GI foods are digested and absorbed faster than foods that are labeled as low GI foods. Many researchers have studied the effects of various GI levels before exercise and have produced contrasting results. Performance has been shown to be improved by pre-exercise ingestion of those foods that have low GI levels compared to foods that have high GI levels (Kirwan et al., 1998; DeMarco et al., 1999; Frail and Buke, 1994). Thomas et al. (1991) compared the exercise response after the ingestion of a low GI food (lentils), a high GI food (potatoes), and glucose and water one hour prior to exercising at 65-70% VO_2max until exhaustion. The group that ingested the low GI food showed significant endurance...
time improvements of 20 minutes, along with less post-prandial hyperglycemia and hyperinsulinemia, and higher levels of plasma glucose and free fatty acids (FFA) during critical periods of exercise than the high GI group (Thomas et al., 1991). While these researchers claim that pre-exercise consumption of low GI foods improve performance (Kirwan et al., 1998; DeMarco et al., 1999; Thomas et al., 1991), many other researchers have shown contrary results indicating no significant improvements (Wee et al., 1999; Febbraio and Stewart, 1996; Stannard et al., 2000; Sparks et al., 1998). It is noteworthy; however, that there were favorable metabolic changes in the low GI food groups, despite no difference in performance. These large discrepancies in the outcomes of the studies when using similar subject demographics may be due to variations in the methods used, such as; exercise intensity, meal composition, specific metabolic responses to the meals, exercise protocol, and timing of pre-exercise food ingestion.

In the previously mentioned studies, the timing of the pre-exercise food ingestions were given at 30 minutes (DeMarco et al., 1999), 45 minutes (Kirwan et al., 1998; Febbraio and Stewart, 1996; Sparks et al., 1998), 1 hour (Thomas et al., 1991), 65 minutes (Stannard et al., 2000), and 3 hours (Wee et al., 1999) prior to exercise. These differences may play a key role in the contradicting findings concerning exercise performance. Few researchers have evaluated time of carbohydrate feedings prior to exercise (Moseldy et al., 2003). Hawley and Burke (1997) identified two metabolically significant stages of pre-exercise ingestion of carbohydrate: 2-4 hours and 30-60 minutes. The 2-4 hours are essential in the replenishing of muscle glycogen and hepatic stores that have been depleted from
previous activity. Ingesting carbohydrates 4 hours before exercise has been shown to increase CHO oxidation (Coyle et al., 1985; Neuffer et al., 1987; Sherman et al., 1989). Ingesting carbohydrates 6 hours prior to exercise has been shown necessary to return metabolism to values found after an overnight fast (i.e., 12 h) (Montain et al., 1991). Flynn et al. (Flynn et al., 1989) observed no differences of substrate use and performance when increasing pre-exercise CHO ingestion time from 4 hours to 8 hours pre-exercise. The 30-60 minute stage prior to exercise is important in adding to the carbohydrate stores during prolonged exercise. In reviewing the literature, only one published study has examined the 30-60 minute pre-exercise carbohydrate ingestion on exercise performance (Moseley et al., 2003). Moseley L., Lancaster G., and Jeukendrup A. (2003) studied eight subjects in three trials ingesting carbohydrates 15-min, 45-min, and 75-min before starting exercise. The investigators concluded that there were no significant improvements in performance when comparing the three different timings of ingestion prior to exercise. The subjects in this study consumed a drink containing 75 g glucose, which would be considered a high GI food.