THE EFFECT OF HIGH-CARBOHYDRATE, LOW-FAT & LOW-CARBOHYDRATE, HIGH PROTEIN DIETS ON PHYSIOLOGIC AND PERFORMANCE VARIABLES ON ROW ERGOMETRY TRAINING

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This thesis entitled
THE EFFECT OF HIGH-CARBOHYDRATE, LOW-FAT & LOW-CARBOHYDRATE, HIGH PROTEIN DIETS ON PHYSIOLOGIC AND PERFORMANCE VARIABLES ON ROW ERGOMETRY TRAINING

by

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has been approved for
the School of Recreation and Sport Sciences and
the College of Health and Human Services

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This investigation examined the possible benefits or problems of high carbohydrate, low fat (high CHO) & low carbohydrate, high protein (low CHO) diets on row ergometry training and performance. The body’s metabolism changes with different fuel sources, but the changes in metabolism during exercise stress, while on the low CHO, high protein diet still remains unclear. The study included 18 fit, non-smoking males aged 18-40 from Ohio University. During the 7 week study these subjects were asked to consume a high CHO ($n=10$) or low CHO ($n=8$) diet and follow the same row training schedule. Anthropometric, strength & endurance, and other performance changes were collected pre- and post-training. Diet and performance data were also collected during the 7 weeks of training. It was hypothesized that there would be a difference in anthropometric measurements and performance in the low CHO group compared to the high CHO group. All statistical analysis was performed on SPSS Advanced Models 12.0 for Windows. The results showed no significant difference ($p < 0.05$) between the two groups in anthropometric, performance, and training variables. It was conclude low CHO diets do not provide any added benefits over a high CHO diet.

Approved:

Roger Gilders
Professor of Recreation and Sport Sciences
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Chapter 1.

Introduction

Research has shown that athletic performance is optimized with a diet high in carbohydrate (Mahan & Escott-Stump, 2000). However, low carbohydrate (low CHO), high fat diets are some of the most popular diets recommended on the market today. This type of diet is used by the general population for the purpose of weight loss and control of body weight. The use of this diet by an athletic population may allow for changes in body composition, but its effect on athletic performance are still largely unknown. This study attempted to determine the effects of a low carbohydrate (low CHO) diet on rowing physiology and performance.

Statement of Problem

An athlete may go to extreme lengths to acquire acceptable weight requirements in his or her sport. Athletes involved in sports such as wrestling, dance, rowing, and equestrian are more inclined to follow a low CHO diet as a way of obtaining desirable body weight. Athletic performance may be sacrificed for the ability to compete in a weight class.

Purpose

This study was necessary to contribute to the limited research conducted in the field of diet and exercise. It was the hope that this study would provide a greater understanding of diet composition in exercise to the field of exercise physiology, nutrition, sports medicine, and to the public in general. Such information is vital to the public and health professionals so that they are better able to make an informed decision with regards to dieting, training and athletic performance.
Significance

This study provides useful knowledge concerning the beneficial and/or harmful effects of this diet on rowing performance. The results could help explain why the body reacts differently to diverse concentrations of fuel sources. The information generated from this study could spawn new ideas about how close we are to the ideal diet with exercise.

Delimitations

Eighteen, male students from Ohio University participated in this study. The subjects were all physically active and in good health at the time of the study.

Limitations

The limitation of this study was the inability to control variables such as amount of sleep and outside physical activity. Subject’s psychological and emotional behavior also could not be controlled.

Assumptions

It was assumed that subjects followed all instructions recording their food logs and following the diet plan. It was also assumed that every subject did not change their physical activity outside the study for the duration of the research project.

Hypotheses

The first hypothesis of the study was there would be a significant improvement in oxygen consumption, muscular endurance, and strength as the result of the rowing training program. The second hypothesis of the study was the improvements in oxygen consumption, muscular endurance, and strength would not be different between the high CHO and low CHO group. The third hypothesis was there would be no change in body
fat, body weight, and fat free mass as the result of the rowing training program. The fourth hypothesis was there would be no training differences in body fat, body weight, and fat free mass between groups.

Definition of Terms

Terms inherent in this study are the following:

Food Log

A food log is a way of recording food consumption over a pre-determined period of time. The most common period of time is 3 days. In this study this included 2 week days and 1 week end day.

Graded Exercise Test

A graded exercise test is an exercise test in which the rate of work is increased gradually until fatigue or exhaustion is reached.

Heart Rate

Heart rate is the number of times the heart beats in 1 minute.

Hydrostatic Weighing

Hydrostatic weighing is a method used in determining body volume by submerging a person underwater. Body volume is used to determine body density and body composition.

Isokinetic

Isokinetic is an action in which the angular velocity is constant through the range of motion while maximum force is exerted.
Lactic Acid

Lactic acid is an end product of carbohydrate metabolism. It is primarily formed during anaerobic conditions.

Oxygen Pulse

The oxygen pulse is used to monitor trends in stroke volume and cardiovascular efficiency.

Peak Oxygen Consumption

The greatest rate of oxygen uptake obtained during a progressive intensity exercise bout. Peak oxygen consumption is determined when the criteria for maximal oxygen consumption are not reached. The criteria for maximal oxygen consumption are: a plateau in oxygen consumption, attainment of age-predicted maximum heart rate, rating of perceived exertion ≥18, lactic acid levels ≥8mmol/dl, and a respiratory exchange ratio of ≥1.1.

Respiratory Exchange Ratio

The respiratory exchange ratio is the ratio of carbon dioxide to oxygen consumed, determined at the level of the lungs. It is used to determine the percentage of carbohydrates and fats contributing to metabolism.

Row Ergometer

Row ergometer is an exercise device that allows the amount and rate of work to be controlled and measured.

Stroke Volume

Stroke volume is the amount of blood pump through each ventricle during one contraction of the heart.
Chapter 2.

Review of Literature

Overview of Topics

For purposes of this proposal a low CHO diet will be defined as anything lower than the recommended ADA diet (<45% of calories from carbohydrate) (Mahan & Escott-Stump, 2000). The percentage of fats and proteins in these diets may vary. Many of the popular diets fall into this category including Atkins, South Beach, Sugar Busters, Protein Power, and The Zone. The late Dr. Atkins, creator of the Atkins’ diet, believed weight gain was caused by too much carbohydrate intake that could lead to insulin resistance (Atkins, 2002). He advocated that a diet containing <20 grams/day of carbohydrate would force the body into a ketotic state, thus resulting in greater fat metabolism. The Protein Power diet prescribes <30 grams/day of carbohydrates (Eades & Eades, 1996). It also seeks to reduce insulin levels, which it identifies as the main culprit for increased cholesterol, triglycerides, and blood pressure. The proposed mechanism by which insulin produces these negative effects was never fully explained by either diet. The Sugar Busters diet describes the case of sugar toxicity (Stewart, Bethea, Andrews, & Balart, 1995). People on this diet are asked to consume more low-glycemic index foods which would lower insulin levels. A lower concentration of insulin in the blood was believed to alter the body’s metabolism into a fat burning mode which would eat away fat deposits around the waist and thigh regions. Finally The Zone diet, which was the least carbohydrate restrictive of them all, encourages people to consume a diet that is 30% protein, 30% fat, and 40% carbohydrate (Sears & Lawren, 1995). Eating in
such a manner would cause the dieter to be in a very efficient metabolic state, the “zone”, and would lead to better feelings of comfort and would produce more energy.

America’s obsession with dieting is nothing new. According to polls conducted in May 2004 by CBS News, it was estimated that 26 million Americans were currently on a low CHO diet and 70 million consciously restricted their carbohydrate intake (Senay, 2004). It has even been speculated that low CHO diets were to blame for the rise in the price of meat (Sherman, 2003). The number of athletes and exercising-dieters on a low CHO diet is unknown. This type of diet is appealing to athletes involved in sports with weight requirements such as: rowing, dance, equestrian, wrestling, and boxing because it may provide a “quick fix” to their weight problem. A low CHO diet is advertised as having a faster rate of weight loss than most diets (Atkins, 2002). Athletes on this type of diet create a possible cause for concern. No evidence, as of yet, is available about the effects of a low CHO diet on health and performance.

Altered Metabolism

When a low CHO diet is consumed the body must make adjustments to accommodate for the changes in fuel sources. Cutler et al. (1995) reported a significant decrease in the activity of skeletal muscle pyruvate dehydrogenase (PDH) in men on an 8% carbohydrate diet during a 3 week exercise program. When PDH was limited glucose oxidation dramatically declined. The subjects became more dependent on fat as the main fuel source and were only producing a minimal amount of lactate as a result of the low CHO diet.

Cutler et al. (1995) reported an increase in lipid oxidation in a low CHO group as compared to the high CHO group after a 3 week exercise program. Metabolism switched
from a carbohydrate burning mode to more of a fat burning mode. The amount of free fatty acids (FFA) in circulation was twice as high in the low CHO group. The following factor was suggested as a probable cause in the shifting of metabolism: the low CHO group was ingesting a higher percentage of fat in their diet which caused an increase in FFA and although it was not examined, it was speculated that beta-oxidative enzymes were higher in the low CHO group (Cutler et al., 1995).

In the same study, two other enzymes in glycolysis, phosphofructokinase and hexokinase, decreased activity levels in the low CHO group after the subjects were tested again at the end of the exercise program (Cutler et al., 1995). This was expected because the metabolic by-products required for their activation were not present in the carbohydrate depleted state. The activity level of glycogen synthase stayed the same in a standard diet (51% carb, 35% fat, and 14% protein) and a low CHO diet after 3 weeks of physical activity (Cutler et al., 1995). Although the total amount of glycogen stored was different (the standard diet group had increased their skeletal muscle glycogen stores), the activity level of glycogen synthase was constant in both groups. With only a few studies reporting on the subject, it is still too soon to speculate on the activity of glycogen synthase following a carbohydrate restricting diet.

Goedecke et al. (1999) found there was a significant increase in carnitine acyltransferase in the skeletal muscle after consumption of a low CHO diet and completing a training program. Skeletal muscle appeared to be adapting to the amount of fat ingested through the diet by creating more L-carnitine to shuttle the free fatty acid (FFA) molecules into the mitochondria. Podolin, Wei, and Pagliassotti (1999) found the process of gluconeogenesis was increased in the body when consuming a high fat diet.
The true mechanism was never fully explained. Many organ systems in the body such as the nervous system depend heavily on glucose as the primary energy source. If the diet is low in carbohydrates, the metabolism will shift so that carbohydrate can be built from glycerol backbones and amino acids.

The biggest reason why low CHO diets work is because they slow down the secretion levels of insulin from the pancreas. Every low CHO diet suggests insulin is the main culprit of obesity and overweight problems. Certain types of sugars, highly refined with a high glycemic-index, are more problematic according to Dr. Atkins (Atkins, 2002). In any event ingestion of carbohydrates triggers an insulin response from the pancreas. Insulin has a variety of functions inside the body including stimulating the glucose-4 receptors inside the muscle cell to increase glucose uptake. It also stimulates the activity of an enzyme known as Acetyl CoA Carboxylase which is involved in a reaction that converts FFA into stored fat (Berg, Tymoczko, & Stryer, 2002).

Carbohydrate ingested will lead to increases in insulin production and secretion which will stimulate Acetyl CoA Carboxylase to store more fat and increase a person’s adipose stores. The low CHO entrepreneurs suggest bypassing this process by simply consuming less carbohydrate. Langfort, Zarzeczny, Nazar, Pilis, and Kaciuba (1997) found that insulin levels are lower in subjects consuming a diet of 5% carb, 50% fat, and 45% protein at rest after a few weeks of consuming the diet. In a study conducted by Lavoie, Peronnet, Cousineau, and Provencher (1984) evaluating the effects of a low CHO diet (10% CHO) on endurance training found insulin levels to drop considerably 24 hours before and during the training bout after adaptation to the diet occurred.
Athletic Performance

There are very few studies investigating the potential effects of a low CHO diet on athletic performance, particularly rowing. There are a few reasons for this limitation. One, the popularity of low CHO diets have only begun to rise in the last few years and there was no justification for this type of research in the past. Two, it has been well established that carbohydrate requirements are much higher for athletes (Mahan & Escott-Stump, 2000). However, more and more research is beginning to be conducted on low CHO diets and exercise simply because of the increased demand for this knowledge.

Research conducted by Roltsch, Flohr, and Brevard (2002) showed there were no significant changes between untrained groups in maximal aerobic capacity (VO₂ max) after 7 days of consuming a high CHO, low CHO, high fat, or normal diet. A VO₂ max test was completed a day prior to the start of the diet and on the final day of the diet.

Kavouras, Troup, and Berning (2004) found similar results after examining the effects of a 3 day high CHO or low CHO diet on cycling exercise.

Simonsen et al. (1991) examined the effects of a low CHO and high CHO diet on 4 weeks of rowing endurance. Subjects were required to row twice a day at 70-90% of VO₂ max. A timed test of endurance was completed prior to the start of the diet and again at the end of 4 weeks. The results indicate that neither diet led to endurance impairment during rowing training. It was thought that the subjects may have adapted to the low CHO diet by utilizing more fat or by converting more dietary carbohydrates into muscle glycogen (Simonsen et al., 1991).

Helge, Richter, and Kiens (1996) found significant differences in endurance tests to exhaustion between a high CHO and low CHO diet after 8 weeks of a cycling program. The high CHO group increased their time...
to exhaustion by 191% as compared to the 68% achieved by the low CHO group. Though highly debatable, unpublished research conducted at the Copenhagen Muscle Research Center has shown low CHO, high fat diets can change the composition of phospholipids on the sacroplasmic reticulum (SR) of skeletal muscle such that calcium transport could be limited (Helge et al., 1996). Muscle endurance would be negatively affected by requiring more energy to operate the calcium pumps on the SR.

Van Zant, Conway, and Seale (2002) studied the effects of a high CHO and low CHO diet on strength performance in moderately trained athletes. Each subject consumed both diets for 3 weeks in a randomly assigned crossover design. Subjects were tested prior to the start of the diet and again on the final day of the diet using a one repetition maximum (1 RM) bench press. Strength training was monitored throughout the study. The findings indicate there was no significant difference in 1 RM between the groups or with training (Van Zant et al., 2002). Muscular strength is not altered when variations in macronutrient content occur.

Low CHO diets may directly inhibit muscle mass gains in training athletes. If an athlete were to consume a diet high in protein and fat and low in carbohydrates, the body will accommodate by making changes in metabolism. When carbohydrate ingestion is decreased for long periods of time, new sources of oxaloacetate must be found. Oxaloacetate is normally produced from intermediate steps of glycolysis (Berg et al., 2002). Oxaloacetate is required in the formation of citrate as part of the Kreb’s Cycle. The only way fat can be utilized as a fuel source is through the metabolism of the Kreb’s Cycle. If there is little-to-no carbohydrate in the diet (and hence in the body), no oxaloacetate will be formed to run the Kreb’s Cycle and burn fat. Studies conducted by
Czarnowski, Langford, Pilis, and Gorski (1995); Langfort et al. (2001); and Volek, Sharman, Gomez, Scheet and Kraemer (2003) have all reported that there is an increase in fat oxidation while on a low CHO diet. Oxaloacetate can also be formed from an alternative fuel source: protein (Berg et al., 2002). The break down of the body’s own proteins (dietary and somatic) can possibly serve as a facilitator in fat utilization. It is believed the catabolism of somatic proteins found in the skeletal muscle could lead to significant losses in fat free mass or inhibiting muscle growth and development.

Health Implications

Low CHO diets have been criticized for promoting the consumption of more fat, particularly saturated fat, in the diet. Eating more fat can increase the risks of cardiovascular disease by increasing atherosclerotic plaque forming in blood vessels (Mahan & Escott-Stump, 2000). Anderson, Konz, and Jenkins (2000) developed a computer program to study the effect of popular low CHO diets on the body’s blood lipids. A mathematical formula was devised taking into account the amount of fat, protein, carbohydrate, and calories present in a typical diet. After entering prescribed low CHO diets from Atkins, Protein Power, Sugar Busters, and the Zone a computer printout comparing the diets was made. It was calculated that the Atkins and Protein Power diets would significantly increase total cholesterol by 37.3mg/dl and 21.1mg/dl respectively. The Zone and Sugar Busters diet were shown to decrease total cholesterol levels (Anderson et al., 2000). Some of the most severe carbohydrate restrictions are made by the Adkins’ and Protein Power diets. In these diets the dieter is recommended to eat all the meat he or she desires without taking into consideration fat content. The Sugar
Busters and The Zone diets recommend to their dieters to limit their fat consumption by reducing their meat intake and focus more on fruits and milk (Anderson et al., 2000).

Cardiovascular disease and low CHO diets is an area of heated debate. There is evidence on both sides of the argument to suggest beneficial/harmful effects of a low CHO diet. Obarzanek, Velletri, and Cutler (1996) reviewed all literature on low CHO diets and hypertension prior to 1996 and concluded there was no association between the two. Foster et al. (2003) followed 63 people for a year on the Atkins’ diet. Subjects in the Atkins’ diet group had positive changes in triglycerides and high density lipoprotein-cholesterol (HDL-C) at the end of the study (Foster et al., 2003). The diet was shown to reduce risk factors associated with coronary heart disease. Alford, Blankenship, and Hagen (1990) and Skov, Toubro, and Ronn (1999) found no significant differences in lipid profiles between subjects consuming a high or low CHO diet. The argument can best be summed up by a review on the efficacy and safety of low CHO diets. Bravata et al. (2003) conducted a review of 2,609 articles relating to low CHO diets and concluded that there was insufficient evidence to make recommendations for or against the use of low CHO diet for chronic use or with exercise.

There are several other health considerations that must also be taken into account before consuming a low CHO diet. High fat, low CHO diets have been shown to induce insulin resistance in rats (Rosholt, King, & Horton, 1994) and in humans (Culter et al., 1995). Bone mass reduction can result after chronic consumption of a low CHO diet by causing metabolic acidosis which may increase osteoclastic or decrease osteoblastic activity (Bushinsky, 1994 & Kurtz, Maher, & Hulter 1983). Some studies suggest there is an increase risk for osteoporosis when dietary protein is increased (Abelow, Holford, &

Kidney disease is thought to be caused or exacerbated by a high protein, low CHO diet (Dwyer, Madans, & Turnbull, 1994). Patients on kidney dialysis are required to limit protein intake to slow progression of the disease. High protein, low CHO diets are believed to cause hyperfiltration by destroying the glomerular filtration process and inhibiting the kidney from controlling electrolyte and water balance (Brandle, Sieberth, & Hautmann, 1996; Rodriguez-Iturbe, Herrera, & Garcia, 1988; Schuette, Zemel, & Linkswiler, 1980).

Summary

Low CHO diets are widely known to cause significant weight loss in a short amount of time (Mahan & Escott-Stump, 2000). And for this reason, athletes trying to make a certain weight class may find the diet as an attractive alternative to calorie restrictions or more exercise to lose those few extra pounds. Metabolism is altered when consumption of a carbohydrate restrictive diet occurs. When key enzymes of glycolysis are inhibited, fat becomes the primary fuel source and skeletal muscle protein is catabolised and used in fat metabolism. As a result, changes may occur in muscle strength, size, and endurance. There are still too few studies published on the topic to provide any clear answer on how a lower CHO diet may affect athletic performance. This study attempts to determine the effects of a low CHO diet on athletic performance in the hopes of providing new understand about changes in physiology and metabolism after 7 weeks of row training.
Chapter 3.

Methods

This study was conducted over a 10 week period starting in January 2005 and ending in March 2005. The first 2 weeks included all pre-testing procedures and instructions in rowing technique, and diet intervention and maintenance. Subjects were randomly placed into a high or low carbohydrate group and given proper instruction of food choices to maintain this diet. Before initiating the training program the following tests were performed to evaluate exercise performance: isokinetic leg extension (muscular strength and endurance), hydrostatic weighing (body composition), and maximum oxygen consumption (aerobic capacity). Each test was conducted at least 1 day apart.

Prior to the initiation of training and during each week of the training program urinary ketone analysis was performed. Subjects also filled out a 3 day food log every other week during the training period. Four food logs were collected and analyzed for each subject. After the training concluded, subjects’ exercise performance was retested in the identical fashion of the pre-testing. On the 10th week, subjects performed another Biodex test, hydrostatic weighing, and a graded exercise test (GXT). Upon the conclusion of data analysis the subjects were given a report of their performance during the study. The research project was conducted in Ohio University’s Exercise Physiology Lab and weight room. A schedule of the study protocol was as follows:

Week 1 & 2    -    Pre – Testing

Rowing and Dietary Instruction
Week 3 – 9 - Exercise Training

Food logs collected at the end of week 4, 6, 8, & 9.

Week 10 - Post - Testing

Subjects

Twenty male, non-smoking, fit subjects aged 19-40 years old were recruited from Ohio University and Athens county. Recruitment flyers for the study were distributed to all the residence halls at Ohio University. The flyers (see Appendix A) contained a brief outline of the study and investigator contact information. Subjects were also recruited through announcements made in the beginning of undergraduate classes in the Department of Biological Sciences and the College of Health and Human Services at Ohio University. In addition, an informational meeting was held for all prospective subjects prior to the start of the study explaining the study. The testing, training, and dieting procedures required for participation in this study were explained at this meeting. Once the subjects indicated their interests to participate, they were asked to complete a health history questionnaire and an informed consent document (see Appendix B). Criteria for exclusion were dealt with on case by case bases; however, in general, subjects were excluded from the study if they suffered from cancer, gastrointestinal, lung, kidney, and liver disease, or reported the use of anabolic steroids, recreational drugs, and diuretics. Subjects read and signed a consent form approved by Ohio University’s Institutional Review Board (IRB) prior to the beginning of the study. All personal information was kept confidential. Any identifiers used in the research were destroyed at the end of the study. Ohio University’s IRB committee reviewed and accepted this study’s research plan and methodology (see Appendix D).
The subjects were pair-matched based on their pre-test GXT oxygen consumption values. They were randomly assigned from these pairs into one of the two dietary groups. The subjects were instructed to train using only the prescribed rowing program. Subjects currently performing regular exercise were allowed to participate under the condition they did not alter any of their current exercise routines. To ensure the subjects were not deviating from exercise outside the study an exercise/activity questionnaire (see Appendix C) was completed by each subject prior to the initiation of the pre-trial testing period and again at the end of the study at the time of the post-testing. This questionnaire documented all physical activity occurring outside the training sessions during the study.

Groups

The subjects were randomly selected into one of two groups: high CHO group or low CHO group. In each diet, the subjects monitored servings of carbohydrate, protein, and fat. Although this diet plan did not restrict the total amount of calories consumed by the subject, it did however, suggest a range of total calories the subjects should consume daily by determining an estimate of total energy expenditure (TEE) calculated using the Harris-Benedict formula (Mahan & Escott-Stump, 2000). The Harris-Benedict formula takes into consideration resting energy expenditure (REE), physical activity levels, and the thermal effect of food (TEF). The formula is as follows:

\[
\text{REE(kcal)} = 66.5 + 13.75(W) + 5.0(H) - 6.78(A)
\]

where \(W = \text{weight in kilograms}, H = \text{height in centimeters}, \) and \(A = \text{age}.\)

The REE was multiplied by a Physical Activity Level indicator, a number between 1.2 and 2.4 (see Appendix E) and then additional 10% for TEF to calculate TEE.
Diet

A diet plan was provided to all the subjects in both dietary groups. The plan closely followed the recommendations of Butki, Baumstark, and Drive, (2003): 50% protein, 35% fat, and 25% CHO in the low CHO group and 55% CHO, 30% fat, and 15% protein in the high CHO group. Meal recommendations for both groups included: a breakfast, lunch, dinner, and snacks. A food guide pyramid adjusted to each diet plan, example diets, serving sizes, a list of foods that should be included in the diet, and foods not to be included were provided to the subjects in the form of handouts (see Appendix F & G). Verbal and written instructions were given on how to prepare and measure the food and how to record the food consumed on a daily food log (see Appendix H). Dietary instruction was supervised by a registered dietitian. The subjects’ diet was analyzed four times every other week throughout the study from a 3 day food log for the total caloric intake, and fat, protein, alcohol, and carbohydrate percentages. The subjects recorded their diet on 2 week days and 1 weekend day. Food logs were due at the end of weeks 4, 6, 8, and 9 of training. All food logs were analyzed using Diet Analysis Plus Version 6.0 (ESHA Research, Oregon). If the subjects were not on track with the diet plan, appropriate adjustments were made with more diet instruction (Hays et al., 2004). The diet was initiated 4 days before the start of the training and was terminated 4 days before the post-testing began. Therefore both pre- and post-testing were performed when the subjects’ were consuming their normal diet.

Ketostix dip sticks (Bayer, Pittsburgh) were used to monitor relative urinary ketone production. A urine sample was taken before the beginning of training at the end of every week to provide updates on their ketone production. The goal of this study was
not to push subjects to the point of ketosis that might occur with extremely low carbohydrate intakes. The Ketostix was dipped into the urine sample and immediately removed. After a 15 second waiting period, the stick was analyzed by comparing its color to a standard of colors which indicate ketone levels in the body. If ketones were present in trace or moderate amounts the subject was asked to provide another sample the following day. If the urine sample on the following day was also positive, adjustments were made in the diet by increasing the total percentage of carbohydrates.

Training

Two sessions were held during the instructional week for the subjects to learn proper rowing technique through the use of an instructional video (Concept 2, Vermont) and hands-on experience with the row ergometer. Here the subjects were trained how to record heart rate, power, document time, and duration from the ergometer. After the instruction and pre-testing sessions were completed the subjects began their training. The 7 week rowing training protocol (developed by Bonnie Hagerman in the Ohio University’s Exercise Physiology Lab, 2000) was as follows:

**Instructional week:** 2 days/week 5-minute rowing at comfortable intensity 3 sets with 4-minute rest between sets

**Week 1:** 2 days/week 5-minute rowing at 70% of maximum power output (determined from the GXT pre-test)/ 4 sets with 4-minute rest between sets

**Week 2:** 2 days/week 5-minute rowing at 70% of maximum power output (determined from the GXT pre-test)/ 4 sets with 3-minute rest between sets

**Week 3:** 2 days/week 10-minute rowing at 70% of maximum power output (determined from the GXT pre-test)/ 2 sets with 5-minute rest between sets
Week 4: 3 days/week 10-minute rowing at 80% of maximum power output (determined from the GXT pre-test)/ 2 sets with 5-minute rest between sets

Week 5: 3 days/week 10-minute rowing at 80% of maximum power output (determined from the GXT pre-test)/ 3 sets with 4-minute rest between sets

Week 6: 3 days/week 10-minute rowing at 80% of maximum power output (determined from the GXT pre-test)/ 4 sets with 5-minute rest between sets

Week 7: 2 days/week 10-minute rowing at 80% of maximum power output (determined from the GXT pre-test)/ 4 sets with 5-minute rest between sets

The subjects were given a choice of Monday-Thursday or Tuesday-Friday routine for the first 4 weeks and last week of training. When an extra day was added to the training protocol in weeks 4, 5, and 6, subjects were given a choice of working out on a Monday-Wednesday-Friday or a Sunday-Tuesday-Thursday schedule. If a subject missed a training session he was asked to make it up the following day. More than three missed sessions resulted in disqualification from the study. No subject was disqualified for missing training sessions. Week 7 had two training sessions. This allowed the subject time to make up any missed training session(s).

A Polar A5 heart rate monitor (Polar Electro Inc., New York) was used to monitor heart rate during exercise. The subjects recorded their exercising heart rates as soon as the exercise bout was completed.

The Concept 2 Model B Indoor Rower (Concept 2, Vermont) was used to test and train the subjects. Instructions were given on the rate and intensity of the training bouts desired in the study. An exercise plan was written on the subject’s training log daily (see Appendix I). The plan consisted of a warm-up phase (5-10 minutes), exercise
phase (approximately 15-40 minutes), and warm-down phase (5-10 minutes). The intensity during the exercise phase was changed weekly to allow them to train in the range of 70-90% maximum power output.

Graded Exercise Test

Changes in cardio-respiratory function were evaluated using open-circuit spirometry. Oxygen consumption (VO₂), carbon dioxide production (VCO₂), and respiratory exchange ratio (RER) were measured during the graded exercise test (GXT). This required the subject to wear a nose clip and breathe through a mouth piece connected to a one-way breathing valve throughout the testing phase. The mouth pieces were sanitized according to manufacturer’s specifications with Alconox Johnson & Johnson (White Plains, New York) and Cirtanox Johnson & Johnson (White Plains, New York). The subject’s expired air was analyzed by Vacu-Med’s Turbofit 5.04a (Vacu-Med, California) metabolic system and VO₂, VCO₂, and RER were calculated. Vacu-Med’s gas analyzer Model 17515 for CO₂% and Model 17518 for O₂% (Vacu-Med, California) were used to measure the fractional expired gases after being calibrated according to manufacturer’s specifications. Peak oxygen consumption was determined during a progressive intensity protocol on the row ergometer that was terminated with a maximal intensity exercise stimulus. Heart rate was monitored and recorded every minute. The intensity (measured by power output) began at 80-120 Watts and increased in increments of 20 Watts per minute. This procedure lasted approximately 8-12 minutes. After the test was completed the subject was asked to cool down quietly for 5 minutes and then a blood sample approximately 150µl was drawn into a capillary tube following a finger prick using a lancet (MediSense, Illinois). The blood sample was then
placed in a storing tube containing a hemolyzing and antiglycolytic agent (Camco Platecount, Florida) and was immediately refrigerated. The blood was analyzed for lactate concentrations 5-8 hours after the exercise bout using the Yellow Spring Instrument 2300 STAT Plus (Yellow Springs, Ohio) which was autocalibrated.

Oxygen pulse ($O_2$ pulse) was calculated to determine if changes in stroke volume and/or A-VO$_2$ difference occurred as a result from the diet and/or training. The following formula was used to calculate $O_2$ pulse (Roitman & Herridge, 2001):

$$O_2 \text{ pulse} = \frac{VO_2 (ml/min)}{HR (bt/min)}$$

**Strength and Endurance**

Strength changes for maximal knee extension were determined from pre and post training measurements using the Biodex Isokinetic device during the study. The Biodex Isokinetic system was calibrated according to the manufacturer’s specifications. The subject performed two sets of three maximal repetitions with 1 minute rest in between each set. A speed of 30°/sec was used on the concentric phase and the highest torque value was recorded. After 1 minute the strength measurements had concluded a Thorstensson Test was performed to evaluate muscular endurance. This test required the subject to perform 30 maximal repetitions at a speed of 180°/sec. A fatigue index (Surakka et al., 2004) measurement was generated to assess the subjects’ overall endurance. Fatigue index (FI) was derived from the following formula:

$$FI = \frac{(\text{mean torque of the last third of contractions}) \times 100}{(\text{mean torque of the first third of contractions})}$$

**Body Composition**

Body composition was analyzed with the use of hydrostatic weighing, which uses water displacement to calculate body density. This procedure uses a force transducer
(West Coast Research, California) hooked to a plastic framed chair suspended in the water. Prior to the procedure the instruments were calibrated according to the manufacturer’s specifications. The subjects were instructed to wear only swimming trunks and all jewelry was removed before they entered the tank. The subject first entered the water and scrubbed off any air bubbles caught on the skin, hair, or swimming trunks. He then sat on the chair and when instructed, he began to forcefully exhale all the air in his lungs and completely submerge himself under the water. Four trials were conducted in order to insure accuracy. The signal from the force transducer was displayed on a computer. The voltage from the force transducer was processed by the Acknowledge computer program (Biopac, California) as a calibrated load or weight. The formula for body density (Roitman & Herridge, 2001) was as follows:

\[
\text{Body density} = \frac{\text{Weight in air}}{\left[\frac{\text{Weight in air} - \text{Weight in water}}{\text{Density of Water}}\right] - (\text{Residual Volume} + 0.10)}
\]

Where residual volume (Roitman, 2001) was estimated using the following formula:

\[
\text{RV} = 0.017 \times \text{age in years} + 0.06858 \times \text{height in inches} - 3.477
\]

Body weight in the air was recorded on an electronic scale (Toledo, Ohio) and was also monitored throughout the study.

After the body density was calculated, the Siri’s formula (Steinkamp et al., 1965) was used to calculate body fat percent. The body fat percent formula is as follows:

\[
\% \text{ body fat} = \frac{(4.950/\text{body density}) - 4.500}{100}
\]

Testing Procedure

The 1st day of testing required the subjects to perform muscular strength and endurance tests on the Biodex isokinetic device. Each Biodex testing session lasted
approximately 20 minutes. After at least 24 hours rest the subjects returned for the 2nd
day of testing. On the 2nd day of tests the subjects completed a GXT. These tests
generally lasted around 8-12 minutes. Hydrostatic weighing and body weight
measurements were performed on all the subjects a day after the VO₂max tests. The
hydrostatic weighing procedure took approximately 20-25 minutes to collect all the data.
During the final 2 days of the 1st week of the study the subjects were provided diet
instruction. This instruction lasted about 25-30 minutes. The 2nd week was used for
anyone who could not schedule a testing time in the 1st week.

The last 2 weeks of the academic quarter modeled the first 2 weeks of the quarter
with the exception of diet and rowing instruction. Post-study testing and measurements
were all conducted in the same order as the pre-study testing. A post exercise/activity
questionnaire was filled out upon completion of the GXT. And a performance evaluation
report was offered to the subject as a sign of courtesy for participation in the study. It
contained information regarding the subject’s personal testing results and the four diet
reports.

Statistics

All data gathered from coded and statistically analyzed by SPSS Advanced
Models 12.0 for Windows (Chicago, IL). Analyses of variance (ANOVA) were
conducted on the group’s means using a two-way (Group x Time) model to evaluate the
changes between pre- and post-tests and between groups. If a significant difference was
found, means of interest were compared using paired t-tests. Significance was considered
at an alpha level less than 0.05.
Chapter 4.

Results

Training Groups

The study started with 20 subjects including 10 within each group. All 10 of the subjects in the high CHO group completed the study, however only 8 of the 10 subjects in the low CHO group finished the training and the post training testing. One subject dropped out from the low CHO group during the 3rd week of training citing problems with his gastrointestinal tract, sleeping, and depression as reasons for quitting the study. The other subject was removed from the study due to excessive absences from training and the inability to provide completed food logs in a timely matter. General subject data is listed in Table 1. Subjects were pair-matched based on their pre training GXT performance. There was no significant difference in pre-VO$_2$peak [$t = -0.047, df(1,16), p = 0.967$], height [$t = -0.096, df(1,16), p = 0.925$], age [$t = -0.889, df(1,16), p = 0.387$], and weight [$t = 0.876, df(1,16), p = 0.394$] between the groups.

Ketone levels were checked every week throughout the study. Two subjects in the low CHO group tested positive for ketones. One subject tested with trace amounts on 2 separate day (5mg/dl) and another had a moderate level (40mg/dl) of ketones on separate occasions. The follow up test on the next day were negative for both subjects. No subjects in the high CHO group tested positive for ketones.

The exercise logs recording all physical activity outside the study suggested there was no significant difference in activity levels between groups [$F = 0.723, df(1,16), p = 0.408$] or from the beginning to the end of the study [$F = 0.027, df(1,16), p = 0.872$]. The high CHO group recorded an average physical activity level (reported in minutes) of
132.00±69.57 during the pre-testing and 127.50±60.93 following the post-testing. The low CHO group recorded an average pre-testing physical activity level of 161.25±118.856 and 159.38±93.825 during the post-testing. Running, jogging, cycling, and weight lifting were some of the more common activities listed by the subjects.

Table 1

Descriptive Data of Training Groups

<table>
<thead>
<tr>
<th>Variables</th>
<th>High CHO</th>
<th>Low CHO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Subjects</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>70.64±2.43</td>
<td>70.76±2.98</td>
</tr>
<tr>
<td>Age</td>
<td>22.40±2.75</td>
<td>23.75±3.69</td>
</tr>
<tr>
<td>Pre-Training Weight (kg)</td>
<td>79.30±11.57</td>
<td>74.61±10.90</td>
</tr>
<tr>
<td>Pre-VO_{2}\text{peak} (ml/kg/min)</td>
<td>55.44±9.30</td>
<td>55.61±7.43</td>
</tr>
</tbody>
</table>

Diet

The average of four food logs intake of macronutrients over the 7 week training period was significantly different between groups (see Table 2 and Figures 1 and 2): carbohydrate \([t = 8.709, df(1,16), p = 0.000]\), protein \([t = -7.37, df(1,16), p = 0.001]\), and fat \([t = -3.829, df(1,16), p = 0.001]\). There was no significant difference in alcohol consumption between the two groups \([t = 1.72, df(1,16), p = 0.105]\) (see Table 2). There was also no significant difference in total caloric consumption between the two groups \([t = -0.359, df(1,16), p = 0.724]\) (see Table 2). Based on the Harris-Benedict formula both groups were hypocaloric, however, there was no significant difference between the
two groups on how much they were underfed \(F = 0.031, df(1,16), p = 0.863\). The amount of calories \(F = 0.276, df(1,16), p = 0.601\), carbohydrate \(F = 0.935, df(1,16), p = 0.427\), protein \(F = 1.254, df(1,16), p = 0.295\), fat \(F = 0.788, df(1,16), p = 0.382\), and alcohol \(F = 1.072, df(1,16), p = 0.365\) consumed over the 7 week period did not significantly differ with training in the groups from food log 1, food log 2, food log 3 and food log 4 (see Figures 1, 2, & 3).

Table 2

*Mean Nutrient Intake*

<table>
<thead>
<tr>
<th>Variables</th>
<th>High CHO</th>
<th>% from Goal</th>
<th>Low CHO</th>
<th>% from Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Carbohydrate*</td>
<td>56.47±5.32</td>
<td>(+3%)</td>
<td>30.62±7.28</td>
<td>(+18.3%)</td>
</tr>
<tr>
<td>% Protein*</td>
<td>14.26±1.74</td>
<td>(-4.9%)</td>
<td>29.90±6.46</td>
<td>(-40.2%)</td>
</tr>
<tr>
<td>% Fat*</td>
<td>26.03±4.50</td>
<td>(-13.2%)</td>
<td>38.54±9.07</td>
<td>(+9.2%)</td>
</tr>
<tr>
<td>% Alcohol</td>
<td>3.35±3.36</td>
<td>N/A</td>
<td>1.06±3.36</td>
<td>N/A</td>
</tr>
<tr>
<td>Predicted Calories</td>
<td>4,190±408.11</td>
<td>N/A</td>
<td>4,025±397.31</td>
<td>N/A</td>
</tr>
<tr>
<td>Actual Calories</td>
<td>2,502±350.96</td>
<td>[-40.3%]</td>
<td>2,605±820.28</td>
<td>[-35.3%]</td>
</tr>
</tbody>
</table>

Note. * Significant difference between groups, \(p < 0.05\); (indicates the absolute % from goal, where a (-) indicates a deficit and a (+) excess of the goal); [indicates the absolute % from predicted value, where a (-) indicates a deficit and a (+) excess of the predicted value]. Not applicable (N/A).
Figure 1. High CHO groups' average total intake of four food logs.

Figure 2. Low CHO groups' average total intake of four food logs.
Figure 3. Average daily caloric intake throughout the study.

Training Variables

There were a significant difference between groups with training intensities in average power outputs from training day 1 to day 6, day 7 to day 13, and day 14 to day 17 \( F = 208.621, df(1,16), p = 0.000 \) (see Tables 3 & 4 & Figure 4). No significant changes were found in average power outputs with training between day 1 to day 6, day 7 to day 13, and day 14 to day 17 \( F = 1.043, df(1,16), p = 0.375 \) (see Tables 3 & 4 & Figure 4).

There was a significant decrease in the low CHO groups’ training heart rates compared to the high CHO group from training day 1 to day 6, day 7 to day 13, and day 14 to day 17 \( F = 46.505, df(1,16), p = 0.000 \) (see Tables 3 & 4 & Figure 5). No changes were found with training from day 1 to day 6, day 7 to day 13, and day 14 to day 17 \( F = 4.787, df(1,16), p = 0.06 \) (see Tables 3 & 4 & Figure 5).
Table 3

*Training Responses in the High CHO Group*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Day 1 to 6</th>
<th>Day 7 to 12</th>
<th>Day 13 to 17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute Intensity (Watts)</td>
<td>177±26.80*</td>
<td>189±24.30*</td>
<td>186±24.30*</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>175±2.74*</td>
<td>177±2.07*</td>
<td>172±2.30*</td>
</tr>
</tbody>
</table>

Note. * Significant difference between groups, *p* < 0.05

Table 4

*Training Responses in the Low CHO Group*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Day 1 to 6</th>
<th>Day 7 to 12</th>
<th>Day 13 to 17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute Intensity (Watts)</td>
<td>158±15.30*</td>
<td>165±15.60*</td>
<td>165±17.20*</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>174±3.33*</td>
<td>174±2.48*</td>
<td>166±1.58*</td>
</tr>
</tbody>
</table>

Note. * Significant difference between groups, *p* < 0.05
Figure 4. Average training power outputs throughout the study.

Note. * Significant difference between groups, $p < 0.05$

Figure 5. Average training heart rate throughout the study.

Note. Figure 5 shows the average HR for each of the 17 training days. * Significant difference between groups, $p < 0.05$
Performance Evaluations

Strength assessment on the Biodex leg extension apparatus showed no significant differences in leg strength from pre-testing to post-testing between groups \([F = 1.383, df(1,16), p = 0.257]\) or with training \([F = 0.067, df(1,16), p = 0.799]\) (see Tables 5 & 6, Figure 6).

Table 5

*Muscular Strength and Endurance in the High CHO Group*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Pre</th>
<th>Post</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leg Extension (ft/lbs)</td>
<td>219.29±29.06</td>
<td>227.07±31.98</td>
<td>+3.43</td>
</tr>
<tr>
<td>Fatigue Index (%)</td>
<td>75.27±9.09</td>
<td>69.05±13.81</td>
<td>-8.27</td>
</tr>
<tr>
<td>Total Work (Joules)</td>
<td>1691.22±405.20**</td>
<td>1896.59±383.06**</td>
<td>+10.83</td>
</tr>
</tbody>
</table>

Note. ** Significant difference between groups, \(p < 0.05\)

Table 6

*Muscular Strength and Endurance in the Low CHO Group*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Pre</th>
<th>Post</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leg Extension (ft/lbs)</td>
<td>199.10±54.27</td>
<td>204.45±42.77</td>
<td>+2.62</td>
</tr>
<tr>
<td>Fatigue Index (%)</td>
<td>73.17±12.54</td>
<td>63.02±6.65*</td>
<td>-13.88</td>
</tr>
<tr>
<td>Total Work (Joules)</td>
<td>1138.50±329.47**</td>
<td>1700.67±485.65* **</td>
<td>+33.06</td>
</tr>
</tbody>
</table>

Note. * Significant difference with training from pre values, \(p < 0.05\). ** Significant difference between groups, \(p < 0.05\)
Fatigue index (FI) was not significantly different between groups \( F = 0.953, df(1,16), p = 0.344 \); however, there was a significant decrease with training in the low CHO group \( F = 0.019, df(1,16), p = 0.019 \) (see Tables 5 & 6 & Figure 7).

Total work during the Thorstensson test was found to be significantly different between groups \( F = 5.39, df(1,16), p = 0.035 \) and with training \( F = 10.914, df(1,16), p = 0.005 \). The total work performed by the high CHO group (see Tables 5 & 6 & Figure 8) did not significantly change with training \( t = -1.211, df(9), p = 0.257 \). The low CHO group was significantly lower than the high CHO group both pre and post testing and they had a significant increase in total work performed from pre to post during the Thorstensson test \( t = -4.165, df(6), p = 0.006 \) (see Tables 5 & 6 & Figure 8).
Figure 7. Fatigue index.

Note. *Significant difference with training from pre values, p < 0.05

Figure 8. Total work during the Thorstensson Test.
During the measurement of aerobic capacity a VO$_2$ plateau of <0.15L/min was not attained in all subjects. Therefore these data will be referred to as peak oxygen consumption (VO$_2$peak) values instead of VO$_2$max. There was no significant difference in VO$_2$peak between groups [$F = 0.126$, $df(1,16)$, $p = 0.728$] but there was a significant increase with training [$F = 11.361$, $df(1,16)$, $p = 0.004$] (see Tables 7 & 8 & Figure 9).

The high CHO group (see Figure 8) showed a significant increase in VO$_2$peak from pre-testing to post-testing [$t = -2.269$, $df(9)$, $p = 0.047$]. The low CHO group (see Figure 9) had a significant increase in VO$_2$peak as well [$t = -2.406$, $df(7)$, $p = 0.049$].

Table 7

*Aerobic Capacity in the High CHO Group*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Pre</th>
<th>Post</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO$_2$peak (ml/kg/min)</td>
<td>55.44±9.30</td>
<td>59.76±9.72*</td>
<td>+7.23</td>
</tr>
<tr>
<td>Peak RER</td>
<td>0.98±0.08</td>
<td>0.96±0.07</td>
<td>-2.05</td>
</tr>
<tr>
<td>LA (mmol/L)</td>
<td>11.70±2.92</td>
<td>13.63±3.20*</td>
<td>+14.16</td>
</tr>
<tr>
<td>Maximum Power (Watts)</td>
<td>226.18±42.91</td>
<td>276.01±36.17*</td>
<td>+18.06</td>
</tr>
<tr>
<td>Maximum HR (bpm)</td>
<td>191.40±8.12</td>
<td>190.30±7.64</td>
<td>-0.58</td>
</tr>
<tr>
<td>O$_2$ Pulse (ml/beat)</td>
<td>22.85±4.69</td>
<td>24.49±4.42</td>
<td>+6.70</td>
</tr>
</tbody>
</table>

Note. *Significant difference with training from pre values, $p < 0.05$.

Maximum RER values obtained during the GXT were not significantly different between groups [$F = 0.108$, $df(1,16)$, $p = 0.746$] or with training [$F = 1.263$, $df(1,16)$, $p = 0.277$] (see Tables 7 & 8 & Figure 10).
Table 8

*Aerobic Capacity in the Low CHO Group*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Pre</th>
<th>Post</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO$_2$peak (ml/kg/min)</td>
<td>55.61±7.43</td>
<td>62.36±8.83*</td>
<td>+10.83</td>
</tr>
<tr>
<td>Peak RER</td>
<td>0.96±0.05</td>
<td>0.99±0.07</td>
<td>+3.04</td>
</tr>
<tr>
<td>LA (mmol/L)</td>
<td>12.05±2.03</td>
<td>14.77±2.84*</td>
<td>+18.42</td>
</tr>
<tr>
<td>Maximum Power (Watts)</td>
<td>206.45±17.4</td>
<td>251.75±28.14*</td>
<td>+18.00</td>
</tr>
<tr>
<td>Maximum HR (bpm)</td>
<td>190.70±3.63</td>
<td>187.50±4.23</td>
<td>-1.68</td>
</tr>
<tr>
<td>O$_2$ Pulse (ml/beat)</td>
<td>21.09±2.51</td>
<td>24.26±4.05*</td>
<td>+13.07</td>
</tr>
</tbody>
</table>

Note. *Significant difference with training from pre values, p < 0.05.

Figure 9. VO$_2$peak.

Note. *Significant difference with training from pre values, p < 0.05
Note. *Significant difference with training from pre values, $p < 0.05$
Lactic acid (LA) levels 5 minutes after the GXT demonstrated no significant differences in LA between groups \([F = 0.360, df(1,16), p = 0.557]\), but there was a significant increase with training \([F = 21.648, df(1,16), p = 0.001]\) (see Tables 7 & 8 & Figure 11). The high CHO group (see Figure 11) had a significant increase in LA \([t = -2.766, df(9), p = 0.022]\). The low CHO group (see Figure 11) also demonstrated a significant increase in LA \([t = -3.909, df(7), p = 0.006]\).

Maximum power outputs during the GXT were not significantly different between groups \([F = 2.225, df(1,16), p = 0.155]\). There was, however, a significant increase with training \([F = 63.177, df(1,16), p = 0.000]\). A significant increase in maximum power output in the high CHO group \([t = -7.153, df(9), p = 0.000]\) and low CHO group \([t = -4.444, df(7), p = 0.003]\) occurred (see Tables 7 & 8 & Figure 12).

![Figure 12. Maximum power outputs.](image)

*Significant difference with training from pre values, \(p < 0.05\)
Maximum HR did not significantly differ between groups \( [F = 0.326, df(1,15), p = 0.577] \) and it did not change with training \( [F = 2.754, df(1,15), p = 0.118] \) (see Tables 7 & 8 & Figure 13)

![Figure 13. Maximum hr.](image)

Oxygen pulse did not significantly differ between groups \( [F = 0.278, df(1,15), p = 0.605] \). A significant difference was found with training \( [F = 10.327, df(1,15), p = 0.006] \). The high CHO group (see Figure 14) showed no significant changes in O2 pulse \( [t = -1.716, df(9), p = 0.120] \) with training, where as the low CHO group (see Figure 14) had a significant increase in O2 pulse \( [t = -2.745, df(6), p = 0.034] \) (see Tables 7 & 8 & Figure 14).
Figure 14. O2 pulse.

*Significant difference with training from pre values, $p < 0.05$

Anthropometric Measurements

There was no significant difference in body weight (see Tables 9 & 10 & Figure 15) between groups [$F = 0.808$, $df(1,16)$, $p = 0.382$] and no significant changes with training [$F = 1.114$, $df(1,16)$, $p = 0.307$]. There was no significant difference in body fat percent (BF%) between the two groups [$F = 0.002$, $df(1,16)$, $p = 0.969$]. There was a significant decrease in BF% with training in the high CHO group [$t = 4.377$, $df(9)$, $p = 0.002$] and low CHO group [$t = 3.768$, $df(7)$, $p = 0.007$] (see Tables 9 & 10 & Figure 16).

There was no significant difference in fat free mass (FFM) between groups [$F = 0.892$, $df(1,16)$, $p = 0.359$] and there were no significant changes with training [$F = 0.049$, $df(1,16)$, $p = 0.828$ ] (see Tables 9 & 10 & Figure 17).
Table 9

*Anthropometric Data for the High CHO Group*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Pre</th>
<th>Post</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Weight (kg)</td>
<td>79.3±11.57</td>
<td>78.6±12.34</td>
<td>-0.89</td>
</tr>
<tr>
<td>BF%</td>
<td>16.1±5.95</td>
<td>13.9±5.75*</td>
<td>-13.67</td>
</tr>
<tr>
<td>FFM (kg)</td>
<td>66.3±9.32</td>
<td>67.4±9.92</td>
<td>+1.64</td>
</tr>
</tbody>
</table>

*Significant difference with training from pre values, \( p < 0.05 \)

Table 10

*Anthropometric Data for the Low CHO Group*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Pre</th>
<th>Post</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Weight (kg)</td>
<td>74.6±10.89</td>
<td>73.7±10.55</td>
<td>-1.21</td>
</tr>
<tr>
<td>BF%</td>
<td>15.9±5.30</td>
<td>13.9±5.43*</td>
<td>-12.58</td>
</tr>
<tr>
<td>FFM (kg)</td>
<td>62.5±8.35</td>
<td>63.2±8.38</td>
<td>+1.11</td>
</tr>
</tbody>
</table>

*Significant difference with training from pre values, \( p < 0.05 \)
Figure 15. Body weight changes.

Figure 16. Body fat percent changes.

*Significant difference with training from pre values, $p < 0.05$
Figure 17. Fat free mass.
Chapter 5.

Discussion

Review of Results

The main objective of this study was to compare the effects of a low CHO, high protein diet vs. a high CHO, low fat diet on healthy, active subjects while performing seven weeks of rowing ergometer training. Physically active subjects, who were not highly trained, were chosen in order to access a wider spectrum of the athletic population and allow a greater potential training effect. Miller, Koceja, and Hamilton 1997 reviewed 493 studies where a therapeutic intervention of diet, exercise, or diet plus exercise was employed and concluded most diet and exercise research has a very narrow focus. The majority of research has been conducted on an obese population over the age of 40. A large part of the value of the current research was to increase the knowledge on diet and exercise in a healthy, young population and more specifically a competitive, athletic population. The major finding of this research is that an adaptation to a low CHO, high protein diet does not provide significant training, performance, or body compositional benefits over a high-CHO, low fat diet.

Diet

The prescribed diet for the high CHO group was 55% CHO, 30% fat and 15% protein. After careful analysis of all the food logs, the high CHO group was approximately on target for their CHO and protein goals. Their fat intake was 4% lower than expected. This was due to eating more carbohydrate dense foods for example pastas, granolas, and breads that are generally lower in fat content. The percent contribution of alcohol to the total diet was not significantly different between the groups,
3.35% and 1.06% in the high CHO and low CHO respectively. The high CHO and low CHO group were both very consistent in their macronutrient consumption from food logs one to four (see Figures 1 & 2).

The low CHO group was prescribed a diet of 50% protein, 25% fat, and 25% CHO. Despite several efforts including extra diet counseling and example meal plans, only a 30% level of protein could be maintained by the group (less than 40.2% of expected), as well as a 5% greater intake of CHO and a 13% greater fat intake. There are several potential explanations for subjects not meeting their prescribed protein requirement. First, these subjects were in a free-living environment and thus the cost of high quality protein from meat may have been financially prohibited since its cost has dramatically increased in the last few years (Butler, 2004). Second, the effect of a high protein diet mediates a higher satiety level that may result in lower food and calorie consumption per day (Eisenstein, Roberts, Dallal, & Saltzman, 2002). Third, two subjects reported they were unable to maintain a lower percent of CHO for any given period of time citing problems with headaches, fatigue, GI distress, depression and nightmares. Lastly, subject error in food recording may have contributed to their inability to meet the prescribed diet plan. Rebro, Patterson, Kristal, & Cheney (1998) compared 176 4-day food records to actual food consumption and found on average people underestimate their energy intake by 17%. This underestimation is consistent with CHO and fat intake as well. Even though such an error can occur with diet records, food log recording is still considered the gold standard of dietary assessment (Rebro et al., 1998).
The results of protein intake being lower than anticipated yielded a fat content in the low CHO group averaging 13% greater than the 25% prescribed. Each subject controlled their nutrient intake by following the Food Guide Pyramid’s suggested serving sizes. A numerical list of serving from each food group was given to the subjects prior to the start of the study. For the most part, every subject ate their prescribed number of servings without incident. However, a few problems occurred with use of this system. Subjects were under the impression that they were consuming the prescribed amount of protein, however, inadvertently they were also consuming a greater amount of saturated fat. There are two good examples where this occurred. Walnuts and peanuts are listed in the meat group of the Food Guide Pyramid. However, walnuts and peanuts are both composed of a high percentage of fat. Despite efforts to steer subjects away from heavy nut consumption, many still recorded eating as much as a pound a day of nuts. Peanut butter, a common staple in the kitchen of college students was also consumed in great amounts (as much as 1.5 cups a day). Meats, and in particular red meat, were also favored among the group and are another food example of the Food Guide Pyramid “grey area”. Some cuts of meat contain as much as 30% fat. Red meat substitute suggestions, such as substituting ground white turkey meat for ground beef in a meat loaf recipe, were provided when applicable.

Both groups consumed roughly the same amount of calories on each day of their food log recordings, 2,502 calories and 2,605 calories in the high CHO and low CHO group respectively (see Table 2). However, the low CHO group reported on average a 35.3% deficiency and the high CHO group a 40.3% deficiency in their caloric needs based on the Harris-Benedict formula for estimating daily caloric intake. Several efforts
were made to increase their caloric consumption including counseling, food serving adjustments, and more meal examples. Despite the investigators efforts most subjects reported consuming calories at their satiety level or beyond their normal intake. However, since there were no significant decreases on body weight in either group over the 7 week period, the accuracy of the nutrient deficiency from the Harris-Benedict estimation is questionable.

Training Variables

Average work rate increased in both groups as the training progressed until it plateau in the last few training sessions. The high CHO group performed at significantly higher power outputs, approximately 20-25 watts higher (see Table 3), then the low CHO group. Diet and exercise studies conducted by Simonsen et al. (1991) and Jacobs and Sherman (1999) demonstrated that rowers who consumed a high CHO, low fat diet during a four week training period were able to train at a higher absolute work rate compared to the lower CHO group. Jacobs and Sherman (1999) reported a significantly higher training wattage in the high CHO group compared to the lower CHO group. Training power outputs always increased in the high CHO group during training but the lower CHO group maintained their power outputs of 165 watts during the last few weeks of training. And training work rates where about the same as maximum work rates during the GXT. Jacobs and Sherman (1999) concluded training intensity is optimized with a high CHO diet. However, there is some discrepancy in the literature. Lambert, Speechly, Dennis, and Noakes (1994) found nutrient composition of the diet to have no effect on muscle power when cyclists performed endurance trials following two weeks of adapting to a high CHO or high fat diet. Despite the inconsistencies of the research, a
higher carbohydrate diet is believed to boost training power outputs due to improved muscle adaptations by increasing muscle glycogen. A chronic high CHO diet will increase glycogen stores in the muscle allowing the athlete to perform at higher intensities (Jacobs & Sherman, 1999).

In this study, average training heart rates decreased in both groups as the training period progressed (see Table 3). This could be due to study design for training recommendations. The exercise protocol was based the training intensities from maximum power outputs recorded during the pre-testing. It did not take into account subjects’ ability to adapt to the training regime in seven weeks. The low CHO group had a significantly lower training heart rate at the same absolute training intensity from training day 7 to 17. This is in contrast with studies preformed by Galbo, Holst, and Christensen, (1979) and Jansson, Hjemdahl, and Kaijser, (1982). In these studies training heart rates in the low CHO groups were found to increase due to increases in the secretion of noradrenalin induced by a low CHO diet (Jansson et al., 1982). It was thought higher levels of noradrenalin were a response to elevate blood-glucose levels from increased glycogen breakdown. However, the physiologic mechanism was not explored in either study. It was not known if noradrenalin levels were lower in our low CHO group.

In the current study, reduced training heart rates in the low CHO group could also be explained by a diet high in protein which could result in increased circulating amino acids that alters the osmolarity of the blood plasma (Gleeson, Blannin, Walsh, Bishop, & Clark, 1998). A higher osmolarity would cause a rise in plasma volume eventually
leading to an increase in stroke volume (Candas et al., 1986). Because of the elevated
stroke volume, cardiac output could be maintained with a lower heart rate (see Figure 18).

\[
\text{VO}_2 = Q \times A-\text{VO}_2\text{diff}
\]

\[\uparrow\]

\[\downarrow \text{HR} \times \uparrow \text{SV}\]

\[\uparrow\text{plasma volume}\]

\[\uparrow\text{circulating amino acids}\]

Figure 18. Circulating amino acid theory.

Another possible reason could be that a high protein diet is consistently higher in
iron (Johnson & Walker, 1992). A diet high in iron may increase hemoglobin
concentration. Edozien and Switzer (1977) showed a significant increase in hemoglobin
concentration and hematocrit in rats after increasing protein in their diet. Arterial-
Venous oxygen difference (A-VO\textsubscript{2}diff) is increased with improvements in hemoglobin
concentration. An increase in A-VO\textsubscript{2}diff would also allow the body to conserve energy
by lowering heart rate while VO\textsubscript{2} is still maintained (see Figure 19).

\[
\text{VO}_2 = \downarrow Q \times \uparrow A-\text{VO}_2\text{diff}
\]

\[\downarrow\]

\[\uparrow \text{Hemoglobin concentration}\]

\[\downarrow \]

\[\uparrow \text{Iron}\]

\[\downarrow \text{HR} \times \text{SV}\]

Figure 19. Increased iron theory.
Another possible reason for the reduction in training heart rates could be subject’s lack of effort during final few training sessions. A few subjects verbalized their lack of enthusiasm with the training despite constant encouragement and complained of the duration of the study.

Performance Variables

There were no significant strength changes on the isokinetic knee extension and flexion test in either group. Strength changes may have been expected due to the fact that subjects were training up to three times a week on a rowing ergometer. However, the intensity of the training and the duration of the study were likely not high or long enough to promote the neural adaptations that increase muscular strength during the first 15-20 days of resistance training (McArdle, Katch, & Katch, 1991). Van Zant et al. 2002 placed moderately trained subjects on a resistance training program for 6 weeks. They consumed a high CHO, low fat or low CHO, high protein diet and were periodically tested using an isokinetic knee extension and flexion apparatus. No significant changes were found in knee strength from pre- to post-testing (Van Zant et al., 2002). The results of the current study indicated that the overload placed on the knee extensor and flexor muscles during rowing training is not significant enough to produce increases in isokinetic force production.

Post hoc analysis indicated there was not a significant difference between groups for the Thorstensson test. However, fatigue index was significantly lower in the low CHO group after the training period. Their muscular endurance was not maintained, but rather was reduced. There are mixed results in the literature concerning this topic. On the positive side, studies conducted by Miller, Bryce, and Conlee (1984) and Simi,
Sempore, Mayet, and Favier (1991) found improvements in muscular endurance in the low CHO group following a training program. Adaptations in the oxidative metabolic pathway such as increases in citrate synthase and development of more mitochondria occurred after the diet intervention and training. However, on the negative side, Rosholt et al. (1994) concluded that low CHO, high fat diets produce effects resembling the insulin resistance of starvation. The activity of glucose transporters are hindered in a low CHO diet leading to poor muscular endurance. Jacobs et al. (1999) found no improvements in endurance performance in a low CHO group after a training program. This was not due to lack of CHO availability but rather to suboptimal CHO utilization during exercise, creating a greater reliance on fat. It is believed the reduction in CHO oxidation was likely due to a decrease oxidation of plasma glucose (Jacobs et al., 1999). Helge et al. (1996) reported a greater endurance capacity in a high CHO group compared to a lower CHO group after 8 weeks of endurance training.

While the consensus is still out about the potential effects a low CHO diet may have on endurance performance, another variable could possibly explain a lower fatigue index in the low CHO group. Subject’s lack of effort may explain the irregularities in the data. Many subjects complained about completing a second Thorstensson and the muscular discomfort experienced afterwards prior to the post testing. However, subjects were encouraged to provide maximal efforts and the total work during the Thorstensson test was significantly increased in the low CHO group. Therefore, it would appear that effort was not a limiting factor to these results. Even though the total work increased significantly in the low CHO group their values were still well below the high CHO group. This finding is in conflict with studies conducted by Van Zant et al., (2002),
Simonsen et al., (1991), Jacobs et al., (1999), and Lambert et al., (1994). Perhaps the low CHO subjects were able to perform at higher outputs initially and wore down more quickly as a result. Another possible explanation could be differences in diet composition at the time of the testing. They were on a normal diet at pre-testing and only back on normal diet for 2-3 days before post-testing. The muscle cells should, theoretically, have been higher in glycogen during the pre-test, but they may have recovered during the 2-3 day period.

The VO$_2$ peaks increased by 10.83% and 7.23% in the low CHO and high CHO group respectively. However, even though those were significant increases with training, there were no significant differences found between groups. Helge et al. (1996) found similar results in a study involving subjects on a low or high CHO diet and cycling training for 7 weeks. VO$_2$max increased 11% in both groups. Kavouras, Troup, & Berning (2004), Phinney et al. (1980), Fleming et al. (2003), and Roltsch et al. (2002) all concluded diet manipulation has little to no effect on VO$_2$max following a training program. Though diet manipulation may affect other variables such as fatigue and power outputs, it does not appear to improve oxygen extraction and uptake.

Muoio, Leddy, Horvath, Awad, and Pendergast (1994) conducted a study at the University of New York, placing members of the track team on the same training program for 3 weeks while consuming either a low or high CHO diet. VO$_2$max significantly increased in response to a low CHO diet, as well as, the high CHO diet (Muoio et al., 1994). The present study also found VO$_2$peak to increase in the low CHO group, though not significantly greater than the high CHO group. It has been suggested that an increase in VO$_2$max in a low CHO group may be caused by a higher oxygen cost
of producing ATP from stored fat. More oxygen is needed to efficiently harness energy in the form of lipids when adaptation to a low CHO diet has occurred.

Peak RER values did not change with the diet and training. The high CHO group had a slight decrease and the low CHO group a slight increase in peak RER. This is consistent with work done by Roltsch et al., (2002); Kavouras et al., (2004); Jacobs et al., (1999); and Hays et al., (2004). A probable reason for no changes in RER values in the low CHO group was that the increased amount of fat consumed did not change the RER values because their reliance on carbohydrates as an energy source was not hindered by the diet. In other words, the changes in macronutrient percentages did not affect RER values. The high CHO group may have had an increase in fat oxidation with training observed by the slight decrease in RER at the same relative intensity. The advantage of this would be to reduce the oxidation of carbohydrate stores (Jacobs et al., 1999).

Another possible reason for no changes in RER response was the fact that the subjects were off the diets for 3-4 days before post-testing began. This might have been enough time for their metabolism to readjust to their normal diets and change the RER responses.

Lactate levels 5 minutes after a maximal rowing bout did increase from pre- to post-testing in both groups. This is in agreement with Greenhaff, Gleeson, and Maughan (1987). A few studies suggest maximum lactate levels will not change after CHO manipulation and training [Phinney et al., 1980; Muoio et al.,1994; & Maughan et al., 1997]. However, these studies were looking at acute changes to exercise. A higher maximal lactate level indicates an increased tolerance or improvements in pH buffering capacity. The subjects were better able to handle the higher acidic environments created by the working muscle.
No peak heart rate changes occurred as a result of the diet and training program. Others have found similar results [Fleming et al., 2003; Kavouras et al., 2004; & Roltsch et al., 2002]. Diet manipulation may not affect peak heart rate values on a healthy population; it can have a great impact on an obese population. Phinney et. al. (1980) placed six obese subjects on a ketogenic diet and treadmill exercise for six weeks. Peak heart rate values significantly dropped over the course of the study. Though it was not analyzed, improvements in the parasympathetic nervous system were believed to have dramatically reduced peak heart rates.

Oxygen pulse significantly increased after training in the low CHO group. After canceling out heart rate from the formula (because no changes occurred in testing heart rates), $O_2$ pulse is only dependent upon stroke volume and $A-VO_2$diff. It has been shown in rats when increasing the total percentage of protein in the diet a significant increase in blood hemoglobin and hematocrit will occur as a result (Edozien & Switzer, 1977). It is possible the higher protein content in the low CHO group positively effected stroke volume, $A-VO_2$diff, or both. Like the mechanisms described in Figure 17 and 18, improvements in hemoglobin concentration could increase $A-VO_2$diff. A rise in $A-VO_2$diff could potentially increase $O_2$ pulse. And at the same time, an increase in hematocrit would increase blood volume promoting improvements in stroke volume. Improvements in stroke volume (though not analyzed in this study) could also be a reason for the significant improvements in $O_2$ pulse.

**Anthropometrics**

Body weight and fat free mass did not significantly change in either group over the course of this study. Total body fat percent did significantly decrease in both groups.
from pre- to post-testing. Although body weight did not change over the course of the study, subjects reported a hypocaloric diet on every food log. This may have occurred because the subjects did not record all of their meals and snacks properly due to disinterest and apathy.

These findings are consistent with most studies on diet control and exercise. Johnston, Tjonn, and Swan (2004) found both a high CHO group and low CHO group lost the same amount of body weight and body fat percent but subjects consuming a low CHO diet were reported to be more satisfied with the meals and more compliant with the training. Weight loss promoting effect of higher protein diets work by mediating an increase satiety level and decrease energy intake aiding the weight loss (Mahan & Escott-Stump 2000). In a 6 week study conducted by Golay et al. (1996), no differences in body weight between a high and low CHO group were found indicating that weight loss might be more dependent upon energy intake and less on nutrient composition. Golay et al. (1996) concluded neither diet offers significant advantages when comparing weight loss.

Recently, a study in the *Archives of Internal Medicine* found conflicting evidence suggesting low fat, high CHO diets and exercise are actually more beneficial to weight loss. Ad libitum low fat diets produce weight loss of 1.6g/day for each 1% reduction in energy supplied by dietary fat (Hays et al., 2004). Low fat, high CHO diets might decrease body weight by reducing food intake because complex CHO foods are more satisfying and less energy dense than higher fat foods. Proponents of a low CHO diet claim that CHO stimulates insulin causing de novo lipogenesis resulting in a positive fat balance. However, hypocaloric diets often result in metabolic adaptations consistent with weight gain, such as a significant reduction in metabolic rate (Hays et al., 2004).
Individuals on a high CHO diet do not demonstrate a metabolic adjustment. High CHO diets do not increase fat stores by reducing fat oxidation and increasing de novo lipogenesis (Hays et al., 2004). This study supports the fact that fat balance is maintained by total energy intake and not by nutrient composition.

How much does diet or exercise contribute to the changes that occurred in body fat percent remains unsolved. This study tested subjects when they were told to exercise and consume a neutral caloric content diet. There was really no way of figuring out how much diet and/or exercise contributed to the changes seen in body composition. Miller, Koceja, and Hamilton (1997) analyzed 493 studies were a therapeutic intervention of diet or diet plus exercise was employed. Dieting and dieting plus exercise intervention produced roughly 1.0 kg of weight lost and 0.75 kg of fat loss per week. As indicated, diet and diet plus exercise intervention creates nearly the same outcomes with weight and fat loss.

It was hypothesized fat free mass would significantly decrease more in the low CHO group due to the mechanism described in the second chapter. Briefly, when the diet is limited in carbohydrate, oxaceloacetate must be produced from alternate sources. One of these potential sources is skeletal muscle protein. However, the lack of difference in fat free mass in the present study suggests that this was not the case. Both groups were calculated to be in a daily hypocaloric state. Eisenstein et al. (2002) demonstrated that a high dietary protein diet does not prevent loss of lean tissue during negative energy balance, and this problem of lean muscle tissue loss is further exacerbated the effect a low CHO diet has on satiety. In a study conducted by Golay et al. (1996), subjects consumed a hypocaloric low or high CHO diet for 12 weeks. Lean body mass loss was
significantly reduced in the low CHO, high protein group. Once again the present study did not agree with these findings.

If an athlete was trying to lose body weight while at the same time maintain muscle mass, he/she would expect to obtain better results on a high CHO diet. High CHO diets promote less protein break down and offer significant advantages in other performance variables (Lemon & Mullin, 1980). One possible reason why our study did not show the same results is because the low CHO groups’ carbohydrate consumption was not very restrictive (30.6% CHO). Perhaps a diet lower in carbohydrates would produce different results.

Conclusion

During training the low CHO group was able to maintain power outputs at lower heart rates suggesting improved cardiovascular efficiency. Improvements in stroke volume and arterial-venous difference, though not analyzed, may explain these findings, and are supported by changes in O₂ pulse. Despite the fact the high CHO and low CHO groups were hypocaloric, both lost the same amount of weight and body fat. Therefore, consumption of a low CHO diet while training did not increase the rate of weight loss beyond the rate of a high CHO diet.

The high CHO group had relatively few problems in maintaining their diet for 7 weeks. However, the low CHO group was unable to maintain a lower carbohydrate consumption of 25% despite several attempts at different diet interventions. Though fat free mass (FFM) increased and there were no significant differences between groups, a decrease in FFM was expected in the low CHO group. In theory, a diet low in CHO (<25%) would convert metabolism into a carbohydrate sparing mode, forcing the use
secondary and tertiary fuel sources such as protein from skeletal muscle and free fatty acids.

In conclusion low CHO diets do not provide any added benefits in body composition, strength, endurance, and performance related variables when compared to a diet higher in carbohydrates. The first and second hypotheses of this study were accepted, except there was a significant increase in VO$_2$ peak in both groups with training. One should exercise caution when considering a low CHO diet while training. With respect to body composition, it has been shown a low CHO diet does not accelerate the rate of body fat and weight loss any faster than a high CHO diet. The third and fourth hypothesis of this study were also accepted, except there was a significant decrease in body fat percent in both groups with training. One of the major objectives for conducting this study was to show the effect of diets on weight loss. Despite previous theories, it was also shown a low CHO diet does not have any negative effects on FFM. Perhaps a diet with more severe carbohydrate restriction would alter the metabolism such that negative changes in FFM could occur. More research is needed in this area.

Most performance and training variables (Biodex strength assessment, fatigue index, VO$_2$ peak, power outputs, RER, LA, and maximum heart rate) were not different between the groups. However, a few interesting changes did occur. Training heart rates and O$_2$ pulse responses in the low CHO group suggest an alteration in the physiology. Adaptation to the low CHO diet could have provided a beneficial response in heart rate. Blood volume may have increased and/or A-VO$_2$ difference improved as result of the diet.
Future research on low CHO diets and athletic performance should focus on cardiovascular responses. Resting and training heart rates responses and heart rate irregularities are areas of needed insight. The large scale effect of low CHO diets on cardiovascular efficiency is still unknown. Research looking at athlete’s depression and anxiety levels while on a low CHO regimen would also be beneficial to health professionals and exercise specialists.
References


Appendix A: Flyer

ARE YOU INTERESTED IN EXERCISE & DIET?
If so, here is your chance to learn exercise and diet:

An opportunity to participate in a rowing training and diet.
Increase cardiovascular function, gain muscle, and learn nutritional information, as well as more about yourself and your capabilities!

To qualify:
Male
19-40 years of age
Non-smoker

For more information, contact
Kumika Toma  Tim Werner
593-0450      589-5436
kt247191@ohio.edu  tw276898@ohio.edu

This project will look for the effects of rowing training and different diets on strength and muscle over the course of 7 weeks of training. Tests include maximum oxygen consumption test, maximum knee extension test, % body fat measurement, blood sample, and muscle biopsy. There will be 18 rowing sessions required for those assigned in two different diet groups. Rowing training will approximately 45 minutes including warming-up and cooling-down in duration and 2 or 3 times a week.
Appendix B: Consent Form

Ohio University Consent Form

Title of Research: Physiological effects of high-carbohydrate, low-fat and high-protein, low-carbohydrate diets on high-intensity aerobic training

Principal Investigator: Kumika Toma

Co-Investigator: Tim Werner, Jason White

Department: Biological Sciences, School of Recreation and Sport Sciences

Federal and university regulations require signed consent for participation in research involving human subjects. After reading the statements below, please indicate your consent by signing this form.

Explanation of Study

Purpose of the research

The purpose of this research project is to assess the effects of two different diet regimens and exercise training programs on various physiological measurements.

Procedures to be followed

Prior to any of the following tests being conducted, you will fill out a health history questionnaire. You will not be allowed to participate in the study if it is determined from your health history questionnaire that you are at risk of injury due to cardiovascular, metabolic, pulmonary or musculoskeletal problems or diseases.

Following medical/health clearance, rowing training will start. During the first week of rowing, you will be instructed in filling out a food log. Rowing training will be composed of two 4-week sessions. After the first 4-weeks training, several different measurements will be taken (pre-test). Based on the results of pre-test, you will be assigned into one of two diet groups: high-carbohydrate, low-fat group or high-protein, low-carbohydrate group. You will have instruction regarding restricted food and recommended food. The post-test will be performed after the last 4-weeks training. These measurements and the training are described below:

Percent body fat and lean body mass determinations:

Your height and weight will be measured. Percent body fat will be calculated by body density determined by an underwater weighing method. This is a noninvasive, no-risk evaluation. Lean body mass will be determined from the total body mass and percent body fat measurements.
Prior to underwater weighing, you will perform a pulmonary function test to estimate residual volume in the lungs. Since percent body fat will be calculated by body weight in the air and body weight in water, estimating the amount air in the lung is important to this calculation. On the day of underwater weighing, you will report to the lab in the morning without having eaten or drunk anything before the measurement. You will urinate and defecate if possible before beginning the underwater weighing procedure and will be in swimsuits. Body weight in the air will be determined by an electronic scale while weight in water will be assessed by the force transducer which is located on the chair interfaced through the transbridge to the computer. The chair is hung in the water tank. You will sit in the chair and exhale as much air as possible so that minimal air remains in your lungs. In the sitting position, water will be up around your chest. You will bend forward so that your body is immersed into the water and you will hold your breath for at least 3 seconds so that the reading of weight is stable. You will be notified of the end of each measurement by sound and will be allowed to get your face out of the water to breath. You can terminate this measurement anytime during each trial if you feel discomfort and/or difficulty. You will perform the underwater weighing measurement until at least 2 trials are within 3 percent difference, or 10 trials a day.

Maximal Dynamic Strength and Local Muscular Endurance Measurements:
Maximal dynamic strength and local muscular endurance will be determined to assess potential improvements as a result of the rowing training. Isokinetic dynamometer will be used to assess strength and endurance of thigh muscles through knee extension action. The arm of the dynamometer will be set to move at the speed of 30 degrees per second for the maximal dynamic strength test. You will push the dynamometer’s arm as forcefully as possible in the same direction as the arm moves. Three knee extension actions will be performed in a set. Three sets of tests will be done with at least one-minute rest period between each set. Highest force of total 9 trails will be recorded as maximal dynamic strength.

After recovering from the maximal dynamic strength test, you will perform a local muscular endurance test. The arm of the dynamometer will be set to move 180 degrees per second. You will push the dynamometer’s arm as forcefully as possible in the same direction the arm moves 30 times. The fatigue index will be calculated as the total force during the last 10 repetitions divided by the total force during the first 10 repetitions. Fatigue index indicates your ability to maintain force output.

Prior to and after the muscular strength and endurance tests, you will be encouraged to perform light exercise and/or stretching for warm-up and cool-down. Although no severe physical risks or hazards are anticipated, there may be temporary muscle/joint pain following the strength testing.

Maximal Oxygen Consumption:
Aerobic capacity will be determined at the middle and end of the study during a rowing ergometer exercise of increasing intensity. You will be fitted with headgear and a mouthpiece in order to collect expired gases using semi-computerized open-circuit spirometry. This will measure your oxygen consumption (VO2), ventilation (VE), expired carbon dioxide (VCO2), and respiratory exchange rate (RER).
You will be asked to produce target power. Either how forcefully or the rate at which you row, or both, determines the power. After performing light exercise and/or stretching, you will begin rowing for 1 minute at 75 watts and the target power will be increased by 25 Watts every minute during the exercise until one or more of the following criteria are observed: 1) a failure to maintain required power, 2) attaining age-predicted maximal heart rate, 3) plateau or decline in VO2 in later power stages, 4) RER of greater than 1.1, or 5) volitional cessation of exercise. At five minutes of recovery period, a small microliter blood sample (25µl) will taken by finger prick and then analyzed for lactic acid concentration. The variables that will be recorded during this test are maximal VO2, maximal VE, maximal power output obtained, and time to volitional exhaustion.

**Muscle Biopsy Procedure**

A total of two muscle biopsies per subject will be taken from your large thigh muscle (vastus lateralis). All muscle biopsies will be performed by Dr. Fredrick Hagerman under the medical supervision of a physician. The biopsy procedure yields a small (60-100 mg) piece of muscle tissue for subsequent analysis. Prior to having a muscle biopsy taken, you will be given a thorough verbal orientation of the procedures described above (Percutaneous Needle Muscle Biopsy Procedure). Following the biopsy procedure, you will be given instructions on the proper care of the incision (Life After a Muscle Biopsy). Both written and verbal instructions will be given at the time of the biopsy. The incision will be checked daily for the subsequent 48 hours post-biopsy by Dr. Hagerman (or one of the investigators) and a new dressing will be applied if necessary.

**Blood Sampling Procedure**

You will report to the laboratory in the early morning of blood sampling day. You will refrain from having any food and beverage except water after dinner on the night before until finishing blood sampling. About 10 cc blood will be drawn from the vein at the forearm by a certified phlebotomist. Collected blood will be centrifuged and plasma will be collected for several analyses.

**Diet**

You must keep a daily log of food eaten and report this to one of investigators via e-mail weekly. You will be taught to record the food log during the introductory period. You will report your diet through 7 weeks. After pre-testing, you will be given the list of restricted food and recommended food based on which diet group you are assigned. You will be encouraged to ask questions regarding choice of food and beverage and method of recording. During the 7-week rowing training, you will continue recording dietary records and reporting them weekly. The dietary records will be analyzed to obtain group difference in total caloric intake and nutrient composition.

The food log will consist of 6 sections: meal time, food consumed, where the meal was consumed, with whom the meal/snack was eaten, how you were feeling at this time, and rate your hunger. The food log will be turned in. A random identifier number will be used when logging the data into the computer. Nutritionist Pro Nutrition Analysis
is the software program that will analyze and interpret the data. After data processing is complete, a Client Diet Record Report and Client Diet Record Nutrition Summary will be generated. A Client Diet Record Report lists all the foods and drinks consumed in a specified time and calculates amount of sodium, calories, protein, carbohydrate, fat, cholesterol, saturated fat, monounsaturated fat, polyunsaturated fat, and dietary fiber in each food or drink. The Client Diet Record Nutrition Summary will sum up and average the total amount of most macronutrients, vitamins, and minerals over a specified time.

**Rowing Training**
Following the introduction and pre-testing, you will begin to train for 7 weeks on rowing ergometers. Before and after training, you will perform warm-up exercise and cool-down exercise. During training, you will wear a heart rate monitor and training intensity will be determined by target heart rate during rowing. No training will take place without supervision. The training routines are delineated below:

| Week 1: 2 days/week | 5-minute rowing at 70% of maximum heart rate obtained in pre-test, 3 sets with 4-minute rest between sets |
| Week 2: 2 days/week | 5-minute rowing at 70% of maximum heart rate obtained in pre-test, 4 sets with 4-minute rest between sets |
| Week 3: 2 days/week | 10-minute rowing at 70% of maximum heart rate obtained in pre-test, 2 sets with 5-minute rest between sets |
| Week 4: 3 days/week | 10-minute rowing at 80% of maximum heart rate obtained in pre-test, 2 sets with 5-minute rest between sets |
| Week 5: 3 days/week | 10-minute rowing at 80% of maximum heart rate obtained in pre-test, 3 sets with 4-minute rest between sets |
| Week 6: 3 days/week | 20-minute rowing at 80% of maximum heart rate obtained in pre-test, 2 sets with 5-minute rest between sets |
| Week 7: 3 days/week | 2-minute rowing at 90% of maximum heart rate obtained in pre-test, 8 sets with 1-minute rest between sets |

**Risk and Discomfort**

**Percent Body Fat measures**
The only anticipated risk for these measurements is the possible fear of being in water in the relatively small tank. If you do not feel comfortable in the tank, you are free to get out from water.

**Maximal Dynamic Strength and Local Muscular Endurance**
The risks associated with these tests include possible muscle/joint soreness and a temporary increase in blood pressure during knee extension actions. Although isokinetic dynamic action does not have an eccentric mode, which normally causes muscle damage and pain, there is slight possibility that the subjects will feel soreness after the tests. You will be screened for hypertensive problems prior to participation, and not be allowed to participate in the study if any problems are found. There will be proper supervision and explanations/demonstrations of the tests to be performed.

**Maximal Oxygen Consumption**

The risks associated with this test are muscle fatigue and slight muscle soreness, increase in blood pressure, dizziness, nausea, and a slight risk of heart attack, and a very slight risk of sudden death. You will also be instructed to drink plenty of fluid in the hours prior to the rowing ergometer test, and to eat a small meal at least three hours prior to the test, in order to avoid nausea. Throughout the test and after the test, you will be monitored by laboratory personnel trained in CPR. If an emergency should arise, the laboratory personnel will call EMS and provide emergency care until emergency medical personnel arrive. Emergency numbers are posted by the phone in the laboratory. In addition, you will be informed that if you are unable to continue a test, you may stop at any time. You will also be instructed as to how to perform stretches, which may help alleviate any muscle soreness that may occur after the test. Because of the invasive nature of blood withdrawal, there is a slight risk of infection and hematoma but the likelihood of such events occurring from a finger prick is very rare.

**Muscle Biopsy Procedure**

The muscle biopsy procedure does not cause any permanent damage. There will, however, be a small scar that should become undetectable over time. Local discomfort may occur over the initial 24 hours after the biopsy, but this is no more painful than a slight bruise to the thigh and will subside in a day or two. Risks associated with the biopsy procedure include mild bleeding, hematoma, infection, post-procedure pain, localized temporary loss of skin sensitivity, and slight scarring of the skin. Every precaution will be taken to keep these risks to a minimum. Ice therapy, mild pain medication (aspirin), compression, and elevation have been used separately or in combination to alleviate these problems. For all of the tests in this study, there is very little possibility of potential problems. All of the tests, including the muscle biopsies, have been performed in the laboratory for several years by the same investigators without incident.

**Blood Sampling**

Because of the invasive nature of blood withdrawal, there is a slight risk of infection and bleeding. Every precaution will be taken to keep these risks to a minimum.

**Diet**

There is a slight possibility that high-protein, a low-carbohydrate diet will cause ketosis, which may inhibit the central nervous system. During the 7 weeks rowing training, a small amount of urine (about 1 oz) will be collected before the training and
will be tested for ketosis at the site using the dip-stick method. If ketosis is observed, carbohydrate intake will be increased slightly.

**Benefits**

You will gain knowledge about your current fitness level and diet and how to improve it after the study. Also, you will be able to gain musculoskeletal fitness throughout the study due to the rowing training. There are also academic benefits that can occur from the study. You will gain insight into rowing training and diet and will also learn about the physiological adaptations to training and diet. Along with the mentioned benefits, you will gain knowledge about the research side of exercise physiology and nutrition.

Society will benefit from this investigation since it will increase knowledge about the effects of high-protein, low-carbohydrate diets and high-intensity aerobic training. This will help to educate the public about how this type of training and diet modification really affects the body so that proper exercise and diet choices may be made. The anticipated benefits to the scientific community will also include increasing knowledge of the physiological effects of the effects of high-protein, low-carbohydrate diet and high-intensity aerobic training.

**Alternative Treatments (if applicable)**

N/A

**Confidentiality and Records**

Your file will only be identified with a subject number and it will be kept in a locked file in the investigator’s office. A code key will be developed to match your name and subject number. It will be kept in the locked file. The only reason the information will be used will be for research purposes, and you will not be identified as more than a number in that case. The health history form will also be kept in a locked file, and will not be shared with anyone other than the investigators. It will be destroyed within five years of study completion.

**Compensation**

There is no monetary compensation for participating in this study. You are free to withdraw from the study at any time without affecting your relationship with the investigators.

**Contact Information**

If you have any questions regarding this study, please contact:

Kumika Toma, 593-0450 (office), 662-3024 (home), kt247191@ohio.edu
Tim Werner, 589-5436 (home), tw276898@ohio.edu
Roger Gilders, 593-0101 (office), gilders@ohio.edu
Bob Hikida, 593-2323 (office), hikida@ohio.edu
If you have any questions regarding your rights as a research participant, please contact Jo Ellen Sherow, Director of Research Compliance, Ohio University, (740)593-0664.

I certify that I have read and understand this consent form and agree to participate as a subject in the research described. I agree that known risks to me have been explained to my satisfaction and I understand that no compensation is available from Ohio University and its employees for any injury resulting from my participation in this research. I certify that I am 18 years of age or older. My participation in this research is given voluntarily. I understand that I may discontinue participation at any time without penalty or loss of any benefits to which I may otherwise be entitled. I certify that I have been given a copy of this consent form to take with me.

Signature________________________ Date________________________ Printed
Name________________________
Title of Research Study: Physiological effects of high-carbohydrate, low-fat and high-protein, low-carbohydrate diets and high-intensity endurance training on skeletal muscle

Principal Investigator: Kumika Toma, MS.

Co-Investigators: Tim Werner, BS.
Jason White, MS.

Supervisors: Robert S. Hikida, Ph.D.
Roger M. Gilders, Ph.D.
Please fill out **ALL** information! Please **PRINT!**

**ID#** ______  **Date** ______________________

**DIET**

1. Do you consider yourself (circle one)
   a. Underweight by more than 10 pounds
   b. Underweight by 6 to 10 pounds
   c. Underweight by 5 pounds or less
   d. Just right
   e. Overweight by 5 pounds or less
   f. Overweight by 6 to 10 pounds
   g. Overweight by more than 10 pounds

2. Which of the following best describes your usual diet (circle all that apply)
   a. Strict vegetarian
   b. Lacto-vegetarian (include eggs and milk products)
   c. Modified vegetarian (include eggs, milk, fish, and poultry)
   d. Mixed diet (include red meat)
   e. Low fat diet
   f. Low calories
   g. Other. Please specify

3. Do you count your daily caloric intake? (circle one)  yes / no

4. Approximately how many calories per day do you think you eat?
   a. Less than 1000
   b. 1000 to 1500
   c. 1501 to 2000
   d. 2001 to 2500
   e. More than 2500
   f. Unknown
5. Circle all the habits you have used in order to lose weight.
   a. I have never tried to lose weight
   b. A diet recommended by a physician, trainer, or coach
   c. Severely reducing calories (eating less than 1000 calories/day)
   d. Group plan (such as Weight Watcher)
   e. Popular diet plan (such as the Scarsdale diet)
   f. Over-the-counter diet pills
   g. Fasting for one or more days
   h. Vomiting
   i. Exercise more
   j. A lipid or powder diet mix (such as lipid protein)
   k. Reducing calories in general
   l. Other. Please
      specify____________________________________________________

6. Have your parents or friends ever been more concerned than you about your body weight being too
   low? (circle one)                                yes / no

7. Have your parents or friends ever been more concerned than you about your body weight being
   too high? (circle one)                           yes / no

8. On the average how often do you have an alcoholic drink in a week?  0 / 1 / 2 / 3
   / 4 / 5/ 6 / 7

9. What occasion do you have alcohol? (circle as many)
   a. At dinner
   b. At party
   c. While watching TV/movie
   d. Other. Please
      specify____________________________________________________

10. What type of alcohol do you usually drink? (circle as many)
    beer / wine / whisky / hard liquors / other_____________________

11. On the average how much do you drink alcohol beverage in a week?
    ____________________________________________________________________
MEDICAL HISTORY

I. Please circle one

1. Are you allergic to any food? yes / no
   If yes, please specify ________________________________

2. Are you allergic to any medication? yes / no
   If yes, please specify ________________________________

3. Tobacco smoking
   a. I now smoke tobacco.
   b. I do not smoke tobacco now but I previously did smoke tobacco.
   c. I have never smoked tobacco.

II. For the following medical conditions circle one. If you have ever been diagnosed for the condition, specify the number of the years ago that the initial diagnosis was made.

1. Cardiovascular condition
   a. Persistent high blood pressure yes, continues today / yes, but does not exist today / no, since ________
   b. Congenital heart condition yes, continues today / yes, but does not exist today / no, since ________
      Please specify ________________________________
   c. Heart murmur
      yes, continues today / yes, but does not exist today / no, since ________
   d. Mitral valve prolapse
      yes, continues today / yes, but does not exist today / no, since ________
   e. Other heart conditions
      yes, continues today / yes, but does not exist today / no, since ________
      Please specify ________________________________
f. Rheumatic fever
yes, continues today / yes, but does not exist today / no, since _______

2. Organ condition
a. Blood disorder
yes, continues today / yes, but does not exist today / no, since ____

Please specify _________________________________

b. Nervous system disorder
yes, continues today / yes, but does not exist today / no, since ____

Please specify _________________________________

c. Gastrointestinal disease
yes, continues today / yes, but does not exist today / no, since ____

Please specify _________________________________

d. Kidney disease
yes, continues today / yes, but does not exist today / no, since ____

Please specify _________________________________

e. Gall bladder or liver disease
yes, continues today / yes, but does not exist today / no, since ____

Please specify _________________________________

f. Lung disease
yes, continues today / yes, but does not exist today / no, since ____

Please specify _________________________________

g. Cancer
yes, continues today / yes, but does not exist today / no, since ____

Please specify _________________________________

3. Other conditions
a. Thyroid disorder
yes, continues today / yes, but does not exist today / no, since ____

Please specify _________________________________
b. Hypoglycemia
   yes, continues today / yes, but does not exist today / no, since _____

c. Diabetes mellitus (sugar diabetes)
   yes, continues today / yes, but does not exist today / no, since _____

d. Diabetes insipidus (increased urination)
   yes, continues today / yes, but does not exist today / no, since _____

e. Hirsutism (increase in body hair)
   yes, continues today / yes, but does not exist today / no, since _____

f. Hyperprolactinemia (increased levels of prolactin in blood)
   yes, continues today / yes, but does not exist today / no, since _____

g. Epilepsy
   yes, continues today / yes, but does not exist today / no, since _____

h. Recurrent urinary tract infections
   yes, continues today / yes, but does not exist today / no, since _____

i. Anorexia nervosa
   yes, continues today / yes, but does not exist today / no, since _____

j. Bulimia nervosa
   yes, continues today / yes, but does not exist today / no, since _____

k. Stress fracture
   yes, continues today / yes, but does not exist today / no, since _____

l. Other condition
   yes, continues today / yes, but does not exist today / no, since _____

4. Recent medical and personal problems. Circle the appropriate response for each item.

   a. Hepatitis   yes, in last 6 months / yes, but not in last 6 months / never occurred

   b. Anemia     yes, in last 6 months / yes, but not in last 6 months / never occurred

   c. Frequent headaches
      yes, in last 6 months / yes, but not in last 6 months / never occurred

   d. Frequent indigestion or upset stomach
      yes, in last 6 months / yes, but not in last 6 months / never occurred
5. Please estimate as closely as possible your use of the following in the past six (6) months.

a. Aspirin or other non-prescription pain relievers
daily or almost daily / several times per month / several times / never

b. Prescription pain reliever (e.g., codeine)
daily or almost daily / several times per month / several times / never

c. Prescription drugs to relax you (valium, librium)
daily or almost daily / several times per month / several times / never

d. Prescription anti-depressants
daily or almost daily / several times per month / several times / never

e. Recreational drugs (e.g., marijuana, cocaine, LSD, heroin)
daily or almost daily / several times per month / several times / never

f. Diet or “pep” pill
daily or almost daily / several times per month / several times / never

g. Sleeping pills
daily or almost daily / several times per month / several times / never

h. Diuretics
daily or almost daily / several times per month / several times / never

i. Laxatives
daily or almost daily / several times per month / several times / never

j. Medication for indigestion
daily or almost daily / several times per month / several times / never

k. Anti inflammatory drugs (e.g., Motrin, Naprosyn, Indocin) for inflammatory pain
daily or almost daily / several times per month / several times / never

l. Anabolic steroids
daily or almost daily / several times per month / several times / never
m. Other prescribed medication
   daily or almost daily / several times per month / several times / never
   Please specify ____________________________

n. Vitamins
   daily or almost daily / several times per month / several times / never

o. Iron supplements
   daily or almost daily / several times per month / several times / never

p. Calcium supplements
   daily or almost daily / several times per month / several times / never

q. Other mineral supplements
   daily or almost daily / several times per month / several times / never

r. Energy producing products (e.g., amino acids, creatine, protein powder, etc.)
   daily or almost daily / several times per month / several times / never

6. Please estimate as closely as possible your use of the following in the past six (6) months.
   a. Alcohol
      several times / once daily / several times / several times / rarely or never
      per day       per week       per month
   b. Coffee
      several times / once daily / several times / several times / rarely or never
      per day       per week       per month
   c. Tea
      several times / once daily / several times / several times / rarely or never
      per day       per week       per month
   d. Soft drinks
      several times / once daily / several times / several times / rarely or never
      per day       per week       per month

7. Circle following medical conditions that have occurred in your family in the last two generations. Answer the question with respect to your closest genetic relatives: paternal grandfather, paternal grandmother, maternal grandmother, maternal grandfather, father, mother, sister, brother.
   a. High blood pressure       yes / no / unknown       Family member(s) ________________
<table>
<thead>
<tr>
<th>Condition</th>
<th>Status</th>
<th>Family member(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>b. Heart disease</td>
<td>yes / no / unknown</td>
<td></td>
</tr>
<tr>
<td>c. Stroke</td>
<td>yes / no / unknown</td>
<td></td>
</tr>
<tr>
<td>d. Osteoporosis</td>
<td>yes / no / unknown</td>
<td></td>
</tr>
<tr>
<td>e. Anorexia nervosa</td>
<td>yes / no / unknown</td>
<td></td>
</tr>
<tr>
<td>f. Bulimia nervosa</td>
<td>yes / no / unknown</td>
<td></td>
</tr>
</tbody>
</table>
Appendix C: Activity Log

Exercise / Training

1. Currently how often do you exercise/training in a week? seldom / 1 / 2 / more than 3 times

2. How long do you exercise at each time?

___________________________________________________________________

3. What type of exercises/training do you do? (list all)

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

4. Are you most physically active now? yes / no

If no,

a. When were you most physically active?

___________________________________________________________________

b. What type of exercise/training did you do? (list all)

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Title of Research Proposal: Physiological effects of high-carbohydrate, low-fat and high-protein, low-carbohydrate diets on high-intensity aerobic training

Investigator(s) Information

Primary Investigator

Name: Kumika Toma
Department: Biological Sciences
Address: Irvine Hall 015
Email: kt247191@ohio.edu
Phone: 593-0450

Training Module Completed? Yes □ No (Attach Certificate as Appendix H) (www.research.ohiou.edu/cbt)

Co-investigators

Name: Tim Werner
Department: School of Recreation and Sport Sciences
Address: 2 Andover Dr. Apt. H5, Athens, OH 45701
Email: tw276898@ohio.edu
Phone: 589-5436

Training Module Completed? Yes □ No (Attach Certificate as Appendix H)
Advisor Information (if applicable)

Name  Robert S. Hikida, Ph.D.  Department  Biomedical Sciences
Address  Life Science Building 117  Phone  593-2323
Email  hikida@ohio.edu
Training Module Completed?  Yes  □  No  (Attach Certificate as Appendix H)

Name  Roger M. Gilders, Ph.D.  Department  School of Recreation and Sport Sciences
Address  Grover Center E184  Phone  593-0101
Email  gilders@ohio.edu
Training Module Completed?  Yes  □  No  (Attach Certificate as Appendix H)
Anticipated Starting Date: September 1, 2004

Duration: 12 mos (Work, including recruitment, cannot begin prior to IRB approval. This date should never precede the submission date)

Funding Status
Is the researcher receiving or applying for external funding?  □ Yes  ✔ No
(Note – This refers to funding from entities outside of Ohio University)

If yes, list source: ________________________________

(Note – If an application for funding has been submitted, a FULL copy of the funding application must accompany this form as APPENDIX G)

If yes, describe any consulting or other financial relationships with this sponsor.

Is there a payment of any kind connected with enrollment of participants on this study that will be paid to persons other than the research participants?  □ Yes  ✔ No
(If yes, describe.)

Review Level
Based on the definition in the guidelines, do you believe your research qualifies for:

□ Exempt Review Category: __________
□ Expedited Review Category: __________
X Full Committee Review

Final determination of review level will be determined by Office of Research Compliance in accordance with the categories defined in the Code of Federal Regulations

Prior Approval
If this or a similar protocol been approved by OU IRB or any other, please attach copy of approval and label as Appendix E.

Recruitment/Selection of Subjects
Estimated Number of Human Participants: 30

Characteristics of subjects (check as many boxes as appropriate).

□ Minors  □ Physically or Mentally Disabled  □ Elementary School Students
-X Adults  □ Legal Incompetency  □ Secondary School Students
□ Prisoners  □ Pregnant Females  √ University Students
□ Others (Specify): ________________________________
Briefly describe the criteria for selection of subjects (inclusion/exclusion). Include such information as age range, health status, etc. Attach additional pages if necessary.

The subjects recruited will be male, apparently healthy volunteers between the ages of 19-40 years. Included (Appendix F) is a copy from the 2000 edition of ACSM’s Guidelines for Exercise Testing and Prescription. This states that for apparently healthy and younger individuals (younger implies less than 55 years old for females) a medical exam and physician supervision is not needed for maximal or submaximal testing. A subject will be precluded from the study if it is determined from his health history questionnaire (attached) that he is at risk of injury due to cardiovascular, metabolic, pulmonary or musculoskeletal problems or diseases. The methodology section of this outline gives a more elaborate explanation of the subject selection.

How will you identify and recruit prospective participants? If subjects are chosen from records, indicate who gave approval for the use of the records. If records are "private" medical or student records, provide the protocol, consent forms, letters, etc., for securing consent of the subjects for the records. Written documentation for cooperation/permission from the holder or custodian of the records should be attached. (Initial contact of subjects identified through a records search must be made by the official holder of the record, i.e. primary physician, therapist, public school official.)

Subjects will be recruited by posting flyers (Appendix B) around the University. Verbal announcements and a written description will be presented to undergraduate students in both science and non-science classes. Because the data collection and training of the subjects will take place throughout the Fall quarter, 2004, we hope to begin recruiting subjects as soon as the Fall 2004 quarter starts.

Please describe your relationship to the potential participants, i.e. instructor of class, co-worker, etc. If no relationship, state no relationship.

The investigator relationship with the participants could be as an instructor, teaching assistant, or no relationship at all.

Attach copies of all recruitment tools (advertisements, posters, etc.) and label as APPENDIX B

Performance Sites

List all collaborating and performance sites, and provide copy of IRB approval from that site and/or letters of cooperation or support.
Project Description

Please provide a brief summary of this project, using non-technical terms that would be understood by a non-scientific reader. Attach an additional page, if needed, but please limit this description to no more than one typewritten page.

It is well known that diets affect exercise performance. Among the three major nutrients, carbohydrates, fats, and proteins, carbohydrates and fats are the main fuel for metabolism. Proteins are a good dietary resource for muscle synthesis. To enhance the exercise performance a high-carbohydrate, low-fat diet has been recommended to athletes who participate in high-intensity aerobic exercise while a high-fat diet is beneficial to low-intensity long-duration exercise. Recently high-protein, low-carbohydrate diets have become popular. This high-protein, low-carbohydrate diet is proposed to reduce body weight. Many active individuals seem to practice this diet while they are participating in aerobic exercise. Although proteins can be broken-down and converted to glucose, which is derived from carbohydrates, there has been no previous study investigating the effects of a high-protein, low-carbohydrate diet and aerobic exercise. Therefore, this study is aimed to see if a high-protein, low-carbohydrate diet is effective as a high-carbohydrate, low-fat diet.

The subjects will be introduced to the rowing technique and how to maintain a dietary log during the first week. After this introductory period, pre-testing will take place.

These tests include:
1. Strength testing by assessing maximal dynamic muscular strength and muscular endurance on knee extension.
2. Muscle biopsy from the vastus lateralis (one of the knee extensors). This will be done to determine physiological changes, cellular responses, and stem cell activation of the muscle fibers in response to training.
3. Cardiovascular capacity will be tested to determine the maximal amount of oxygen that can be consumed. This measurement is highly correlated to performance of aerobic activities.
4. Anthropometric measurements: this will include percent body fat, height and weight.
5. Blood sampling to test nutritional substrates in blood and pH for acidity.

Based on the result of the cardiovascular capacity test, the subjects who have similar values for maximum oxygen consumption will be paired and then randomly assigned into one of the following two groups.
1. High-carbohydrate, low-fat diet group
2. High-protein, low-carbohydrate diet group.
The subjects will train for 7 weeks total (2 times a week for the first 3 weeks and 3 times a week for the last 4 weeks) on rowing ergometers. The subjects will go through a traditional warm-up and cool-down. After the 7th week, post-testing will take place.

Please describe the specific scientific objectives (aims) of this research and any previous relevant research.

It has been documented that a high-carbohydrate, low-fat diet affects muscular strength and endurance, cardiorespiratory fitness, and physiological, morphological, or histochemical changes in the trained muscle fibers. While high-protein, low-carbohydrate diet became popular, there has been no previous study that has examined these aspects of high-protein, low-carbohydrate diet. Therefore, this study is aimed to examine if this diet is as effective as a high-carbohydrate, low-fat diet on high-intensity aerobic exercise.

Methodology: please describe the procedures (sequentially) that will be performed/followed with human participants.

Upon recruiting a subject, the testing and training procedures will be explained verbally, and questions as to the procedures will be answered at that time. The potential subjects will be given code numbers to protect their identity. They will fill out the health history questionnaires and submit their urine sample for ketone testing, which will be used as screening. The individuals who have a history of cardiovascular, neuromuscular, and/or dietary problems will be eliminated from participating in this study. The individuals whose urine samples are positive for ketone will also be eliminated from participating in this study. The health history questionnaires will be shredded when the individuals are eliminated from participating in this study or when the study is completed. The subjects will then be asked to read and sign the informed consent document if intending to participate in the study. Again, when reading a description of the testing and training procedures, the subjects will have a chance to ask questions of the researchers. Since this study is to be conducted during one quarter (fall quarter of 2004), we hope to be able to recruit subjects in the first 2 weeks of fall quarter. A total of 30 subjects will be recruited. They will be divided into 2 groups (high-carbohydrate, low-fat diet or high-protein, low-carbohydrate diet groups) after the first 4 weeks training and the pre-testing. All of the testing and training will be done in the Exercise Physiology facilities located in the basement of Irvine Hall. The subjects who choose to participate in the study will be free to withdraw from the study at any time without affecting relations with the investigators.

There will be several different measurements that will be performed at the beginning and end of this study. These measurements are described below:

**Percent body fat and lean body mass determinations:**

The subjects will be weighed and their heights measured. Percent body fat will be calculated by body density determined by an underwater weighing method. This is a
noninvasive, no-risk evaluation. Lean body mass will be determined from the total body mass and percent body fat measurements.

Prior to underwater weighing, the subjects will perform a pulmonary function test to estimate residual volume in the lungs. Since percent body fat will be calculated by body weight in the air and body weight in water, estimating the amount air in the lung is important to this calculation. On the day of underwater weighing, the subjects will report to the lab in the morning without having eaten or drunk anything before the measurement. The subjects will urinate and defecate if possible before beginning the underwater weighing procedure and will be in swimsuits. Body weight in the air will be determined by an electronic scale while weight in water will be assessed by the force transducer which is located on the chair interfaced through the transbridge to the computer. The chair is hung in the water tank. The subjects will be asked to sit in the chair. In this position, water will be up around the subjects’ chest. The subjects will be asked to exhale as much air as possible so that minimal air remains in their lungs. The subject will bend forward so that the body is immersed into the water and the subject holds his breath for at least 3 seconds so that the reading of weight is stable. The subjects will be notified of the end of each measurement by sound and will be allowed to get their faces out of the water to breath. The subjects can terminate this measurement anytime during each trial if they feel discomfort and/or difficulty. The subjects will perform the underwater weighing measurement until at least 2 trials are within 3 percent difference, or 10 trials a day.

**Maximal Dynamic Strength and Local Muscular Endurance Measurements:**

Maximal dynamic strength and local muscular endurance will be determined to assess potential improvements as a result of the rowing training. Isokinetic dynamometer will be used to assess strength and endurance of thigh muscles through knee extension action. The arm of the dynamometer will be set to move at the speed of 30 degrees per second for the maximal dynamic strength test. The subject will push the dynamometer’s arm as forcefully as possible in the same direction as the arm moves. Three knee extension actions will be performed in a set. Three sets of tests will be done with at least one-minute rest period between each set. Highest force of total 9 trails will be recorded as maximal dynamic strength.

After recovering from the maximal dynamic strength test, the subject will be asked to perform a local muscular endurance test. The arm of the dynamometer will be set to move 180 degrees per second. The subject will push the dynamometer’s arm as forcefully as possible in the same direction the arm moves 30 times. The fatigue index will be calculated as the total force during the last 10 repetitions divided by the total force during the first 10 repetitions. Fatigue index indicates the subject’s ability to maintain force output.

Prior to and after the muscular strength and endurance tests, the subjects will be encouraged to perform light exercise and/or stretching for warm-up and cool-down. Although no severe physical risks or hazards are anticipated, there may be temporary muscle/joint pain following the strength testing.

**Maximal Oxygen Consumption:**
Aerobic capacity will be determined at the middle and end of the study during a rowing ergometer exercise of increasing intensity. The subject will be fitted with headgear and a mouthpiece in order to collect expired gases using semi-computerized open-circuit spirometry. This will measure the subject’s oxygen consumption (VO2), ventilation (VE), expired carbon dioxide (VCO2), and respiratory exchange rate (RER).

The subjects will be asked to produce target power. Either how forcefully or the rate at which the subject rows or both, determines the power. After performing light exercise and/or stretching, the subject will begin rowing for 1 minute at 75 watts and the target power will be increased by 25 Watts every minute during the exercise until one or more of the following criteria are observed: 1) a failure to maintain required power, 2) attaining age-predicted maximal heart rate, 3) plateau or decline in VO2 in later power stages, 4) RER of greater than 1.1, or 5) volitional cessation of exercise. At five minutes of recovery period a small microliter blood sample (25µl) will be taken by finger prick and then analyzed for lactic acid concentration. The variables that will be recorded during this test are maximal VO2, maximal VE, maximal power output obtained, and time to volitional exhaustion.

Muscle Biopsy Procedure
A total of two muscle biopsies per subject will be taken from a large thigh muscle (vastus lateralis). All muscle biopsies will be performed by Dr. Fredrick Hagerman under the medical supervision of a physician. The biopsy procedure yields a small (60-100 mg) piece of muscle tissue for subsequent analysis. Prior to having a muscle biopsy taken, each subject will be given a thorough verbal orientation of the procedures described above (Appendix F: Percutaneous Needle Muscle Biopsy Procedure). Following the biopsy procedure, the subject will be given instructions on the proper care of the incision (Appendix F: Life After a Muscle Biopsy). Both written and verbal instructions will be given at the time of the biopsy. The incision will be checked daily for the subsequent 48 hours post-biopsy by Dr. Hagerman (or one of the investigators) and a new dressing will be applied if necessary.

Blood Sampling Procedure
The subjects will report to the laboratory in the early morning of blood sampling day. The subjects will refrain from having any food and beverage except water after dinner on the night before until finishing blood sampling. About 10 cc blood will be drawn from the vein at the forearm by a certified phlebotomist. Collected blood will be centrifuged and plasma will be collected for several analyses.

Diet
All subjects will keep a daily log of what they have eaten and report this to one of investigators via e-mail weekly (Appendix F: Food log and its example). The subjects will be taught to record the food log during the introductory period. The subjects will report their diet through 7 weeks. After pre-testing, the subjects will be given the list of restricted food and recommended food based on which diet group they are assigned. The
subjects will be encouraged to ask questions regarding choice of food and beverage and method of recording. During the 7-week rowing training, the subjects will continue recording dietary records and reporting them weekly. The dietary records will be analyzed to obtain group difference in total caloric intake and nutrient composition.

The food log will consist of 6 sections: meal time, food consumed, where the meal was consumed, with whom the meal/snack was eaten, how you were feeling at this time, and rate your hunger. The food log will be turned in. A random identifier number will be used when logging the data into the computer. Nutritionist Pro Nutrition Analysis is the software program that will analyze and interpret the data. After data processing is complete, a Client Diet Record Report and Client Diet Record Nutrition Summary will be generated. A Client Diet Record Report lists all the foods and drinks consumed in a specified time and calculates amount of sodium, calories, protein, carbohydrate, fat, cholesterol, saturated fat, monounsaturated fat, polyunsaturated fat, and dietary fiber in each food or drink. The Client Diet Record Nutrition Summary will sum up and average the total amount of most macronutrients, vitamins, and minerals over a specified time.
**Rowing Training**

Following the introduction, the subjects will begin to train for 8 weeks on rowing ergometers. Before and after training, the subjects will perform warm-up exercise and cool-down exercise. During training, the subjects will wear a heart rate monitor. Training intensity will be determined by target heart rate during rowing. No training will take place without supervision. The training routines are delineated below:

<table>
<thead>
<tr>
<th>Week</th>
<th>Days/Week</th>
<th>Duration</th>
<th>Rest</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>5 minutes</td>
<td>4 minutes</td>
<td>3 sets at 70% of maximum heart rate obtained in pre-test</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>5 minutes</td>
<td>4 minutes</td>
<td>4 sets at 70% of maximum heart rate obtained in pre-test</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>10 minutes</td>
<td>5 minutes</td>
<td>2 sets at 70% of maximum heart rate obtained in pre-test</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>10 minutes</td>
<td>5 minutes</td>
<td>2 sets at 80% of maximum heart rate obtained in pre-test</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>10 minutes</td>
<td>4 minutes</td>
<td>3 sets at 80% of maximum heart rate obtained in pre-test</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>20 minutes</td>
<td>5 minutes</td>
<td>2 sets at 80% of maximum heart rate obtained in pre-test</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>2 minutes</td>
<td>1 minute</td>
<td>8 sets at 90% of maximum heart rate obtained in pre-test</td>
</tr>
</tbody>
</table>
Describe any potential risks or discomforts of participation and the steps that will be taken to minimize them.

**Percent Body Fat measures**

The only anticipated risk for these measurements is the possible fear of being in water in the relatively small tank. If the subject does not feel comfortable in the tank, he is free to get out from water.

**Maximal Dynamic Strength and Local Muscular Endurance**

The risks associated with these tests include possible muscle/joint soreness and a temporary increase in blood pressure during knee extension actions. Although isokinetic dynamic action does not have an eccentric mode, which normally causes muscle damage and pain, there is slight possibility that the subjects will feel soreness after the tests. The subjects will be screened for hypertensive problems prior to participation, and not be allowed to participate in the study if any problems are found. There will be proper supervision and explanations/demonstrations of the tests to be performed.

**Maximal Oxygen Consumption**

The risks associated with this test are muscle fatigue and slight muscle soreness, increase in blood pressure, dizziness, nausea, and a slight risk of heart attack, and a very slight risk of sudden death. The subjects will also be instructed to drink plenty of fluid in the hours prior to the rowing ergometer test, and to eat a small meal at least three hours prior to the test, in order to avoid nausea. Throughout the test and after the test, the subjects will be monitored by laboratory personnel trained in CPR. If an emergency should arise, the laboratory personnel will call EMS and provide emergency care until emergency medical personnel arrive. Emergency numbers are posted by the phone in the laboratory. In addition, subjects will be informed that if they feel unable to continue a test, they may stop at any time. The subjects will also be instructed as to how to perform stretches, which may help alleviate any muscle soreness that may occur after the test. Because of the invasive nature of blood withdrawal, there is a slight risk of infection and hematoma but the likelihood of such events occurring from a finger prick is very rare.

**Muscle Biopsy Procedure**

The muscle biopsy procedure does not cause any permanent damage. There will, however, be a small scar that should become undetectable over time. Local discomfort may occur over the initial 24 hours after the biopsy, but this is no more painful than a slight bruise to the thigh and will subside in a day or two. Risks associated with the biopsy procedure include mild bleeding, hematoma, infection, post-procedure pain, localized temporary loss of skin sensitivity, and slight scarring of the skin. Every precaution will be taken to keep these risks to a minimum. Ice therapy, mild pain medication (aspirin), compression, and elevation have been used separately or in combination to alleviate these problems.
Blood Sampling

Because of the invasive nature of blood withdrawal, there is a slight risk of infection and bleeding. Every precaution will be taken to keep these risks to a minimum.

For all of the tests in this study, there is very little possibility of potential problems. All of the tests, including the muscle biopsies, have been performed in the laboratory for several years by the same investigators without incident.

Diet

There is a slight possibility that a high-protein, low-carbohydrate diet will cause ketosis, which may inhibit the central nervous system. During the 7 weeks rowing training, a small amount of urine (about 1 oz) will be collected before the training and will be tested for ketosis at the site using the dip-stick method.

Ketosis occurs when a person’s diet is composed almost entirely of fat and the body cannot adapt to this change or when a person performs high intensity exercise even when a high-carbohydrate diet is consumed. Proteins would be broken-down and converted to glucose which is mainly derived from carbohydrate. The human body has the ability to adapt to the change of fuel source. If so, ketosis would not be observed. The prior research conducted with high-fat, low-carbohydrate diet and cycling training for 7 weeks did not report ketosis.

The dip-stick has five (5) scales: negative to strongly ketosis to indicate the degree of ketosis. There is no formula or protocol to follow for adjusting the dietary intake because of interindividual difference. Therefore, if high urinary ketosis and ketotic symptom are observed, carbohydrate intake will be increased slightly. Although diabetes is associated with ketosis, the presence of ketosis in urine does not mean that the individual is diabetic.

Describe the anticipated benefits to the individual participants. If none, state that. (Note that compensation is not a benefit, but should be listed in the compensation section on the next page.)

The individual participants will gain knowledge about their current fitness level and diet and how to improve it once the study is completed. Also, the participants will also be able to gain musculoskeletal fitness throughout the study due to the rowing training sessions. There are also academic benefits that can occur from the study. Subjects will gain insight into proper rowing techniques and will also learn about the physiological adaptations to training and diet. Along with the mentioned benefits, subjects will gain knowledge into the research side of exercise physiology and nutrition.

Describe the anticipated benefits to society and/or the scientific community. There must be some benefit to justify the use of human subjects.
Society will benefit from this investigation since it will increase knowledge about the effects of high-protein, low-carbohydrate diets and high-intensity aerobic training. This will help to educate society about how this type of training and diet modification really affects the body so that proper exercise and diet choices may be made. The anticipated benefits to the scientific community will also include increasing knowledge of the physiological effects of the effects of high-protein, low-carbohydrate diet and high-intensity aerobic training.

Describe procedures in place to protect confidentiality. Who will have access to raw data? Will raw data be made available to anyone other than the Principal Investigator and immediate study personnel (e.g., school officials, medical personnel)? If yes, who, how, and why? Describe the procedure for sharing data. Describe how the subject will be informed that the data may be shared.

All data except the health history questionnaires will be kept in the primary investigator’s office in a locked file for five years. The health history questionnaires will be shredded when the individuals are eliminated from participating in the study or when the study is completed. All participants will receive a subject number and only the investigators will be able to identify the individuals. A code key will be developed to match the subject name with their subject number. This key will be kept for 5 years, also in the locked file, to be accessed only by the researchers involved with this study. The health history forms will also be kept in a locked file in the primary investigator’s office. The information from the health history form will not be shared with other researchers in the future, and it will be destroyed within five years. The data will be compiled and only group data will be used for dissemination and research purposes. This will be explained to the subjects both verbally and in the informed consent.

Will participants be: Audiotaped? □ Yes  ✔ No

Videotaped? □ Yes  ✔ No

If so, describe how/where the tapes will be stored (i.e. locked file cabinet in investigator office), who will have access to them, and at what point they will be destroyed.

N/A
Provide details of any compensation (money, course credit, gifts) being offered to participants, including how the compensation will be prorated for participants who discontinue participation prior to completion.

No compensation is being offered to participants. A participant can choose to withdraw from the investigation at any time without negatively affecting his/her relationship with the investigators.

**Instruments**

List all questionnaires, instruments, standardized tests below, with a brief description, and provide copies of each, labeled as APPENDIX C.

1. Health History and Physical Examination forms: this is used to determine the health risks of potential subjects prior to participating in the test (Appendix C).

How will the data be analyzed? State the hypothesis and describe how the analysis of the data will test that hypothesis.

The null hypotheses for the proposed investigation include:

H₀: There is no difference in muscle fiber cross-sectional area between or within groups. Cross sectional areas of 6µm thickness will be measured using an image analysis program and microscope.

H₀: No difference in nuclear domains will be manifested. The nucleus to cytoplasm ratio will be measured from each sample for at least 300 muscle fibers per sample and compared for the different groups.

H₀: Changes in muscle fibers are not fiber type-specific. Immunohistochemical procedures for various myosins will be used to determine muscle fiber type and these will be used to compare fiber type distributions of all changes assayed above.

H₀: There will be no difference in glucose transport protein on the muscle membrane between or within groups. Immunohistochemical procedures for GLUT-4 will be used to determine the population of GLUT-4 on skeletal muscle fiber membrane.

H₀: There will be no difference in type of energy fuel between or within groups. β-hydroxybutyrate in plasma will be analyzed by a spectrophotometer.
H₀: There will be no difference in oxidative enzyme activities between or within groups. Pyruvate dehydrogenase and pyruvate dehydrogenase kinase will be analyzed by a spectrophotometer.

H₀: There will be no difference in blood pH between or within groups.

H₀: There will be no difference in maximal oxygen consumption between or within groups.

H₀: There will be no difference in respiratory exchange ratio between or within groups.

H₀: There will be no difference in muscular strength or endurance between or within groups.

H₀: There will be no difference in body fat between or within groups.

H₀: There will be no difference in body weight between or within groups.

The data collected will be analyzed using repeated analysis of variance to compare the variables between and within groups over time.

**Informed Consent Process**

Attach copies of all consent documents or text and label as APPENDIX A.

Informed consent is a process, not just a form. Potential participants/representatives must be given the information they need to make an informed decision to participate in this research. How will you provide information/obtain permission? Potential participants will be informed verbally, and if they decide to participate, they will also be required to read the informed consent form. Potential participants may ask questions of the researchers at any time to clarify or further understand their role.

How and where will the consent process occur? How will it be structured to enhance independent and thoughtful decision-making? What steps will be taken to avoid coercion or undue influence? Initially, the potential participants will be told about the investigation upon recruitment or first contact with them. They may ask questions at any time. Upon deciding to participate, they will also read the informed consent form and also be able to ask questions at that time. It will be made clear to the potential subjects that participation is totally voluntary, and withdrawal from the study at any time will not adversely affect their relationship with the investigators.

**Will the investigator(s) be obtaining all of the informed consents?**  ☑ Yes  ☐ No

If not, identify by name and training who will be describing the research to subjects/representatives and inviting their participation?
Will all adult participants have the capacity to give informed consent? If not, explain procedures to be followed. All participants will have the capacity to give informed consent.

If any participants will be minors, include procedures/form for parental consent and for the assent from the minor.
N/A

Are you requesting a waiver or alteration of Informed Consent? ☐ Yes  ☑ No

An IRB may approve a consent that does not include, or alters, some or all of the elements of informed consent. Provide justifications below for the waiver. N/A

a. Describe how the proposed research presents no more than minimal risk to participants.

b. Why will a waiver of informed consent not adversely affect the rights and welfare of participants?

c. Why is it impracticable to carry out the research without a waiver or alteration of informed consent?

d. How will pertinent information be provided to participants, if appropriate, at a later date?
Even if waiver of written informed consent is granted, you will likely be required to obtain verbal permission that reflects the elements of informed consent (if appropriate). Please specify below information to be read/given to participants.

Will participants be deceived or incompletely informed regarding any aspect of the study?  

☐ Yes  ✔ No

If so, provide rationale for use of deception.

Attach copies of post-study debriefing information and label as APPENDIX D.

Investigator Assurance

I certify that the information provided in this outline form is complete and correct.

I understand that as Principal Investigator, I have ultimate responsibility for the protection of the rights and welfare of human subjects, conduct of the study and the ethical performance of the project.

I agree to comply with Ohio University policies on research and investigation involving human subjects (O.U. Policy # 19.052), as well as with all applicable federal, state and local laws regarding the protection of human subjects in research, including, but not limited to the following:

- The project will be performed by qualified personnel, according to the OU approved protocol.
- No changes will be made in the protocol or consent form until approved by the OU IRB.
- Legally effective informed consent will be obtained from human subjects if applicable, and documentation of informed consent will be retained, in a secure environment, for three years after termination of the project.
- Adverse events will be reported to the OU IRB promptly, and no later than within 5 working days of the occurrence.
• All protocols are approved for a maximum period of one year. Research must stop at the end of that approval period unless the protocol is re-approved for another term.

I further certify that the proposed research is not currently underway and will not begin until approval has been obtained. A signed approval form, on Office of Research Compliance letterhead, communicates IRB approval.

 Principal Investigator Signature_________________ Date _____________

 Co-Investigator Signature_________________ Date _____________

 Co-Investigator Signature_________________ Date _____________

 Co-Investigator Signature_________________ Date _____________

 Co-Investigator Signature_________________ Date _____________

 Co-Investigator Signature_________________ Date _____________
Faculty Advisor/Sponsor Assurance

By my signature as sponsor on this research application, I certify that the student(s) or guest investigator is knowledgeable about the regulations and policies governing research with human subjects and has sufficient training and experience to conduct this particular study in accord with the approved protocol. In addition:

- I agree to meet with the investigator(s) on a regular basis to monitor study progress.
- Should problems arise during the course of the study, I agree to be available, personally, to supervise the investigator in solving them.
- I assure that the investigator will report significant or untoward adverse events to the IRB in writing promptly, and within 5 working days of the occurrence.
- If I will be unavailable, as when on sabbatical or vacation, I will arrange for an alternate faculty sponsor to assume responsibility during my absence.

I further certify that the proposed research is not currently underway and will not begin until approval has been obtained. A signed approval form, on Office of Research Compliance letterhead, communicates IRB approval.

Advisor/Faculty Sponsor Signature________________________Date ____________

Advisor/Faculty Sponsor Signature________________________Date ____________

*The faculty advisor/sponsor must be a member of the OU faculty. The faculty member is considered the responsible party for legal and ethical performance of the project.
Checklist:

☐ Completed and Signed IRB-1 (this form)

☐ Appendix A - copies of all consent documents (in 12 pt. Font) including
  ___ Informed Consent to Participate in Research (adult subjects)
  ___ Parental Permission/Informed Consent (parents of subjects who are minors or children)
  ___ Assent to Participate in Research (used when subjects are minors or children)

☐ Appendix B - copies of any recruitment tools (advertisements, posters, etc.)

☐ Appendix C – copies of all instruments (surveys, standardized tests, questionnaires, interview topics, etc.).

☐ Appendix D - Copies of debriefing text

☐ Appendix E - Approval from other IRB, School District, Corporation, etc.

☐ Appendix F - Any additional materials that will assist the Board in completing its review

☐ Appendix G – Copies of any IRB approvals

☐ Appendix H – Copies of Human Subjects Research Training Certificates

  (for all key personnel involved in non-exempt research)

All fields on the form must be completed, regardless of review level. If a field is not applicable, indicate by inserting n/a. Incomplete forms will result in delayed processing.
Forward this completed form and all attachments to:

Human Subjects Research
Office of Research Compliance
117 Research & Technology Center, Ohio University, Athens, OH 45701-2979

Questions? Visit the website at www.ohio.edu/research/compliance/ or email compliance@ohio.edu
Title of Research: Physiological effects of high-carbohydrate, low-fat and high-protein, low-carbohydrate diets on high-intensity aerobic training

Principal Investigator: Kumika Toma

Co-Investigator: Tim Werner

Department: Biological Sciences, School of Recreation and Sport Sciences

Federal and university regulations require signed consent for participation in research involving human subjects. After reading the statements below, please indicate your consent by signing this form.

Explanation of Study

Purpose of the research

The purpose of this research project is to assess the effects of two different diet regimens and exercise training programs on various physiological measurements.

Procedures to be followed

Prior to any of the following tests being conducted, you will fill out a health history questionnaire. You will not be allowed to participate in the study if it is determined from your health history questionnaire that you are at risk of injury due to cardiovascular, metabolic, pulmonary or musculoskeletal problems or diseases.

Following medical/health clearance, rowing training will start. During the first week of rowing, you will be instructed in filling out a food log. Rowing training will be composed of two 4-week sessions. After the first 4-weeks training, several different measurements will be taken (pre-test). Based on the results of pre-test, you will be assigned into one of two diet groups: high-carbohydrate, low-fat group or high-protein, low-carbohydrate group. You will have instruction regarding restricted food and recommended food. The post-test will be performed after the last 4-weeks training. These measurements and the training are described below:

Percent body fat and lean body mass determinations:

Your height and weight will be measured. Percent body fat will be calculated by body density determined by an underwater weighing method. This is a noninvasive, no-risk evaluation. Lean body mass will be determined from the total body mass and percent body fat measurements.

Prior to underwater weighing, you will perform a pulmonary function test to estimate residual volume in the lungs. Since percent body fat will be calculated by body weight in the air and body weight in water, estimating the amount air in the lung is
important to this calculation. On the day of underwater weighing, you will report to the lab in the morning without having eaten or drunk anything before the measurement. You will urinate and defecate if possible before beginning the underwater weighing procedure and will be in swimsuits. Body weight in the air will be determined by an electronic scale while weight in water will be assessed by the force transducer which is located on the chair interfaced through the transbrige to the computer. The chair is hung in the water tank. You will sit in the chair and exhale as much air as possible so that minimal air remains in your lungs. In the sitting position, water will be up around your chest. You will bend forward so that your body is immersed into the water and you will hold your breath for at least 3 seconds so that the reading of weight is stable. You will be notified of the end of each measurement by sound and will be allowed to get your face out of the water to breathe. You can terminate this measurement anytime during each trial if you feel discomfort and/or difficulty. You will perform the underwater weighing measurement until at least 2 trials are within 3 percent difference, or 10 trials a day.

Maximal Dynamic Strength and Local Muscular Endurance Measurements:

Maximal dynamic strength and local muscular endurance will be determined to assess potential improvements as a result of the rowing training. Isokinetic dynamometer will be used to assess strength and endurance of thigh muscles through knee extension action. The arm of the dynamometer will be set to move at the speed of 30 degrees per second for the maximal dynamic strength test. You will push the dynamometer’s arm as forcefully as possible in the same direction as the arm moves. Three knee extension actions will be performed in a set. Three sets of tests will be done with at least one-minute rest period between each set. Highest force of total 9 trails will be recorded as maximal dynamic strength.

After recovering from the maximal dynamic strength test, you will perform a local muscular endurance test. The arm of the dynamometer will be set to move 180 degrees per second. You will push the dynamometer’s arm as forcefully as possible in the same direction the arm moves 30 times. The fatigue index will be calculated as the total force during the last 10 repetitions divided by the total force during the first 10 repetitions. Fatigue index indicates your ability to maintain force output.

Prior to and after the muscular strength and endurance tests, you will be encouraged to perform light exercise and/or stretching for warm-up and cool-down. Although no severe physical risks or hazards are anticipated, there may be temporary muscle/joint pain following the strength testing.

Maximal Oxygen Consumption:

Aerobic capacity will be determined at the middle and end of the study during a rowing ergometer exercise of increasing intensity. You will be fitted with headgear and a mouthpiece in order to collect expired gases using semi-computerized open-circuit spirometry. This will measure your oxygen consumption (VO₂), ventilation (VE), expired carbon dioxide (VCO₂), and respiratory exchange rate (RER).

You will be asked to produce target power. Either how forcefully or the rate at which you row, or both, determines the power. After performing light exercise and/or stretching, you will begin rowing for 1 minute at 75 watts and the target power will be
increased by 25 Watts every minute during the exercise until one or more of the following criteria are observed: 1) a failure to maintain required power, 2) attaining age-predicted maximal heart rate, 3) plateau or decline in VO$_2$ in later power stages, 4) RER of greater than 1.1, or 5) volitional cessation of exercise. At five minutes of recovery period, a small microliter blood sample (25µl) will be taken by finger prick and then analyzed for lactic acid concentration. The variables that will be recorded during this test are maximal VO$_2$, maximal $V_E$, maximal power output obtained, and time to volitional exhaustion.

**Muscle Biopsy Procedure**

A total of two muscle biopsies per subject will be taken from your large thigh muscle (vastus lateralis). All muscle biopsies will be performed by Dr. Fredrick Hagerman under the medical supervision of a physician. The biopsy procedure yields a small (60-100 mg) piece of muscle tissue for subsequent analysis. Prior to having a muscle biopsy taken, you will be given a thorough verbal orientation of the procedures described above (Percutaneous Needle Muscle Biopsy Procedure). Following the biopsy procedure, you will be given instructions on the proper care of the incision (Life After a Muscle Biopsy). Both written and verbal instructions will be given at the time of the biopsy. The incision will be checked daily for the subsequent 48 hours post-biopsy by Dr. Hagerman (or one of the investigators) and a new dressing will be applied if necessary.

**Blood Sampling Procedure**

You will report to the laboratory in the early morning of blood sampling day. You will refrain from having any food and beverage except water after dinner on the night before until finishing blood sampling. About 10 cc blood will be drawn from the vein at the forearm by a certified phlebotomist. Collected blood will be centrifuged and plasma will be collected for several analyses.

**Diet**

You must keep a daily log of food eaten and report this to one of investigators via e-mail weekly. You will be taught to record the food log during the introductory period. You will report your diet through 7 weeks. After pre-testing, you will be given the list of restricted food and recommended food based on which diet group you are assigned. You will be encouraged to ask questions regarding choice of food and beverage and method of recording. During the 7-week rowing training, you will continue recording dietary records and reporting them weekly. The dietary records will be analyzed to obtain group difference in total caloric intake and nutrient composition.

The food log will consist of 6 sections: meal time, food consumed, where the meal was consumed, with whom the meal/snack was eaten, how you were feeling at this time, and rate your hunger. The food log will be turned in. A random identifier number will be used when logging the data into the computer. Nutritionist Pro Nutrition Analysis is the software program that will analyze and interpret the data. After data processing is
complete, a Client Diet Record Report and Client Diet Record Nutrition Summary will be generated. A Client Diet Record Report lists all the foods and drinks consumed in a specified time and calculates amount of sodium, calories, protein, carbohydrate, fat, cholesterol, saturated fat, monounsaturated fat, polyunsaturated fat, and dietary fiber in each food or drink. The Client Diet Record Nutrition Summary will sum up and average the total amount of most macronutrients, vitamins, and minerals over a specified time.

**Rowing Training**

Following the introduction and pre-testing, you will begin to train for 7 weeks on rowing ergometers. Before and after training, you will perform warm-up exercise and cool-down exercise. During training, you will wear a heart rate monitor and training intensity will be determined by target heart rate during rowing. No training will take place without supervision. The training routines are delineated below:

- **Week 1:** 2 days/week 5-minute rowing at 70% of maximum heart rate obtained in pre-test
  - 3 sets with 4-minute rest between sets
- **Week 2:** 2 days/week 5-minute rowing at 70% of maximum heart rate obtained in pre-test
  - 4 sets with 4-minute rest between sets
- **Week 3:** 2 days/week 10-minute rowing at 70% of maximum heart rate obtained in pre-test
  - 2 sets with 5-minute rest between sets
- **Week 4:** 3 days/week 10-minute rowing at 80% of maximum heart rate obtained in pre-test
  - 2 sets with 5-minute rest between sets
- **Week 5:** 3 days/week 10-minute rowing at 80% of maximum heart rate obtained in pre-test
  - 3 sets with 4-minute rest between sets
- **Week 6:** 3 days/week 20-minute rowing at 80% of maximum heart rate obtained in pre-test
  - 2 sets with 5-minute rest between sets
- **Week 7:** 3 days/week 2-minute rowing at 90% of maximum heart rate obtained in pre-test
  - 8 sets with 1-minute rest between sets

**Risk and Discomfort**
Percent Body Fat measures
The only anticipated risk for these measurements is the possible fear of being in water in the relatively small tank. If you do not feel comfortable in the tank, you are free to get out from water.

Maximal Dynamic Strength and Local Muscular Endurance
The risks associated with these tests include possible muscle/joint soreness and a temporary increase in blood pressure during knee extension actions. Although isokinetic dynamic action does not have an eccentric mode, which normally causes muscle damage and pain, there is slight possibility that the subjects will feel soreness after the tests. You will be screened for hypertensive problems prior to participation, and not be allowed to participate in the study if any problems are found. There will be proper supervision and explanations/demonstrations of the tests to be performed.

Maximal Oxygen Consumption
The risks associated with this test are muscle fatigue and slight muscle soreness, increase in blood pressure, dizziness, nausea, and a slight risk of heart attack, and a very slight risk of sudden death. You will also be instructed to drink plenty of fluid in the hours prior to the rowing ergometer test, and to eat a small meal at least three hours prior to the test, in order to avoid nausea. Throughout the test and after the test, you will be monitored by laboratory personnel trained in CPR. If an emergency should arise, the laboratory personnel will call EMS and provide emergency care until emergency medical personnel arrive. Emergency numbers are posted by the phone in the laboratory. In addition, you will be informed that if you are unable to continue a test, you may stop at any time. You will also be instructed as to how to perform stretches, which may help alleviate any muscle soreness that may occur after the test. Because of the invasive nature of blood withdrawal, there is a slight risk of infection and hematoma but the likelihood of such events occurring from a finger prick is very rare.

Muscle Biopsy Procedure
The muscle biopsy procedure does not cause any permanent damage. There will, however, be a small scar that should become undetectable over time. Local discomfort may occur over the initial 24 hours after the biopsy, but this is no more painful than a slight bruise to the thigh and will subside in a day or two. Risks associated with the biopsy procedure include mild bleeding, hematoma, infection, post-procedure pain, localized temporary loss of skin sensitivity, and slight scarring of the skin. Every precaution will be taken to keep these risks to a minimum. Ice therapy, mild pain medication (aspirin), compression, and elevation have been used separately or in combination to alleviate these problems. For all of the tests in this study, there is very little possibility of potential problems. All of the tests, including the muscle biopsies, have been performed in the laboratory for several years by the same investigators without incident.

Blood Sampling
Because of the invasive nature of blood withdrawal, there is a slight risk of infection and bleeding. Every precaution will be taken to keep these risks to a minimum.

**Diet**

There is a slight possibility that high-protein, a low-carbohydrate diet will cause ketosis, which may inhibit the central nervous system. During the 7 weeks rowing training, a small amount of urine (about 1 oz) will be collected before the training and will be tested for ketosis at the site using the dip-stick method. If ketosis is observed, carbohydrate intake will be increased slightly.

**Benefits**

You will gain knowledge about your current fitness level and diet and how to improve it after the study. Also, you will be able to gain musculoskeletal fitness throughout the study due to the rowing training. There are also academic benefits that can occur from the study. You will gain insight into rowing training and diet and will also learn about the physiological adaptations to training and diet. Along with the mentioned benefits, you will gain knowledge about the research side of exercise physiology and nutrition.

Society will benefit from this investigation since it will increase knowledge about the effects of high-protein, low-carbohydrate diets and high-intensity aerobic training. This will help to educate the public about how this type of training and diet modification really affects the body so that proper exercise and diet choices may be made. The anticipated benefits to the scientific community will also include increasing knowledge of the physiological effects of the effects of high-protein, low-carbohydrate diet and high-intensity aerobic training.

**Alternative Treatments (if applicable)**

N/A

**Confidentiality and Records**

Your file will only be identified with a subject number and it will be kept in a locked file in the investigator’s office. A code key will be developed to match your name and subject number. It will be kept in the locked file. The only reason the information will be used will be for research purposes, and you will not be identified as more than a number in that case. The health history form will also be kept in a locked file, and will not be shared with anyone other than the investigators. It will be destroyed within five years of study completion.

**Compensation**

There is no monetary compensation for participating in this study. You are free to withdraw from the study at any time without affecting your relationship with the investigators.
Contact Information
If you have any questions regarding this study, please contact:

Kumika Toma, 593-0450 (office), 662-3024 (home), kt247191@ohio.edu
Tim Werner, 589-5436 (home), tw276898@ohio.edu
Roger Gilders, 593-0101 (office), gilders@ohio.edu
Bob Hikida, 593-2323 (office), hikida@ohio.edu

If you have any questions regarding your rights as a research participant, please contact

Jo Ellen Sherow, Director of Research Compliance, Ohio University, (740)593-0664.

I certify that I have read and understand this consent form and agree to participate as a subject in the research described. I agree that known risks to me have been explained to my satisfaction and I understand that no compensation is available from Ohio University and its employees for any injury resulting from my participation in this research. I certify that I am 18 years of age or older. My participation in this research is given voluntarily. I understand that I may discontinue participation at any time without penalty or loss of any benefits to which I may otherwise be entitled. I certify that I have been given a copy of this consent form to take with me.

Signature_________________________________________ Date_______
Printed Name________________________________________
Appendix E: Energy Expenditure

Subject ______________________________

**Diet Calculations**

\[
\text{REE(kcal)} = 66.5 + 13.75( \text{W}) + 5.0( \text{H}) - 6.78( \text{A})
\]

W = weight in kilograms  
H = height in centimeters  
A = age

Multiply REE by Physical Activity Level (PAL)

<table>
<thead>
<tr>
<th>LIFE STYLE AND LEVEL OF ACTIVITY</th>
<th>FACTOR FOR PAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chair-bound or bed-bound</td>
<td>1.2</td>
</tr>
<tr>
<td>Seated work with no option of moving around and little or no strenuous leisure activity</td>
<td>1.4–1.5</td>
</tr>
<tr>
<td>Seated work with discretion and requirement to move around but little or no strenuous leisure activity</td>
<td>1.5–1.7</td>
</tr>
<tr>
<td>Standing work (e.g., housework, shop assistant)</td>
<td>1.8–1.9</td>
</tr>
<tr>
<td>Significant amounts of sport or strenuous leisure activity (30–60 minutes four to five times per week)</td>
<td>+0.3 (increment)</td>
</tr>
<tr>
<td>Strained work or highly active leisure</td>
<td>2.0–2.4</td>
</tr>
</tbody>
</table>

(Adapted from Shetty PS, et al. Energy requirements of adults: An update on basal metabolic rates (BMRs) and physical activity levels (PALs). Eur J Clin Nutr 50(suppl 1):S11, 1996.)

Add 10% for TEF (thermal effect of food) to calculate TEE (total energy expenditure)
Appendix F: High CHO Diet

Diet Guidelines for the High CHO, Low Fat Group

Your diet will consist of roughly 55% carbohydrate, 30% fat, and 15% protein. In order to accomplish this, nutritional guidelines have been created to help maintain your diet.

### Protein (1-3 servings)

**Serving size:**
- 2-3 ounces of meat
- ½ cup of beans
- 1 egg
- 2 tbsp of peanut butter
- 1 cup milk/yogurt
- 2 ounces of cheese

1 g protein = 4 Kcal

- meat
- eggs
- fish
- nuts
- beans
- milk
- cheese
- peanut butter

### Fat

**Serving Size:**
(No recommendations)

Fats are hidden in the foods we eat.

1 g fat = 9 Kcal

- butter
- mayonnaise
- salad dressing
- cooking oil
- nuts

### Carbohydrate (7-12 servings)

**Serving size:**
- 1 slice bread
- 1 ounce of cereal
- ½ cup pasta/rice
- 1 medium apple, orange
- ¾ cup of fruit juice

1 g carbohydrate = 4 Kcal

- bread
- bagel
- rice
- pasta
- fruit
- cereal
- vegetable

An example of a 2,700 kcal daily diet consisting of 55% carbohydrate, 30% fat, and 15% protein:

**Breakfast:**
- 1 cup of cheerios
- 1 cup 2% milk
- 1 banana and 2 cups of orange juice

**Lunch:**
- 5 oz turkey, 2 slices of whole wheat bread
- 2 slices tomato, ½ cup lettuce
- 2 tbsp mayonnaise
- 1 peach, 1 cup of blueberry yogurt

**Dinner:**
- 2½ cups of spaghetti, 1 cup marinara sauce 2 rolls, 2 tbsp butter
Appendix G: Low CHO Diet

**Diet Guidelines for the Low CHO, High Protein**

Your diet will consist of roughly 50% protein, 25% fat, and 25% carbohydrate. In order to accomplish this, nutritional guidelines have been created to help you maintain the diet.

<table>
<thead>
<tr>
<th>Carbohydrate (2-4 servings)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Serving size:</strong></td>
<td></td>
</tr>
<tr>
<td>1 slice bread</td>
<td></td>
</tr>
<tr>
<td>1 ounce of cereal</td>
<td></td>
</tr>
<tr>
<td>½ cup pasta/rice</td>
<td></td>
</tr>
<tr>
<td>1 medium apple, orange</td>
<td></td>
</tr>
<tr>
<td>¼ cup of fruit juice</td>
<td></td>
</tr>
<tr>
<td><strong>1 g carbohydrate = 4 Kcal</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fat</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Serving Size:</strong></td>
<td></td>
</tr>
<tr>
<td>(no recommendations)</td>
<td></td>
</tr>
<tr>
<td>Fats are hidden in the foods we eat.</td>
<td></td>
</tr>
<tr>
<td><strong>1 g fat = 9 Kcal</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Protein (7-12 servings)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Serving size:</strong></td>
<td></td>
</tr>
<tr>
<td>2-3 ounces of meat</td>
<td></td>
</tr>
<tr>
<td>½ cup of beans</td>
<td></td>
</tr>
<tr>
<td>1 egg</td>
<td></td>
</tr>
<tr>
<td>2 tbsp of peanut butter</td>
<td></td>
</tr>
<tr>
<td>1 cup milk/yogurt</td>
<td></td>
</tr>
<tr>
<td>2 ounces of cheese</td>
<td></td>
</tr>
<tr>
<td><strong>1 g protein = 4 Kcal</strong></td>
<td></td>
</tr>
</tbody>
</table>

An example of a 2,700 Kcal daily diet consisting of 50% protein, 25% fat, & 25% carbohydrate:

**Breakfast:**
- 4 sausage patties (2oz)
- 4 eggs scrambled
- 1 cup 2% milk

**Lunch:**
- 2 cans of albacore tuna in water
- ½ apple
- water

**Dinner:**
- 1 10oz piece of fried chicken
- 1 roll with butter

**Snack:**
- 2 protein bars
Appendix H: Food Log

Name: ____________________________________  
Date: ______________________________

| Time | What are you eating or drinking?  
List amounts and preparation. | How do you feel at each meal?  
5=excellent  
4=good  
3=neutral  
2=bad  
1=terrible |  
--- | --- | --- |
| Breakfast | Breakfast |  
Lunch | Lunch |  
Dinner | Dinner |  
Snack #1 | Snack #1 |  
Snack #2 | Snack #2 |
# Appendix I: Data Sheet

<table>
<thead>
<tr>
<th>Date</th>
<th>Target Watts</th>
<th>Rowing Time</th>
<th>Resting Time</th>
<th>HR</th>
<th>Avg. Watts</th>
<th>RPE</th>
<th>Notes</th>
</tr>
</thead>
</table>