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The Effects of Three Pre-Exercise Meals on Long and Short-Term Submaximal Cycling Endurance Exercise

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FLORIDA STATE UNIVERSITY
COLLEGE OF HUMAN SCIENCES

THE EFFECTS OF THREE PRE-EXERCISE MEALS ON LONG AND SHORT-TERM
SUBMAXIMAL CYCLING ENDURANCE EXERCISE

By

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ABSTRACT

This study examined the effect of three pre-exercise meals on various blood and cardiorespiratory variables during long-term and short-term submaximal endurance cycling. Eighteen endurance trained males between the ages of 18 and 35 years of age participated in this study examining the effects of a 200 iso-caloric meal (in 300 mL) of glucose, whole milk, and an artificially flavored placebo following an overnight fast and two-day diet high (>60%) in complex carbohydrates on three separate rides at 55% of $\text{VO}_{2\text{max}}$ for 120 minutes, followed by a 30 minute rest, and a short high intensity ride to exhaustion at 80% of $\text{VO}_{2\text{max}}$. Subjects were healthy and each paid \$100 for their participation. Variables investigated in this study were blood glucose, blood glycerol, blood free fatty acids, blood lactate, respiratory exchange ratio, heart rate, rating of perceived exertion, and time to exhaustion. Blood and cardiorespiratory variables on the rides were analyzed using a Repeated Measures ANOVA. Significant differences ($p < 0.05$) were tested using a Bonferroni post hoc test.

Only the means of blood free fatty acid were significantly different between the rides ($p < .007$) with milk and glucola significantly blunting the rise in free fatty acid with exercise. However, over time free fatty acid, glucose, glycerol, heart rate, lactate, and respiratory exchange ratio all changed significantly with free fatty acid, glycerol, and heart rate increasing over time and glucose, lactate, and respiratory exchange ratio decreasing over time.

On the short ride there were no significant differences between any of the variables. While the differences were not significant, time to exhaustion for the carbohydrate meal was 18% longer than milk and 20% longer than the placebo suggesting that a higher kilocalorie meal might have made a significant difference. These results demonstrate that, following an overnight fast, a 200 kilocalorie meal prior to endurance exercise will not make a difference in time to exhaustion whether it is a carbohydrate load or a mixed meal like whole milk. Additionally, a mixed meal of carbohydrate and protein will blunt the free fatty acid response during endurance exercise similar to that of a carbohydrate only meal.

CHAPTER I INTRODUCTION

A popular milk commercial states, “Milk, it does a body good”. Milk is the first food that all mammals consume and consists of all six of the major nutrient categories. As a potential ergonomic aid, milk is a significant source of energy containing nutrients with considerable amounts of potential energy from carbohydrate and, in the case of whole milk, fat. Milk protein also contributes energy for activity but the concentration is far less than the other two nutrients and may not be immediately available for the production of energy as one of the two major milk proteins, casein, coagulates in the presence of rennin and calcium.

Prior to its availability as a substrate for exercise, milk has to be digested. This begins in the stomach via hydrolysis of milk triacylglycerols by gastric and lingual lipases. As short and medium chain fatty acids enter the portal vein from the stomach wall, long chain fatty acids congregate into fat droplets to pass on to the duodenum (Murray, Granner, Mayes, & Rodwell, 2000). In the duodenum, pancreatic lipase continues the hydrolysis of milk triacylglycerols to glycerols, 1 and 2-monoglycerols, and free fatty acids. In the lumen of the intestine, however, these by-products of milk are resynthesized to triacylglycerols and the development of chylomicrons to be transported to the blood via the portal duct and the lymph system. In extrahepatic tissue, like muscle, lipoprotein lipase hydrolyzes the triacylglycerol to free fatty acids and glycerol. It is believed that some of these milk-derived fatty acids and, hence, glycerol may contribute to the demand for energy during low intensity endurance activities (Jeukendrup, Saris, Schrauwen, Brouns, & Wagenmakers, 1995; Murray, Granner, Mayes, & Rodwell, 2000).

Prolonged, endurance exercise is maintained through the body's use of the macronutrients derived from the diet. All three macronutrients, protein, carbohydrate, and fat contribute to exercise while the particular percentage of macronutrient used may be determined by availability as well as the mode and, more specifically, by the intensity of the exercise. Early in exercise glucose yields the energy necessary to fuel muscle contraction. As exercise continues or intensity is increased, glycogen stores in the muscle cell are metabolized to derive ATP for fuel. As energy demand increases the aerobic metabolism of pyruvate, a by-product of the metabolism of glucose and glycogen, is matched by the aerobic metabolism of fats and to an insignificant degree in healthy people, protein. Thus a critical determinant in time to exhaustion activities at moderate and higher intensities has been the relatively small quantity of glycogen stored in liver and muscle. There have been many studies on the effectiveness of carbohydrate supplementation in sustaining endurance exercise.

Fat stores in the body, however, represent a considerable, and practically unlimited, resource for the production of energy to fuel endurance exercise. During non-steady state high intensity exercise, though, the body tapers off its use of fats relying, ironically, more on its limited stores of glycogen for fuel.

Not all carbohydrates are equal in their effect on performance. Digestible carbohydrates contribute to (exercise-related) energy needs where indigestible carbohydrate does not, and, carbohydrates possessing widely different glycemic index values may have different effects on the same type of exercise. Whole foods possessing differing amounts of the macronutrients of carbohydrate, protein, and fat – called mixed foods – also vary widely in their effect on exercise.

An early study where a carbohydrate supplement was matched against a non-caloric placebo and a mixed meal (whole cow's milk), produced inconclusive results regarding the effect of milk on moderate to high intensity exercise (Foster, Costill, & Fink, 1979). The combination of food content and intensity of exercise in this early study may have confounded the results of this study. While whole cow's milk is mostly water (87.4%), it also contains some fat (3.2 to 3.7%) and protein (3.4%) (Jensen, 1995) and these two constituents combined with the relatively high intensity of exercise (80% $\text{VO}_{2\text{max}}$) could easily have contributed to decreased gastric emptying and reduced availability of the glucose available from lactose (4.8%) to fuel the exercise in that study.

In a study to examine the effect of a protein-carbohydrate supplement on the hormonal response to endurance exercise, Miller, et al., (2002) examined responses to a supplement of skim milk versus carbohydrate and a placebo during exhaustive (2 hour), low intensity (65% $\text{VO}_{2\text{max}}$) treadmill running. They observed an exercise-induced increase in all the hormones assayed but only glucagon and growth hormone were influenced by the supplements with the former being significantly increased with the skim milk supplement. The authors concluded that there may have been greater fat oxidation with the milk trial. In fact, the respiratory exchange ratio (RER) decreased significantly in both the milk and placebo trials indicating a greater reliance on lipid or other substrate. The RER for the milk remained at about 0.90 while the calculated RQ for protein was 0.82, indicating some effect of the lactose in the skim milk. The effects of milk in this study were primarily due to the protein components. There have been no other studies using the same mixed meal on low intensity exercise.

Exercise at moderate to high intensity exercise is believed to shunt blood from the splanchnic blood vessels to the exercising muscles thereby reducing the intestinal transport of nutrients out of the gut to where they are needed in exercising muscle. Lower intensity exercise may not result in the same shunting of blood from the gut, and providing there are exogenous nutrients available in the gut, these nutrients have been shown to be able to delay fatigue.

Statement of the Problem

The purpose of this study is to determine the effect of whole cow's milk (a mixed meal of protein, carbohydrate, fat, vitamins, minerals and water) versus a carbohydrate supplement and a taste-enhanced placebo on low intensity then high intensity cycle ergometer exercise to exhaustion interspersed by a brief rest period.

Hypotheses

The following hypotheses will be tested:

1. Plasma glucose concentration will be significantly greater for the glucose polymer and for the whole milk supplement compared to the placebo treatment throughout the duration of the long cycling bout.
2. Plasma glycerol concentration will be significantly greater for the whole milk supplement compared to either the glucose polymer or the placebo throughout the duration of the long cycling bout.

3. Plasma free fatty acids will be significantly greater for the whole milk supplement compared to either the glucose polymer supplement or the placebo throughout the duration of the long cycling bout.
4. Plasma lactate will be significantly greater for either the glucose polymer supplement or the placebo supplement compared to the milk group throughout the duration of the long cycling bout.
5. Respiratory exchange ratio (RER) will be significantly greater for either the glucose polymer supplement or the placebo supplement compared to the whole milk supplement for the duration of the long cycling bout.
6. Ratings of perceived exertion (RPE) will be significantly greater for either the placebo supplement or the glucose polymer supplement compared to the whole milk supplement for the duration of the short cycling bout.
7. Time to exhaustion will be significantly greater for the milk supplement compared to either the glucose polymer supplement or the placebo supplement on the short cycling bout.

Operational Definitions

Whole cow's milk	Homogenized, pasteurized whole milk from cows purchased from a local grocery outlet.
Long ride	Cycling exercise at 55% of VO_{2max} for 120 minutes on a Monark Cycle ergometer.
Short ride	Time to exhaustion at 80% VO_{2max} .
Exhaustion	Objective inability to maintain a pedaling rate sufficient to elicit 80% VO_{2max} or voluntary withdrawal from the test indicated by desire to stop or cessation of pedaling.
Placebo	A citrus-flavored drink artificially sweetened with aspartame.
Glucose Polymer	Glucola.

Assumptions

This study is based on the following assumptions:

1. All the participants in the study will be (recreationally) trained cyclists.
2. All the participants in the study will understand and follow directions regarding abstention from exercise for two days prior to each exercise bout.
3. All the participants in the study will understand and follow suggestions regarding adequate carbohydrate consumption in the 48 hours prior to each test ride.
4. All the participants in the study will understand and follow directions regarding abstention from eating for at least 12 hours prior to each exercise bout.
5. All the participants in the study will understand and follow directions regarding abstention from heavy exertion for 24 hours preceding each exercise bout.
6. All the participants in the study will understand and follow directions regarding abstention from caffeine for 48 hours preceding each exercise bout.

Limitations

The subjects in this study consisted of 18 healthy (male) cycling enthusiasts from the South Georgia area, between the ages of 18 and 35 years with generally the same amount of cycling experience, therefore, the results of the study and the generalizations that can be generated from it will be limited to similar populations. Plasma hematocrit and plasma volume were not measured in this study, therefore, corrections to plasma volume could not be made and any generalizations from this study will be limited to similar reports.

Significance of the Study

Whole milk is simply, a whole meal made readily and naturally by the female gender of all mammals for their young. It is a complex mixture made of all six of the major nutrient categories (carbohydrate, fat, protein, vitamins, minerals, and water). Beyond the immediacy of infancy but due to its versatility as a whole food, it has been used in many forms as a staple by many cultures for literally thousands of years.

As a product of biologic synthesis, milk is safely kept at lower temperatures but spoils easily at higher temperatures. This may be why cultures of higher latitudes are more likely to have retained their ability to digest lactose into adulthood. Through technology the components of milk are easily separated. Of the 8.9% milk solids, not fat, 3.4% is a protein mixture of casein (80%) and whey (20%) (Jensen, 1995). Notwithstanding, yet another major benefit of milk consumption is the beneficial mineral content. The calcium content of 8 ounces of milk, a glassful, ranges from 291mg to 316mg (National Dairy Council, 2000). Other significant minerals found in milk include potassium, phosphorus, sodium, and chloride.

Like a good sports drink, milk has it all. Its use as a sports supplement or ergonomic aid, however, has not been adequately explored, particularly in endurance activities at lower intensities.

CHAPTER II

REVIEW OF LITERATURE

The following chapter is intended to familiarize the reader with the current literature on the subject of the current investigation. After a brief description of what milk is this review will present the literature on the use of milk to improve body composition and milk studies on endurance exercise. The review will then present literature regarding carbohydrate supplementation in exercise, evidence that glycemic index affects performance, and finally, effects of protein / carbohydrate supplementation on endurance exercise.

What is milk?

Milk is a complex, mammalian-secreted combination of water, protein, carbohydrate (lactose), and vitamins and minerals (Hurley, 2001; National Dairy Council, 2000). The largest component of (cow's) milk is water, 87% with many of the B vitamins also found in the aqueous phase of milk. The major carbohydrate in milk is the disaccharide lactose (4.8% cow's milk compared to 7% human milk) made from the monosaccharides D-glucose and D-galactose joined in a β -1,4-glycosidic linkage (4-0- β -D-galactopyranosyl-D-glucopyranose). Lactose is cleaved by the enzyme lactase to form glucose and galactose. Other sugars found in low concentrations in cow milk include some free galactose, amino sugars, neutral and acid oligosaccharides, sugar phosphates, and nucleotide sugars. Milk fat, a complex mixture of lipids primarily composed of triglycerides, is composed of short-chain (7%), medium-chain (15 to 20%), and long-chain (73-78%) fatty acids. Of the nearly 400 different fatty acid derivatives found in milk most are saturated (65%) while the other fats are monounsaturated (32%) and polyunsaturated (3%). Milk fat also contains the fat-soluble vitamins A, D, E, and K. The cholesterol content of milk, one of the reasons milk has been maligned, varies with the percent fat (Hurley, 2000).

The proteins in milk, arguably one of cow milk's more controversial components, are made of a heterogeneous mixture of proteins with the two primary groups being casein and whey proteins. The dominant protein, casein (80%), is easily digestible in the intestine and is a significant source of a variety of essential amino acids, including branched chain amino acids. Whey protein (20%), what is left when casein is removed from milk, contains many enzymes, growth factors, hormones, disease resistance factors, and nutrient transporters. Whey also has a large amount of tryptophan (in alpha-lactalbumin), an important precursor of niacin. Undigested whey protein is believed to be the culprit responsible for milk-protein food allergy found in a significant proportion of the population. Lastly, milk is a significant source of calcium and phosphorus which are found in milk but primarily associated with the casein protein (Hurley, 2000; National Dairy Council, 2000).

Milk Consumption and Body Composition

The benefits of cow milk consumption for children beyond the age of one year are practically undeniable with the possible exception of those with milk-protein allergies. The positive effect of calcium, in conjunction with the use of dairy products in the prevention of osteoporosis, is probably the most thoroughly cited area of research on the benefits of dietary

calcium via milk consumption. In a study to review the effects of calcium and dairy product supplements on bone health, Heaney (2000) cited more than 139 bone density studies performed between 1975 and 2000 designed to determine the effects of various dietary interventions in building bone. After confirming from his review that higher intakes of calcium protects bone, Heaney also noted that many of the studies were based on dairy supplements. None of the studies in this review, though, included exercise as a co-factor with diet in modulating bone strength. In a two-year longitudinal study on dairy calcium supplements and moderate exercise, Lin, Lyle, McCabe, McCabe, Weaver, and Teegarden (2000) noted the negative relationship of weight with increased dietary calcium (dairy, 69% of total intake) regardless of exercise.

Lin et al., (2000) assigned 54 sedentary Caucasian women to one of three groups: resistance exercisers, jump rope activities, and non-exercisers. A three-day dietary record was taken at baseline and repeated every six months for 24 months. Non-dairy calcium was the difference between total calcium and dairy calcium; ratios of the means were reported for individuals. Body composition measures were assessed with a dual energy absorptiometer at baseline and at 24 months. Due to the grouping of the subjects the researchers were able to follow nutrient intakes throughout the study. At the end of the study there were no significant differences between the groups in energy intake or in body composition between the exercisers and non-exercisers; however the change in lean mass between the exercisers and non-exercisers was significant. Even though the intake of calcium for this age group (781 +/- 212 mg/d) was below the recommended intake (at the time, 1000 mg/d) calcium/kcal remained significant in predicting changes in fat mass and weight for all groups.

Lin et al. (2000) also studied the relationship of energy intake and dairy calcium to level of energy intake (above and below the mean, 1876 kcal/day). While there was no difference between high and low energy intakes in calcium intake, only dairy calcium intake in the low energy intake group predicted changes in weight or fat mass, meaning that higher intakes of calcium resulted in greater losses in weight for this group. In the higher energy intake group (>1876 kcal/d) energy intake alone predicted weight changes. The authors were able to conclude that the effect of calcium, specific to dairy calcium, predicted changes in body weight and this, they suggested, was due to percent change in body fat.

In a resistance exercise study among overweight police officers to determine the effects of a hypocaloric diet versus diets of the two major milk proteins, casein and whey, Demling and DeSanti (2000) reported similar weight losses among the three groups but different gains in lean mass. Thirty-eight moderately obese members (23-35% body fat) of the Boston police force were placed on a 12-week resistance training program and one of three diet groups. Resistance training included 4 days a week 8-10 repetitions of chest press, shoulder press, and leg extension alternated on other days with aerobic exercises. Maximum effort tests were made on 4th, 8th, and 12th weeks. Body composition measures were made by skinfold analysis. One diet consisted of a 20% reduction of the officers' normal daily diet (hypocaloric) and the other two diets consisted of increased protein (to 25% total calories) via added milk protein in the form of either casein or whey consumed in liquid form twice a day.

The diet alone group experienced a modest decline in percent fat from 27% to 25%. Lean body mass, though, decreased significantly. Similarly, the milk protein groups also experienced a loss of percent fat but the casein group's difference was also significantly different

In their discussion, Freskanich et al. (1997) discounted the possibility that recall-bias of teenaged dairy consumption might have affected their results. But just in case, they attempted to control bias by eliminating women from the study who had begun taking calcium supplements because the consumption of dietary supplements had become popular due to the increased press on the effects of osteoporosis during the study and they might have taken the supplements out of fear of susceptibility due to lack of dairy consumption. While they did not deny the beneficial effect of dairy calcium during the teenaged years they concluded that additional dairy consumption during midlife proffered little protection from hip or forearm fracture.

Similarly, yet in another culture, Nagaya, Yoshida, Hayashi, Takahashi, Kawai, and Matsuda (1996) concluded from data on 12,610 Japanese middle-aged men (30 – 69 years) divided into two groups of milk drinkers (3,553) and non-milk drinkers (9,057) that milk consumption contributed to weight gain and, more significantly, increases in blood lipid levels. A random sample of middle-aged men reporting to a clinic answered whether or not they drank a glass of cow's milk or more a day and screened for whether or not they were being treated for serum lipid abnormalities or total serum cholesterol. Using analysis of covariance, between group differences (drinkers and non-cow milk drinkers) were statistically significant for three of the four lipid measures. The milk-group was significantly higher in total serum cholesterol, high-density lipoprotein cholesterol, and low-density lipoprotein cholesterol (Friedewald's equation) but not on triglycerides or between age groups.

The authors concluded that the Westernization of their diet was contributing to hypercholesterolemia in Japan. They did not, however, ask their subjects whether or not they were consuming whole milk or some other form of milk such as low-fat or skim milk and suggested that, because the Japanese diet is generally calcium deficient, the latter might still provide much needed protective calcium for bone health.

Milk in Endurance Exercise

In 1979 Foster, Costill, and Fink studied the effect of pre-feeding on performance of exhaustive cycling exercise. The purpose was to study the effect of feeding various carbohydrates on exercise performance. In addition, they also studied the effect of a protein-fat-carbohydrate supplement (milk) on exercise performance. After determinations of VO_{2max} , 16 cyclists, eight males and eight females, cycled six separate times under the influence of a 300 ml pre-exercise (30 min. prior) meal of either water (the control), 75g of glucose, or milk (10g protein, 12.5 g fat, 15 g CHO). Each supplement was consumed once under two conditions, a 5 minute short ride to 100% V_{2max} and a 60 minute ride at 80% VO_{2max} .

While the exercise time was generally decreased for the glucose load, Foster et al., (1979) found no significant differences between the meals on the short, intense ride. On the long ride, however, while there were no significant differences between either cardiovascular variables or lactate, blood glucose values dropped significantly for both the glucose and milk trials during the first 20 minutes then either leveled off (glucose) or rose (milk) for the remainder of the ride. On the long ride compared to the control (placebo) ride, only blood glucose levels for the glucose

load dropped significantly and affected exercise time, indicating a substrate preference of the slow twitch muscles. Free fatty acid levels first fell then rose on each long ride but rose significantly slower during the glucose load trial (compared to the control ride). The transient hypoglycemic response following ingestion of the glucose load was explained as an insulin response that resulted in a blunted lipid mobilization of fatty acids. The milk meal had no effect on performance in either the short ride or long ride in this study compared to water.

In a study on the prevention of post-exercise hypoglycemia via consumption of pre-exercise snacks, Nathan, Madnek, and Delahanty (1985) studied the effect of drinking whole milk, skim milk, and orange juice in five intensively treated IDDM patients. While all of the patients were familiar with high intensity exercise, none were currently participating in any structured exercise programs. All of the subjects maintained weight maintenance diets and all diets were nutritionally balanced. None reported milk allergies. On four occasions, following an overnight fast, subjects reported for 45 minutes of bicycle ergometer exercise at an intensity designed to result in a 45 to 50% maximal oxygen uptake. At each exercise test, except for the control ride, subjects were given in a random order either skim milk (9.3g of protein, less than 1g of fat, 95 kcal); whole milk (9.1g of protein, 9.1g of fat, 168 kcal); or orange juice (less than 1g of fat or protein and 54 kcal). Plasma glucose was followed for 180 minutes following exercise.

Without snacks three of the patients experienced a hypoglycemic reaction between 1 and 2 hours following exercise. While there was a significant difference between post exercise plasma glucose levels with and without snacks, plasma glucose responses after exercise, perhaps due to the small number of subjects in the study, were heterogeneous. They found a significant difference between whole milk and the skim milk or orange juice snacks on speed of absorbance as reflected in plasma glucose levels during exercise and following exercise. Orange juice and skim milk, in contrast to water in preventing post exercise hypoglycemia, resulted in faster glycemic responses as well as higher glucose responses during exercise. Whole milk however, perhaps due to the presence of the fat and resultant slower gastric emptying, resulted in both a delayed increase in plasma glucose concentration and prevention of hypoglycemia.

In a study to determine whether a dietary supplement could extend energy consumption after exercise and the resultant weight loss, Lee, Ha, and Lee (1999) studied the effects of various exercise intensities with and without glucose supplements in skim milk on post-exercise oxygen consumption. After baseline measures, 10 conditioned physical education students participated in four randomly assigned separate treadmill runs with and without consuming 1.5g of glucose in 500ml of low fat milk for two hours prior to runs at 85% of $\text{VO}_{2\text{max}}$ (20 minutes) and 40% $\text{VO}_{2\text{max}}$ (40 minutes). Oxygen consumption, RER, and rectal temperatures were followed throughout the test and for two hours during recovery. Fat utilization for the trials was calculated with a Lusk Table where rates for carbohydrate and fat oxidation during exercise can be calculated. Significant increases in excess post-exercise oxygen consumption (EPOC) were found for recovery for both of the glucose trials over trials without the supplement. Also, the high intensity short duration with the glucose load produced a higher EPOC than that of the other trials. Unfortunately, the authors did not control for the effect of the low fat milk alone, so there is was no way to tell what the true effect of the milk was in this study.

Dionne, Van Vugt, and Tremblay (1999) studied the effects of a milk shake on post exercise energy expenditure in eight moderately active young men. Following 24 hours of

whole-body indirect calorimetry (Laval University, Ste-Foy, Canada) and dietary monitoring, subjects participated in both of two randomly assigned conditions of either sedentary activities or 60 minutes of treadmill exercise at their previously determined maximal oxygen consumption. Following exercise subjects were allowed to shower then entered the caloric chamber and were given a milk shake consisting of 2%-fat milk, ice cream, sugar, strawberry jelly, and heavy cream and equal to the same amount of energy expended during the exercise. They found no difference between the two test conditions on twenty-four hour energy expenditure as expressed in either fat or carbohydrate oxidation. The authors concluded that the absence of a change in post exercise energy expenditure with a snack was due to the replenishment of energy balance and glycogen stores.

In a study similar to that of Demling and DeSanti's (2000) study on whey and casein, van Hall, Shirreffs, and Calbet (2000) studied the effects of whey protein and sucrose supplements compared to either sucrose alone or water alone. On three occasions five volunteers were randomly assigned to receive one of the three supplements. Following a 10 minute warm up at 50% of previously determined maximal power output, power tests on the bicycle ergometer in alternating blocks of 90 and 50% of maximal power output were performed until they could not maintain the required pedaling cadence. Immediately after exercise, and a shower, muscle biopsies were taken and boluses of supplement were given every 15 minutes through recovery for four hours. Follow-up biopsies were taken at 1.5 hours and 4 hours. During the first hour of recovery arterial glucose concentration was significantly greater for sucrose than for the CHO-protein mix. The 4-hour non-significant effect of the whey protein carbohydrate combination was similar to that for the sucrose alone in glycogen resynthesis and leg glucose uptake.

In this study it is possible that the early rise in arterial glucose might have masked the effects of the whey protein. The effects of casein protein and carbohydrate supplementation might have been different.

Miller et al., (2000) investigated the interactions of substrates and hormones after supplementation of either a protein-carbohydrate supplement, a carbohydrate, or a placebo to exhaustive treadmill running. Nine male endurance athletes ran for two hours at the treadmill speed predetermined to require 65% of each individual's $\text{VO}_{2\text{max}}$. Three-day food records were obtained prior to enrollment into the study and prior to each run. At each test subjects consumed 835 ml of the supplement during the run (a-straddle the treadmill at 20, 40, 60, and 80 minutes of exercise). The milk supplement consisted of 480 ml skim milk (17 g protein, 27 g carbohydrate) diluted in 355 ml bottled water. The carbohydrate drink consisted of 45 g dextrose diluted in 835 ml bottled water and the placebo consisted of aspartame and non-sweetened flavoring in 835 ml bottled water. Pre and post blood samples were taken while indirect calorimetric values were taken at the 15th minute and 5 minutes following consumption of a supplement. All of the hormones increased significantly with the exercise but only growth hormone and glucagon were affected significantly by the supplement. Growth hormone seemed most influenced by carbohydrate supplementation while glucagon concentrations were elevated most in the milk trial compared to the placebo trial. While epinephrine and norepinephrine levels increased and insulin levels decreased during exercise in all three trials, none differed significantly between trials. Plasma glucose increased with exercise whereas amino acid concentrations changed

according to the supplement. Free fatty acids were elevated in all trials but were significantly lower (than the placebo) in the milk and carbohydrate trials.

Amino acid concentrations increased with milk while branched chain amino acid concentrations were maintained in the milk trial and decreased in the other trials. The authors concluded that milk consumed during the run established a hormonal environment conducive of sparing endogenous carbohydrate and protein.

Carbohydrate Supplementation in Endurance Exercise

Wahren's (1977) seminal paper on glucose turnover in man during basal metabolism stimulated an era of research into the kinetics of carbohydrate supplementation in man during exercise. A number of researchers attempted to answer Wahren's call for studies on muscle substrate utilization (Coyle, Coggan, Hemmert, Lowe, & Walters, 1985; Flynn, Costill, Hawley, Fink, Neufer, Fielding, & Sleeper, 1987; Hargreaves, Costill, Coggan, Fink, & Nishibata, 1984; Hargreaves, Costill, Fink, King, & Fielding, 1987; 1998; Jeukendrup, Mensink, Saris, & Wagenmakers, 1997; Marmy-conus, Fabris, Proietto, & Hargreaves, 1996; Sherman, Peden, & Wright, 1991).

In 1979, Foster et al., studied the effects of different pre-exercise meals on cycling performance. Eight male and eight female subjects participated in a study to determine the effects of pre-exercise carbohydrate feedings and a fat-protein-carbohydrate mixture on exercise time to exhaustion. Subjects performed six separate tests in random order. Thirty minutes after consuming the dietary meal (intervention) of either 75 g of glucose diluted in 300 ml, 300 ml water (control), or a 300 ml mixed meal of 10 g protein, 12.5 g of fat, 15 g of carbohydrate (whole cow's milk), the subjects exercised on a bicycle ergometer at either 100% of their VO_{2max} or at 80% of their previously established VO_{2max} . Variables measured in this study included glucose, lactate, glycerol, free fatty acids, respiratory exchange ratio, rating of perceived exertion, and heart rate.

In this study, compared to the control ride (water), blood glucose dropped significantly in the first 10 minutes for both glucose and milk on the long-ride tests but at 20 minutes only glucose was significantly different from the control ride. For the glucose-long run trial serum free fatty acids were significantly lower at 30 minutes and exhaustion, suggesting impaired lipid mobilization. However, there were no significant differences on either the short run or the long run trials on blood lactate, glycerol, RPE, HR, % VO_2 , RER, or calculated carbohydrate consumption. The timing of the meals, only 30 minutes prior to exercise, was intentional and meant to demonstrate the performance-blunting response of a moderately heavy carbohydrate meal so close to exercise. In the glucose trial, free fatty acids were not available for oxidation, due to the insulin response of the carbohydrate load, therefore muscle glycogen most likely sustained the activity. Milk consumption competed equally with the control (water) on time to exhaustion. Also, while the difference was not significant and the trend for all was downward to exhaustion, there was a noticeable difference in RER for milk at thirty minutes compared to the water and glucose trials.

Similarly, Hargreaves et al., (1984) studied various feedings on muscle glycogen utilization. Ten men participated in a cross-over study on the effects of a solid carbohydrate (43

g of sucrose, 9 g of fat, and 3 g of protein in solid form with 400 ml of water) administered four times during three hours of cycle ergometer exercise (0, 1, 2, and 3rd hours) versus a control trial with a placebo on muscle glycogen and exercise performance. The independent variable was an exercise/rest protocol of half-hour intervals of 20 minutes of cycling at 50% VO_{2max} followed by a ten-minute period of 30s of intense cycling at 100% VO_{2max} followed by 2 minutes of rest with a final timed sprint bout to exhaustion. Muscle glycogen samples were taken by needle biopsy, and venous blood samples were taken periodically for measurement of glucose, glycerol, free fatty acids, and lactate. During the last 10 minutes of each steady-state bout respiratory exchange data were taken as well as heart rates and ratings of perceived exertion.

No differences were found in heart rates, oxygen uptake, or calculated energy expenditure. Significant differences were found between experimental (E) and control (C) treatments on RER (higher for E), blood glucose (higher for E), FFA and glycerol (lower for E), lactate (on the sprint higher for E), on time to exhaustion (longer for E), and muscle glycogen (lower usage for E). These differences were attributed to the glucose feedings and the concomitant maintenance of liver glycogen. The significant difference on RPE was believed to be a more of a reflection of a selective glycogen usage in fast-twitch muscle fibers during the final sprint, more so in the control ride than when carbohydrate was fed.

Coyle et al., (1985) studied substrate usage during prolonged moderate intensity exercise. Seven endurance-trained men exercised at 70% of their predetermined VO_{2max} on two separate occasions for 105 minutes on a bicycle ergometer in a study to determine glycogen utilization in a fasted state with a standardized high carbohydrate meal. Following a 16h fast and restricted activity, subjects were randomly assigned to either a 700 kcal meal (85% carbohydrate and 15% protein), followed by four hours rest and then 105 minutes of moderate intensity exercise, subsequent to return of insulin to basal levels, or 105 minutes of exercise only. Expired gases, blood, and muscle tissues (biopsy) were examined periodically during the exercise.

The pre-exercise meal promoted increased muscle glycogen and carbohydrate consumption (30 to 50% in the vastus lateralis) for up to 100 minutes during the prolonged exercise yet, at 105 minutes, muscle glycogen and blood glucose concentrations were not different between the fasted state and the fed state. The authors concluded that, besides the first hour where there was an increased reliance on carbohydrate and decreased fat oxidation, the increases in muscle glycogen levels by the pre-exercise meal did not limit glycogen availability during prolonged moderate intensity exercise.

In 1987, Hargreaves et al., examined whether or not there were differences between glucose and fructose, versus a placebo, on endurance cycling. Six men cycled to exhaustion at 75% of VO_{2max} after ingesting 75g of supplement in 350 ml of water. They observed no differences between oxygen uptake, RER, heart rate, or time to exhaustion, however, blood glucose and insulin with the glucose feeding were higher than that of fructose and the control. Also, glycogen utilization was the same during the three trials. They concluded that, other than less stable insulin and blood glucose levels with glucose feedings, there was no advantage of either feeding on endurance exercise or muscle glycogen utilization.

Similarly, Flynn et al., (1987) found no improvement in exhaustive cycling performance (2 hours at 70% VO_{2max}) following supplementation of various carbohydrate mixtures during any of 4 exercise trials in eight well-trained male cyclists. The various mixtures consisted of

artificially sweetened water, maltodextrin and fructose, maltodextrin and high fructose corn syrup, and maltodextrin and glucose. Additionally, they found no differences in blood lactate, serum glycerol, perceived effort (RPE), or RER. As expected, blood glucose levels were higher than water with all three of the maltodextrin solutions with blood glucose remaining higher longer for the maltodextrin and fructose combination. Needle biopsies pre and post exercise showed that initially high muscle glycogen levels were not spared by the carbohydrate supplements or that these supplements improved performance.

In contrast to the findings of others regarding lack of improvement in performance Sherman, Peden, and Wright (1991) studied the effects of low carbohydrate (LC: 1.1g/kg bw) versus high carbohydrate (HC:2.2g/kg bw) and a placebo (P) on endurance cycling exercise (70% VO₂max for 90 minutes) in college-aged males and found significant improvements in performance in both carbohydrate trials. Like other studies on muscle glycogen, exercise and diet were controlled prior to the study to equate glycogen reserves. During each of four trials and sixty minutes after consuming the test-drink, each subject cycled for 90 minutes at 70% of maximal oxygen consumption and then performed a timed trial of cycling as fast as they could to finish the same number of revolutions it took to cycle for 45 minutes. Water was provided every 15 minutes of exercise. Lactate, free fatty acids, insulin, glucose, and oxygen consumption variables were studied for differences. Similar to other studies blood glucose levels initially fell then rose and leveled off (LC similar to P), and all three were similar at 30 minutes, but HC blood glucose levels were significantly higher from 60 minutes on to the end of the time trial period. Free fatty acids were significantly lower for HC compared to P at 90 minutes and at the end of the time trial P had significantly higher free fatty acid concentrations than either LC or HC. Insulin levels were significantly different from each other. Compared to the placebo, exercise performance on the timed trial was improved by an average of 12.5%, power was improved by an average of 13.1%, and the percent VO₂max was higher by 11% and 17% for LC and HC respectively.

The authors concluded that carbohydrate availability during exercise was the key issue in this study. Using the performance data and the data on insulin, they suggested one of two outcomes, that HC emptied more slowly than the LC and P and was absorbed faster than it could be oxidized, or that there was a reduction in glucose uptake via insulin or muscle contraction.

In another study, Wright, Sherman, and Dernback (1991) showed similar positive outcomes in exhaustive cycling performance on carbohydrate consumption in nine well trained athletes. In this study, the cyclists were more closely monitored for equating muscle glycogen reserves including the consumption of a 3-day diet similar to a competition diet plus the consumption of two commercially available granola bars and non-caffeinated, non-caloric beverages 10 hours prior to reporting to the laboratory. Similar to the previous study the subjects cycled at 70% of VO₂max until exhaustion and performed time and cadence monitored 3-minute work production tests each 45 minutes requiring 90% VO₂max. However, in this study the pre-exercise carbohydrate supplement (5g/kg bw – 21% glucose polymers, 4% sucrose) or an artificially sweetened placebo was compared to 20 minute intervals of further carbohydrate feedings (5% glucose polymers and 3% fructose) or placebo. Supplementation began 3 hours prior to the test and continued after 20 minutes of exercise. Water was provided each alternate 20 minute period.

Carbohydrate consumption increased work output by an average of 33% more than the placebo only treatment and time to exhaustion by an average of 31% longer than the placebo only treatment. In every case where carbohydrate was consumed, either with a placebo before, during exercise, or alone, there was a significant difference from the placebo only treatment in all measures of insulin, glucose, free fatty acids, work output, performance, or time to exhaustion. However, there were no differences in blood lactate and RPE. The authors concluded that carbohydrate improves performance and pre-exercise carbohydrate feedings along with carbohydrate feedings during exercise extends the benefits.

The glucose sparing effect and enhanced performance provided by carbohydrate consumed prior to and during exercise was investigated by Marmy-conus et al., (1996) in a study of carbohydrate treatment versus placebo. To test the hypothesis that glucose ingestion would dampen liver glucose output and increase muscle glucose uptake, Marmy-conus also used a labeled glucose [6,6-²H₂] infusion in all subjects for 2 hours prior to exercise and for 60 minutes during exercise and contrasted that to the treatment, placebo, and exercise protocol. The carbohydrate treatment consisted of 75g of glucose, also labeled – [3-³H] diluted in 400 ml of water versus an artificially sweetened placebo. The exercise protocol was 60 minutes of cycling at 71% of VO_{2peak} oxygen uptake. Liver glucose output was calculated from total glucose appearance and appearance of the glucose treatment.

Ingested glucose led to an inhibition (62%) of hepatic glucose production during the early stages of exercise while hepatic glucose production increased steadily with the placebo treatment. In the carbohydrate group, plasma lactate was significantly higher after 60 minutes and free fatty acids were lower at the start of exercise to the end but there were no differences between the treatments on plasma epinephrine, norepinephrine, or glucagon. Carbohydrate oxidation, as calculated by RER, was not increased during exercise. The authors speculated that the magnitude of change in plasma glucose and free fatty acids was not great enough to affect the use of muscle glycogen.

Interestingly, the gut-derived glucose rose steadily after ingestion, leveling off during the first 30 minutes of exercise, and then steadily rose until the end of exercise. The authors speculated that the exercise caused a transient decrease in splanchnic blood flow although they did not speculate about the mechanism.

Under the assumption that muscle glycogen and blood glucose are spared in trained subjects by increased fat oxidation during exercise Jeukendrup, Mensink, Saris, and Wagemnakers (1997) investigated the effect of training status on fuel use during moderately intense bicycling. Seven highly trained cyclists and eight untrained subjects participated in a study to determine the differences between a) carbohydrate and fat oxidation and b) the relative contribution of endogenous and exogenous carbohydrate during moderate intensity cycling exercise (50% maximum workload corresponding to about 55 to 60% maximal oxygen uptake for 120 minutes).

Following an overnight fast and a small breakfast of two crackers and cheese, subjects started cycling and immediately drank 8 ml/kg of 8% glucose solution and 2 ml/kg every 15 minutes afterward. Exogenous glucose solutions were made of either corn (test) or potato (control), each having different concentrations of ¹³C. Normal background concentrations of ¹³C had been established prior to the experimental period.

After 15 minutes RER for trained subjects (0.87) was significantly lower than for untrained subjects (0.91) and also significantly lower at the end of the 120 minute trial (0.85 vs. 0.89; $P < 0.05$). There were no significant differences between the groups on endogenous and exogenous carbohydrate oxidation and no difference in absolute amounts of carbohydrate oxidized between the groups ($116.3 \text{ g} \pm 7.5$ vs. $113.7 \pm 3.6 \text{ g}$). Untrained lactate concentrations were significantly higher than for trained subjects.

Jeukendrup et al., (1997) could not show that untrained subjects oxidized more carbohydrate or that prior training led to an increased ability to oxidize ingested carbohydrate. However, total fat oxidation was significantly higher for trained subjects ($37.4 \pm 2.3 \text{ g}$) than the untrained subjects ($22.5 \pm 1.4 \text{ g}$).

Effect of Mixed Fat and Carbohydrate Supplements on Endurance Exercise

In 1987, Welch, Bruce, Hill, and Read studied the effect of lipids on glucose and insulin and gastric emptying. Subjects in this study, however, were not exercising. Instead, following an overnight fast, subjects were infused with either saline or an iso-osmotic fat emulsion (Intralipid, 20%) for 170 minutes at a constant rate of 1.2 ml/min and, twenty minutes later, given a radioactively labeled meal of mashed potato with water. They were then semi-recumbent for the remainder of the study while the radioactivity of the gastric fundus was sampled every 5 minutes up to 170 minutes. They found that lipid in the small intestine delayed gastric emptying and reduced the postprandial rise in blood glucose and insulin.

Welch et al.'s, (1987) findings on lipid's effects on gastric emptying are significant to this study. Whole cow's milk contains a significant quantity of fat, from 3.2% to 3.7% of whole milk (Jensen, 1995). Fat is present in milk at nearly the same quantity as lactose, milk sugar at 4.8% (Jensen, 1995). Of importance to this study are the significant quantities of medium-chain fatty acids, 15% to 20% of total milk-fat.

Romijn, Coyle, Sidossis, Gastaldelli, Horowitz, Endert, and Wolfe (1993) studied the effects of varying exercise intensities (25%, 65% and 85% $\text{VO}_{2\text{max}}$) and exercise duration on the regulation of endogenous fat, principally intramuscular triglycerides, and carbohydrate metabolism in five endurance trained cyclists using indirect calorimetry and stable isotope tracers. Dependent variables studied included plasma glucose, plasma free fatty acids, palmitate, glycerol, and plasma catecholamines.

The lowest intensity exercise (25% $\text{VO}_{2\text{max}}$) was fueled mostly by blood glucose. This conclusion was supported by changes in muscle glycogen concentration as determined by muscle biopsies. Maximal rates of fat oxidation, $>42 \mu\text{mol} \cdot \text{kg}^{-1} \cdot \text{min}$ or three times the rate of appearance of glycerol for the whole body, occurred during the moderate intensity exercise (65% $\text{VO}_{2\text{max}}$). The high intensity exercise (85% $\text{VO}_{2\text{max}}$) elicited a reduction in the release of free fatty acids (FFA) into the plasma however it was not due to a reduction in either peripheral or whole body lipolysis because glycerol concentration was maintained. Plasma FFA increased dramatically right after the high intensity exercise leading the authors to speculate that FFA were entrapped in adipose tissue due to a reduction in blood flow to that tissue. FFA and glycerol are transported in the blood but, because FFA are hydrophobic, they have to be transported in blood bound to albumin. Glycerol, on the other hand, is soluble in water and is transported in plasma.

The authors speculated that during high intensity exercise some mechanism, perhaps α -adrenergic inhibition of adipose tissue blood flow, favors circulation and oxygen delivery over fat metabolism. While glucose uptake and muscle glycogenolysis are associated with a reduction in FFA oxidation, the authors suggested that the reduction in fat oxidation might have been due to the reduction in plasma FFA and that an exogenous supply of FFA might result in an increase in fat oxidation.

Several investigators have studied the effects of medium-chain triglyceride supplements (MCT) either with carbohydrate or alone on endurance exercise (Jeukendrup, Saris, Schrauwen, Brouns, & Wagenmakers, 1995; Jeukendrup, Saris, Van Diesen, Brouns, & Wagenmakers, 1996; Massicotte, Peronnet, Brisson, & Hillaire-Marcel, 1992). While the results of these studies do not suggest that exogenous MCT are superior to any other supplement, they warrant further study.

Massicotte et al., (1992) compared the effects of exogenous [^{13}C] MCT (trioctanoate) to an isocaloric supplement of labeled glucose ([^{13}C]glucose) in six healthy males participating in medium intensity cycling exercise (65% $\text{VO}_{2\text{max}}$). They also studied the effects of MCT and glucose ingestion on metabolic and endocrine responses to endurance exercise. Regarding total energy contribution neither MCT (119 ± 31 Kcal, 7% of total energy production) nor glucose (140 ± 36 kcal, 8.5% total energy production) were significantly different but both, compared to water, contributed to maintaining blood glucose and insulin concentrations and blunted the rise in glucagon and plasma epinephrine. While the MCT supplements contributed to increased FFA availability in the gut and, presumably decreased endogenous fat oxidation, they did not prevent the oxidation of endogenous carbohydrate.

Following up on Massicotte et al.'s (1992) conclusion that MCT provided usable energy in endurance exercise and that they are rapidly hydrolyzed and absorbed, Jeukendrup et al., (1995) investigated the effects of MCT (1,1,1- ^{13}C trioctanoate) coingested with carbohydrates in eight well-trained cyclists during a cycling bout. Cycling at about 57% of $\text{VO}_{2\text{max}}$ the subjects consumed 2 ml/kg isocaloric boluses every 20 minutes for 120 minutes of either carbohydrate or MCT alone, high carbohydrate plus MCT, or low carbohydrate plus MCT.

RER and VO_2 were not significantly different between trials but MCT were more rapidly oxidized in the presence of carbohydrate with 71% to 76% of MCT being oxidized during the second hour in the carbohydrate-MCT trials compared to 33% for MCT alone. Also, with carbohydrate and MCT, plasma glucose was maintained while in the MCT trial alone plasma glucose steadily fell. The authors speculated that either MCT was transformed into triglycerides or other lipids or that the carbohydrate-MCT solutions simply emptied from the stomach faster than the MCT alone. Irregardless, the metabolic availability of the MCT was high, reaching 83% peak oxidation rate during the final hour. The authors concluded that MCT, delivered orally with carbohydrate, might serve as an energy source and that carbohydrate serves to accelerate exogenous MCT during submaximal exercise.

A follow-up study by Jeukendrup et al., (1996) on MCT supplementation versus carbohydrate and MCT produced more equivocal results. Eight cyclists pedaled for 90 minutes at 57% $\text{VO}_{2\text{max}}$ in four trials. In two trials the cyclists performed their ride a day after exhaustive exercise (LG) and in the other trials the day following a glycogen loading phase. After correcting for energy requirements of the entire ride and bicarbonate pool carbon dioxide,

they estimated that nearly one third of the exogenous MCT was oxidized, representing 5.2% to 5.9% of the total energy expenditure. There was no effect of low glycogen on MCT oxidation in this study. The authors concluded that MCT contribution to total energy utilized was small and that MCT oxidation is limited by the entrance of MCFA into the systemic circulation.

Effect of Proteins in Milk on Endurance Exercise

In a study to determine the effects of protein ingestion on glucose and insulin responses Nuttal, Mooradian, Gannon, Billington, and Krezowski (1984) reported that protein ingestion blunted glucose responses and amplified the insulin responses in diabetics (Type II). While this could conceivably conserve glucose, the deleterious effects of the high insulin could mitigate any exercise benefits. Nuttal et al. did not include physical activity in their paradigm.

Milk sugar, lactose, is a disaccharide combination of equal parts galactose and glucose. Leijssen, Saris, Jeukendrup, and Wagenmakers (1995) investigated the individual and combined effects of galactose and glucose on endogenous and exogenous carbohydrate oxidation in eight highly trained athletes who volunteered to participate in a supplement-study on endurance cycling. Each subject bicycled on two separate occasions at 65% of previously established work rate max (Wmax) for 120 minutes, rested for 60 minutes, then bicycled again for 30 minutes at 60% Wmax. Pretest diets were monitored for one week prior to each test and each test was preceded by an identical standardized breakfast. Prior to the test each subject received an initial bolus of 8 ml/kg of either 8% (wt/vol) galactose solution or 8% glucose solution and during the test subjects received 2 ml/kg of either glucose or galactose every 15 minutes. Galactose was labeled with 0.35 g/kg [$1\text{-}^{13}\text{C}$] and glucose was labeled with 0.05 g/kg of [$\text{U-}^{13}\text{C}$]. Both drinks also had 20 mM NaCl added and drinks were consumed at room temperature. Blood was sampled via indwelling antecubital catheter with measurements made of glucose, galactose, lactate, glycerol, and insulin. Expired gases were collected and used to determine substrate usage via the method of Peronnet and Massicotte (1991).

Plasma insulin and glycerol concentrations were not significantly different between the two drinks (glucose - 63%, galactose - 62% for 0 to 120 min; glucose - 64%, galactose - 63% for 60 to 120 min), additionally, total fat oxidation rates were similar as well. The average rate of exogenous carbohydrate oxidation with glucose ingestion was significantly greater (9%) during the test period and rest periods than for galactose ingestion (5%) with the rate of exogenous glucose oxidation increasing significantly from 9% to 12% from 60 minutes to 120 minutes. Exogenous carbohydrate oxidation remained significantly lower for the entire ride, with 46% of the entire glucose ingested being oxidized compared to the oxidation of 21% of the galactose. However, later in the ride from minute 60 to 120 when carbohydrate stores were being depleted, endogenous carbohydrate oxidation was significantly higher (31% with galactose vs. 24% with glucose) and exogenous carbohydrate significantly lower (6% with galactose vs. 12% with glucose) with galactose ingestion. The authors concluded that the peak oxidation rate of galactose was nearly half the peak oxidation rate of glucose even though total energy expenditure was not significantly different between the trials.

Leijssen et al. speculated that the lower oxidation rates of galactose in the first exercise bout could have been because the galactose had to be converted to glucose in the liver before its

oxidation in the muscles, because the galactose was sequestered in glycogen and only oxidized later (in the second exercise bout), or because the conversion of galactose to glucose is rate limited. In this study, the ingestion of galactose contributed to a lower exogenous carbohydrate oxidation which was compensated by a higher rate of endogenous carbohydrate oxidation, which could result an earlier onset of fatigue. However, the co-ingestion of glucose with galactose mitigates the decrease in energy availability due to the increase in fat oxidation.

Conclusion

Cow's milk use for food energy has a long history. This long association with milk as a food lends legitimacy to the current question of its efficacy as a sport supplement or ergonomic aid. While it may be possible that commercial, whole milk may not be efficacious in many sports due to its need for refrigeration the fact still stands that the various components of milk certainly lend themselves to sport/work enhancement. Milk has the energy-yielding macronutrients, vitamins necessary for energy reduction, minerals necessary for muscle contraction, and water necessary for cell hydration.

Some researchers have attempted to control for the effects of different types of milk on exercise performance (skim, low fat, or whole milk) while others have not. More often, milk has been combined with other food supplements and not studied directly. In summary, the components of milk, by themselves, offer compelling evidence that they can be safely used as supplements in human work performance. However, the evidence for whole milk as an exercise/work supplement remains equivocal.

CHAPTER III METHODS

Subjects

Eighteen males were recruited from the student and community population around Valdosta, Georgia. Subjects were all between the ages of 18 and 35 years, physically active at the time of the study, and met the following criteria: 1) self-described as endurance trained on a bicycle; 2) no personal or family history of major diseases such as metabolic or heart disease; 3) absence of musculoskeletal disorders that might be predisposing to injury or injury exacerbation; 4) currently able to consume whole cow's milk; 5) comfortable with having blood drawn by indwelling catheter. The Florida State University Human Subjects Committee approved this study (Appendix A) and the Valdosta State University Institutional Review Board for the Protection of Human Subjects provided approval to collect data on site (Appendix A).

Protocol and Procedures

Prior to collection of any data, informed consent (Appendix A) was administered and signed by each subject. Informed consent consisted of viewing a powerpoint presentation of the procedures of the overall objective of the study. The powerpoint described the protocol of the study that included: rationale for the study, description of the maximal oxygen consumption test, the 2-day pre-ride dietary measures to be taken, how to arrive at the lab and how long each ride would last, and how blood was to be drawn. After each powerpoint presentation there was a period of time where each subject could ask any questions for clarification. After any questions were answered satisfactorily, each subject read the informed consent and either signed it or indicated that they did not want to participate (Appendix A). If the latter occurred, that subject was excused and not approached again for their participation. After the informed consent was filled out, a medical history listing personal or family history of disease, current medications or performance supplements was reviewed with the subject (Appendix B). Any subject indicating a positive personal or family history of disease was thanked for their willingness to participate and excused from the meeting.

A preliminary interview was conducted in the Valdosta State University Human Performance Laboratory prior to scheduling the maximal oxygen consumption test where instructions regarding the protocol prior to each long ride were read and discussed again with each subject (Appendix B). A two-day dietary record was given to each subject at the preliminary interview and the investigator, who teaches nutrition at Valdosta State University, discussed recording of daily food intake. Participants were instructed to follow the same preparatory routine for each long ride on the two days prior to reporting to the Human Performance Lab. For two days prior to each long-ride they were: to consume a diet high in carbohydrate, at least 60% of calories, to abstain from caffeine and alcohol products; and to abstain from vigorous physical activity. These directions were repeated for each subject after each of the first two rides and by email correspondence at least two days prior to beginning the

two-day preliminary protocol. Each of the three rides was separated from the others by at least two weeks to ensure adequate recovery time and to minimize any influence on subsequent trials. All testing protocols occurred in the morning between 6 am and 11 am to minimize the effects of diurnal rhythms.

Preliminary maximal oxygen consumption was obtained using a continuous cycling protocol on a Monark 819 Cycle Ergometer at least one week prior to the first long ride. The initial resistance was set at 0 kp and increased 30 watts every three minutes until exhaustion (Forhaz, Matsudaira, Rodrigues, Nunes, and Negrado, 1998). Cadence was maintained between 60 and 70 RPM. VO_{2max} was established when three of the following criteria were met: 1) no further increase in oxygen uptake with an increase in work; 2) exercise heart rate within ten beats per minute of age-estimated maximal heart rate; 3) a blood lactate > 8 mmol/L; or 4) a respiratory exchange ratio greater than 1.15.

Data Collection

On the day of each long ride, each subject arrived by automobile in a fasting state (nothing but water consumed after dinner the previous night). Each trial subject would turn in their two-day diet record for validation of a minimum carbohydrate intake ($\geq 60\%$). Diets were analyzed by a computer-based dietary analysis software program (The Food Processor [®] SQL, ESHA Research, Salem, OR). Each trial subject was weighed, seated, and fitted with an indwelling catheter, by a licensed nurse (RN), in a vein located in the forearm for blood collection throughout the long and short ride. The forearm site was chosen so as to minimize discomfort to the rider while samples were drawn during the ride. After the catheter was established, two (2) 10 ml samples and one 3 ml sample of blood were drawn for baseline blood analysis of glucose, glycerol, lactate, and free fatty acids. After each blood draw the catheter was flushed with 5cc of sterile saline to keep the vein patent. The subject then consumed one of the three exercise meals provided to them in an opaque container with the contents hidden from both the subject and the primary investigator. Bottled water was available for each subject to dilute the exercise meal if they wished. Each subject then rested quietly for 30 minutes in a chair in the Human Performance Laboratory.

Table 3.1. Blood assays sampling schedule throughout each long-ride.

Analyte	Baseline	Rest	30 minutes	60 minutes	90 minutes	105 minutes	120 minutes	Max
Glucose	☀	☀	☀	☀	☀	☀	☀	☀
Glycerol	☀	☀	☀	☀	☀	☀	☀	☀
FFA	☀	☀	☀	☀	☀	☀	☀	☀
Lactate	☀	☀	☀	☀	☀	☀	☀	☀

After 30 minutes of seated rest, the subject was fitted with a Polar heart rate monitor and seated on the cycle ergometer. A sample of blood was drawn (by the RN) and the subject was fitted with the mouthpiece and nose clip for establishing exercise intensity from the previously determined maximal oxygen consumption test. Each subject rested quietly breathing through the mouthpiece to ensure that all room air had been expelled from the hose and mixing chamber of the metabolic system. This was confirmed by comparing output values of at least one MET (3.5 mL/Kg/min). For the long ride, exercise intensity was established at approximately 55% of each subject's previously measured $\text{VO}_{2\text{max}}$. Exercise intensity was maintained at this level by periodically measuring the subject's oxygen consumption each 15 minutes during the long-ride. Respiratory exchange ratios and heart rates were also taken at this time. Blood samples were taken for analysis every 30 minutes. Cool water ad libitum was provided during the duration of the long ride. Temperature in the lab remained fairly constant between 20 and 27 ° C. A fan was used during the long and short ride tests.

Following the long-ride (120 minutes), each subject rested in a chair for 30 minutes during which time no measurements were taken. After 30 minutes rest, the subject was fitted again with the mouthpiece and nose clip and baseline measures (immediately pre-ride) were taken. The subject then began riding at a speed ≥ 60 RPM to reach a resistance equal to $80\% \pm 5\%$ of their previously determined $\text{VO}_{2\text{max}}$. Time to exhaustion was measured after the subject attained at least two consecutive measurements of VO_2 equal to or greater than their 80% estimate to the point where the subject either voluntarily stopped, the subject could not maintain the required cycling speed of 60 rpm, or the subject could not maintain the required 80% $\text{VO}_{2\text{max}}$. Measurements of oxygen consumption, respiratory exchange ratio, heart rate, and rating of perceived exertion were taken each minute until the subject could not maintain the required cadence or chose to quit, considered to be the end of the test. A final blood sample was drawn at exhaustion and the subject was allowed to slow down during which time the final blood sample was obtained. After the short-ride, each subject pedaled for 3 to 5 minutes at a leisurely pace to recover during which the final blood draw was made. After heart rates and respiratory rates had subsided to resting levels each subject was disconnected from the monitoring equipment, allowed to sit in a chair, and fed a breakfast of fruit and bagels. All subjects were paid for their rides, \$33 for ride 1, \$33 for ride 2, and \$34 for ride 3 to equal \$100 for all three rides.

Instrumentation

Cardiorespiratory Measures. Oxygen consumption measures were obtained in the Human Performance Laboratory at Valdosta State University with the participant pedaling the Monark 819 cycle ergometer. Inspired and expired air samples were analyzed using a True Max 2400 Metabolic Measurement System (PAR-O Medics, Salt Lake City, UT). Respiratory exchange ratio, RER, were calculated from oxygen consumption and carbon dioxide production values by the metabolic measurement system.

Heart rates were monitored with a Polar Heart Rate Monitor and a computer interface system with the True Max 2400 Metabolic Measurement System. After instructions were given

to the subject prior to the ride, ratings of perceived exertion (RPE) were taken verbally each minute during the short ride.

Blood Measures. An indwelling catheter was placed in a forearm vein at least 35 minutes before each exercise trial to allow for blood sampling seven specific times during each exercise trial. A professional nurse/phlebotomist, licensed in the State of Georgia, obtained all blood samples and kept the catheters patent (with saline).

Blood was collected without stasis into a 10 cc sterile syringe and transferred immediately into three vacutainer tubes at each blood draw. Blood was then transferred into a 3 ml gray top vacutainer with antiglycolytic sodium fluoride and into a red top tube. Blood samples were coded, cooled in a refrigerator for at least 15 minutes, and centrifuged for 20 minutes at 3260 rpm in a Horizon Horizontal Separation Centrifuge Model 640B Quest, The Drucker Company, 200 Shady Lane, Phillipsburg, PA, 16866, USA. An aliquot of serum was then separated from one red top tube, aspirated into another red top tube and then frozen at -22° C. Samples were analyzed periodically at the Exercise Physiology laboratory at Florida State University. All hematological assays, with the exception of lactate, were performed in duplicate.

Lactates from each sampling were analyzed immediately in the Valdosta State University Human Performance Laboratory using the Accutrend Lactate portable analyzer manufactured by Sports Resource Group, Inc., 210 Belmont Road, Hawthorne, NY 10532, USA. Glucose was analyzed in the FSU Exercise Physiology Research Laboratory using a glucose (oxidase) reagent. This, #23666287, and a glucose standard, #23666277, were purchased from Fischer Scientific Company, P. O. Box 4829, Norcross, GA, 30091, USA. Glycerol was measured in the FSU Exercise Physiology Research Laboratory using GPO (glucose peroxidase) trinder reagent, #A FG0100. This was purchased from Sigma, P. O. Box 14508, St. Louis, MO, 63178-9916, USA. The glycerol standard, #G 1394, was also purchased from Sigma. Glucose and glycerol were analyzed using a spectrophotometer (Beckman DU640, Corona, CA). Free fatty acids were measured in the Food Science Research Laboratory using the non-esterified fatty acid determination kit, NEFA HR(2) C 994-75409 2 purchased from Wako Chemicals USA, Inc., 1600 Bellwood Rd., Richmond, VA 23237, USA. Free fatty acid absorbance was read using a microplate scanning spectrophotometer (Power-Wave 200, Bio-Tek, Winooski, VT).

Test Drinks. The test drinks in this study consisted of: whole cow's milk purchased from Publix Groceries (200 Kcal / 320 ml fluid volume: 16 g carbohydrate, 10.7 g fat, 10.7 g protein) and two contrast drinks, one consisting of an isocaloric glucose polymer drink isocaloric to the whole milk supplement, glucola, (200 Kcal / 300 ml fluid volume: 50g carbohydrate, 0 g fat, 0 g protein) and a placebo/control drink, water. The glucola (Cat. B5395-7A) was purchased from Cardinal Health, McGaw Park, IL, 60085-6787, USA. The third drink (placebo) was an artificially flavored, unsweetened placebo beverage (2g of NutraSweet in 300 ml bottled water; distributed by Merisant, US, Inc. Chicago, IL). The drinks were chilled and delivered in an opaque container to hide the identity of the drink. This was possible for two of the drinks but not the milk drink.

Statistical Analysis

Eighteen subjects were recruited for the study from the South Georgia area and included university students, citizens, and military personnel. Other studies in the literature have used from 8 to 16 subjects, with most using fewer than 10 participants (Backx, McNaughton, Crickmore, Palmer, & Carlisle, 2000; Davis, Welsh, De Colvve, & Alderson, 1999; DeMarco, Sucher, Cisar, & Butterfield, 1999; Fabbraio & Stewart, 1996; Lee, Ha, & Lee 1999; Massicotte, Peronnet, Brisson, & Hillaire-Carcel, 1992). A repeated measures two-way analysis of variance (general linear model) was used to test for differences between the means, for main effects, and for interactions. Bonferonni analysis was used for post hoc analyses. Alpha was set at $p \leq 0.05$ for all statistical tests. Statistical procedures were performed using Statistical Program for Social Sciences (SPSS) software (version 15). Values are reported as means $\pm$ SE.

CHAPTER IV RESULTS

Descriptive Subject Information

Eighteen subjects were recruited to participate in this study from the South Georgia region. Most of the subjects were residents of Valdosta, GA while several were residents of Albany or Tifton, GA. Subjects were recruited from the Valdosta State University community, from the military community at Moody Air Force Base near Valdosta, GA, and from the private sector, i.e., residents of Valdosta, Albany, and Tifton, GA. All subjects for this test were healthy males between the ages of 18 and 35 years of age and were self-identified as endurance trained on the bicycle.

Table 4.1. Physical characteristics of subjects.

Characteristic	Value
Age, yr	26.7 ± 5.71
Height, cm	182 ± 5.31
Weight, kg	78.2 ± 8.7

Values are means $\pm$ S.D., N = 18.

Pre-Experimental Tests of Aerobic Capacity

The results of VO₂ testing are summarized in Table XX. All subjects self-identified themselves as endurance trained and capable of riding approximately 30 miles on a cycle ergometer, non-stop at a minimum of 60 rpm. On the pre-test to establish work load for the rides a ramp protocol was used to measure maximal oxygen consumption, i.e., achievement of at least 3 of the four criteria for VO_{2max} in the Methods (Chapter III).

Table 4.2. Test of maximal aerobic capacity.

Measurement	Mean	Range
VO _{2max} ml·kg ⁻¹ ·min ⁻¹	50.8 ± 8	37.1 – 62.2
VO _{2max} L·min ⁻¹	3.94 ± 0.6	2.95 – 5.18
Maximum heart rate	181 ± 12	174 – 203
RER at maximum	1.2 ± 0.1	1.08 – 1.48
Lactate at maximum (mmol/L)	10.1 ± 1.5	7.9 – 11.4
Calculated 55% VO ₂ ml·kg ⁻¹ ·min ⁻¹	27.95 ± 4.4	22.6 – 34
Calculated 80% VO ₂ ml·kg ⁻¹ ·min ⁻¹	40.7 ± 6.4	32.8 – 49.4

VO_{2max} is maximal oxygen consumption. Values are means ± S.D., N = 18.

Pre-trial Control Measures

Dietary Analysis. Prior to every test each subject was instructed to consume a diet high in carbohydrate products for the two days prior to the test in the Human Performance Laboratory, to keep a record of their diet, and to abstain from food or drink (with the exception of water) after dinner the night before each ride. Dietary records were analyzed with The Food Processor SQL nutritional analysis software described in Chapter III, METHODS. Each subject was also urged to abstain from caffeine and tobacco products which are known to stimulate the release of free fatty acids. Analysis of the dietary records confirmed that, as a group, the subjects diets consisted of the minimal dietary carbohydrate (60.8%, ± 5.0). To minimize plasma volume shifts and stimulation of free fatty acid release, all subjects arrived at the lab via automobile (or truck).

Environmental Conditions. All rides were performed in the morning starting between 6:30 am and 7:30 am to mitigate any possible effect of circadian rhythms on any of the measurements. The temperature in the laboratory was maintained between 20 ° and 24 ° C and a large fan was used for each ride.

Blood measurements

Glucose. Glucose responses to exercise and type of meal are shown in Figure 4.1. Analysis was performed on the time period immediately preceding exercise, and every 30 minutes through the last minute of the long ride. While there was no significant difference between the means for the drinks, $F(2,32) = 1.066$, $p = .356$, there was a significant Effect for Time, $F(4, 64) = 32.07$, $p < .001$. There was a significant Drink X Time interaction, $F(8, 128) =$

12.898, $p < .001$. Glucose in the glucola trial fell precipitously, from rest, at the onset of exercise and by minute 30 there were no significant differences between the drinks until the third time measure, minute 60, where there was another statistically significant decrease in glucose compared to the last measure at minute 120. Bonferroni post hoc analysis (Appendix H, Table H2) showed that the mean of the glucose on the glucola trial immediately preceding the ride was significantly higher than the means at the subsequent time points. The glucose means on the other drinks were not significantly different over time. Individual glucose data can be found in Appendix E, Tables E1a, E1b, and E1c.

Figure 4.1. Glucose responses to long ride (Means, $\pm$ S.E., N=18).

* $p < .05$ main effect of glucose over time.

† $p < .05$ as compared minute 30 to minute 120.

‡ $p < .05$ interaction of drink (glucose) 0 minutes (rest) between remaining measures.

Glycerol. Glycerol response to exercise and type of meal is shown in Figure 4.2. Analysis was performed on the time period immediately preceding exercise, and every 30 minutes through the last minute of the long ride. There was no significant difference between the means of the drinks for glycerol response, $F(2, 32) = 1.131$, $p = .335$, and there was no significant Drink x Time interaction, $F(8, 28) = 1.164$, $p = .326$. However, there was a significant Effect for Time, $F(4, 64) = 9.574$, $p < .001$. Glycerol values fell with the onset of exercise, then increased significantly over time. Bonferroni post hoc analyses (Appendix H, Table H3) at each time point showed significant differences between resting values and the two last time points (90 minutes and 120 minutes), then between the third time point (60 minutes) and the last two time points (90 minutes and 120 minutes), and finally between the second to last time point and the final time point (90 minutes and 120 minutes respectively). Individual glycerol data can be found in Appendix E, Tables E2a, E2b, and E2c.

Free Fatty Acids. Free fatty acid response to exercise and type of meal is shown in Figure 4.3. Analysis was performed on the time period immediately preceding exercise, and every 30 minutes through the last minute of the long ride. There was a significant difference between the means of the drinks, $F(2, 32) = 5.916$, $p < .007$. Pairwise comparisons showed the difference to exist between the means of the milk and placebo trials (0.505 and 0.689 mEq/L respectively, $p < .030$) but not between glucola and the placebo trials (0.506 and 0.689 mEq/L respectively, $p < .065$). There was a significant main Effect for Time, $F(4, 64) = 43.146$, $p < .001$. Post hoc analysis demonstrated that free fatty acids first fell with the onset of exercise, then rose steadily throughout the ride from minute 30 to minute 120. There was no significant interaction on Drink x Time, $F(8, 128) = 0.881$, $p = .534$. Individual free fatty acid data can be found in Appendix E, Table E3a, E3b, and E3c.

Figure 4.2. Glycerol response to long ride (Means, $\pm$ S.E., N=18).

* = $p < .05$ as compared 0 minutes (rest) to 90 and 120 minutes

† = $p < .05$ as compared 60 minutes to 90 and 120 minutes

‡ = $p < .05$ as compared to between 90 minutes to 120 minutes

Figure 4.3. Free fatty acid responses on the long ride (Means, $\pm$ S.E., N=18).

* = $p < .05$ milk was significantly different from the placebo.

† = $p < .05$ as compared across time from rest to 60, 90, and 120 minutes.

‡ = $p < .05$ as compared across time from minute 30 through 120 minutes.

Lactate response. Lactate response to exercise and type of meal is shown in Figure 4.4. Analysis was made from immediately preceding exercise, and every 30 minutes through the last

minute of the long ride. The means of the drinks on blood lactate were not significantly different, $F(2, 32) = .394$, $p = .678$, nor was there an interaction between Drink and Time, $F(8, 128) = .650$, $p = .734$. However, there was a significant main Effect of Time for lactate, $F(4, 64) = 10.646$, $p = .001$. Bonferroni post hoc analyses (Appendix H, Table H4) across time showed that lactate rose with the onset of exercise to its highest point at the first measure, 30 minutes, ($\bar{X} = 3.073$ mmol/L) where it was significantly different from the following time points ($p < .029$, $p < .001$, $p < .001$). Afterwards, lactate fell until it nearly leveled off between minutes 90 and 120, the end of exercise. Complete raw data and ANOVA summary tables for lactate can be found in Appendix E, Tables E6a, E6b, and E6c.

Heart rate. Heart rate response to exercise and type of meal is shown in Figure 4.5. Analysis was made every 15 minutes through the last minute of the long ride, specifically, nine time points. There was no significant difference between the means of the drinks on heart rate response during the long-ride, $F(2, 32) = 1.180$, $p = .320$, however, there was a significant main Effect of Time on heart rate, $F(8, 128) = 225.075$, $p < .001$, and there was a significant interaction on Drink x Time for heart rate, $F(16, 256) = 2.074$, $p = 0.010$. Bonferroni post hoc analysis (Appendix H, Table H5) across time showed that resting heart rate was significantly different from all of the other time points and that each of the time points were significantly different from the last time point, however, with the exception of minute 15 and minute 120 for milk, they were not significantly different from one another. Heart rates rose with exercise, reached a steady state and rose again at the end of the ride. Individual heart rate data can be found in Appendix E, Tables E4a, E4b, and E4c.

Figure 4.4. Lactate responses to the long ride (Means, $\pm$ S.E., N=18).
† = $p < .05$ as compared minute 30 to 60, 90, and 120 minutes.

Figure 4.5. Heart rate responses to the long ride (Means, $\pm$ S.E., N=18).

* = $p < .05$ for Rest compared to the remaining time points.

† = $p < .05$ as compared to 120 minutes.

‡ = $p < .05$ for glucola as compared to between remaining time points.

© = $p < .05$ for milk as compared between Rest (0 minutes) and 120 minutes.

Respiratory exchange ratio. Respiratory exchange ratio (RER) response to exercise and type of meal is shown in Figure 4.6. Analysis via expired gas sampling was made every 15 minutes through the last minute of the long ride. While there was no significant main effects for the means of the drinks on RER, $F(2, 32) = 1.273$, $p = .294$, there was a significant Effect of Time for RER, $F(8, 128) = 8.267$, $p < .001$, but no significant interaction for RER on Drink x Time, $F(16, 256) = 1.665$, $p = .054$. Bonferroni post hoc analysis (Appendix H, Table H6) across time showed that after 15 minutes of exercise, RER peaked significantly higher than all of the other time points. The only other significantly different time point was a higher RER at 30 minutes than at 120 minutes. Individual RER data can be found in Appendix E, Tables E5a, E5b, and E5c.

Short Ride at 80% $\text{VO}_{2\text{max}}$

Time to exhaustion. Figure 4.7 shows the response of meal type on time to exhaustion at 80% maximal oxygen consumption after two hours of riding at 55% maximal oxygen consumption followed by 30 minutes of rest. While the GLU drink averaged approximately 18% longer at 80% $\text{VO}_{2\text{max}}$ than the MI drink and nearly 20% longer than the PLAC drink there were no statistically significant differences between the drinks on time to exhaustion. Time to exhaustion was not significantly different between the treatments, $F(2, 52) = .428$, $p = .654$. ANOVA summary table for Short Ride values can be found in Appendix F, Table F4.

Free fatty acids. Means for free fatty acid at the end of the short ride were not significantly different between rides, $F(2, 52) = .163$, $p = .850$. ANOVA summary table for Short Ride values can be found in Appendix F, Table F4.

Glucose. Means for glucose at the end of the short ride were not significantly different from one another, $F(2, 52) = .789$, $p = .460$. ANOVA summary table for Short Ride values can be found in Appendix F, Table F4.

Glycerol. Means for glycerol at the end of the short ride were not significantly different from one another, $F(2, 52) = .666$, $p = .518$. ANOVA summary table for Short Ride values can be found in Appendix F, Table F4.

Rating of Perceived Exertion. Means for RPE at the end of the short ride were not significantly different from one another, $F(2, 52) = .190$, $p = .828$. ANOVA summary table for Short Ride values can be found in Appendix F, Table F4.

Heart Rate. Means for heart rate at the end of the short ride were not significantly different from one another, $F(2, 52) = .613$, $p = .546$. ANOVA summary table for Short Ride values can be found in Appendix F, Table F4.

Respiratory Exchange Ratio. Means for RER at the end of the short ride were not significantly different from one another, $F(2, 52) = .462$, $p = .633$. ANOVA summary table for Short Ride values can be found in Appendix F, Table F4.

Figure 4.6. Respiratory exchange (RER) for the groups on the long-ride (Means, $\pm$ S.E., N=18).

* = $p < .05$ for rest compared to 15 minutes.

† = $p < .05$ as compared minute 15 to remaining time points.

‡ = $p < .05$ as compared minute 30 to minute 120.

Figure 4.7 Time to exhaustion on the short-ride (Means, $\pm$ S.E., N=18).

CHAPTER V DISCUSSION

For the purpose of this study it is important to remember that milk is a complex, mammalian-secreted combination of water, protein, carbohydrate (lactose), and vitamins and minerals (Hurley, 2001; National Dairy Council, 2000). The largest component of (cow's) milk is water, 87%, with many of the B vitamins also found in the aqueous phase of milk. The major carbohydrate in milk is the disaccharide lactose (4.8% cow's milk compared to 7% human milk) made from the monosaccharides D-glucose and D-galactose joined in a β -1,4-glycosidic linkage (4-O- β -D-galactopyranosyl-D-glucopyranose). Lactose is cleaved by the enzyme lactase in the small intestine to form glucose and galactose. Other nutrients found in low concentrations in cow milk include some free galactose, amino sugars, neutral and acid oligosaccharides, sugar phosphates, and nucleotide sugars. Milk fat, a complex mixture of lipids primarily composed of triglycerides, is composed of short-chain (7%), medium-chain (15 to 20%), and long-chain (73-78%) fatty acids. Of the nearly 400 different fatty acid derivatives found in milk most are saturated (65%) while the other fats are monounsaturated (32%) and polyunsaturated (3%). Milk fat also contains the fat-soluble vitamins A, D, E, and K (Hurly, 2000). With all these beneficial components, it would follow that milk, or a milk-derived supplement, should contribute to endurance exercise.

The purpose of this study, then, was to determine the effects of different pre-exercise meals on a long ride at approximately 55% of $\text{VO}_{2\text{max}}$ and, after a brief rest, on a short ride at approximately 80% of $\text{VO}_{2\text{max}}$. Eighteen male cyclists participated in the study. Three different conditions were examined where each of the 18 subjects acted as their own controls on three riding bouts and three pre-exercise meals via a 300 ml fluid drink: 200 Kcals of glucola, 200 Kcals of whole milk, and an artificially flavored placebo beverage. In this study, it was hypothesized that the benefits of the whole milk supplement would equal or surpass the effects of the isocaloric supplement of carbohydrate and the artificially flavored placebo on selected variables measured at discrete time points during the long ride, at the end of the short ride, and time to exhaustion on the short ride. All trials were performed in the same environment at approximately the same time of the morning to minimize the effects of circadian rhythms. Blood measurements were made at baseline prior to consumption of the test drink, after resting 30 minutes, every 30 minutes during the long ride, and at the end of the short ride. Cardiovascular measurements were taken at rest, at 15 minute intervals throughout the long ride, and continuously during the short ride.

Descriptive Subject Information

Physiological Profiles. The participants in this study self-described themselves as endurance trained, either at cycling or running and cycling. The degree to which the results of this study can be applied to other men should be based on similarities to the participants in this study. The men in this study were aged 26 ± 5.7 years and weighed 78.2 ± 8.7 kg.

Aerobic Fitness. Maximal oxygen consumption values of the participants in this study suggested that they were moderately trained cyclists (Flynn, et al., 1987; Hargreaves et al., 1984; Saris et al., 1993). However, their maximal oxygen consumption values were near those of

others participating in similar investigations (Foster et al., 1979; Rauch, Noakes, Hawley, Bosch, & Dennis, 1995). The mean oxygen consumption value of the participants in this study was $3.94 \text{ L}\cdot\text{min}^{-1} \pm 0.6$; $50.8 \pm 8 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ (2.95 to $5.18 \text{ L}\cdot\text{min}^{-1}$; $37.1 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ to $62.2 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$).

Diet. The dietary intake of the participants in this study was recorded for two days prior to each ride to assure that each subject's muscle glycogen stores were optimal for the long ride. Each subject was instructed to consume a diet high ($\geq 60\%$) in complex carbohydrates for the two days prior to each test and to keep a written record of what was consumed. Subjects were to avoid caffeine and tobacco for the two days prior to each ride as these substances are known to stimulate the release of free fatty acids into the blood. The mean caloric intake of the subjects in this study was $3,324 \text{ Kcal} \pm 211 \text{ Kcal}$. The subjects in this study reported 60.5% total carbohydrate intake ($2011.4 \text{ Kcal} \pm 103.5 \text{ Kcal}$).

Resting Values. There were no significant differences between the drinks on any of the baseline cardiorespiratory or blood values, indicating a homogenous testing environment from which to compare the test meals. Refer to Table F1, Appendix F for ANOVA F values.

Responses on the Long Ride

Carbohydrate as a Preexercise Meal. There is considerable evidence that supplements of basic foods prior to or during exercise can improve performance. In the case of carbohydrate, there is a general consensus that carbohydrate is beneficial to endurance performance (Coyle et al., 1986; Goodpaster, Costill, Fink, Trappe, Jozi, Starling, & Trappe, 1995; Kirwin, O'Gorman, & Evans, 1998; Sherman, Peden, & Wright, 1991; Thomas, Brotherhood, & Brand, 1991). However, there is also some evidence that carbohydrate supplements may not benefit endurance exercise performance (Cramp, Broad, Martin & Meyer, 2004; Febbraio & Stewart, 1996; Hargreaves et al., 1984; Kirwin, O'Gorman, Cyr-Campbell, Campbell, Yarasheski, & Evans, 2000; Leijssen et al., 1995).

Coyle et al. (1985) compared the effects of a 16 hour fast to a preexercise, high carbohydrate meal on endurance trained cyclists completing a 105 minute ride at $70\% \text{ VO}_{2\text{max}}$. The meal consisted of about 750 Kcal. (85% carbohydrate and 15% protein). Unlike the present study, the subjects consumed the preexercise meal 4 hours before the supplemented ride. Unlike the fasted trial by Coyle et al., but strikingly similar to the present study, blood glucose dropped significantly at the onset of exercise for the fed trial and remained below that of the fasted trial throughout the ride. Similar to the present study, free fatty acids and glycerol levels were high for the fasted trial (placebo in the present study) and low in the fed trial (glucola and milk meals in the present study). Respiratory exchange ratio responses were also similar. RER was higher over time in both studies following the carbohydrate supplement (and the milk in the present study, $p < .001$). Coyle et al. did not report lactate or heart rates.

Coyle et al. (1986) compared the effects of a carbohydrate solution administered during four hours of cycling at approximately $70\% \text{ VO}_{2\text{max}}$ to an artificially flavored placebo also consumed during another cycling bout on glucose, glycerol, free fatty acids, heart rate, lactate, muscle glycogen, RER, and time to exhaustion. Similar to the present study they found reductions in time with plasma glucose, particularly with the placebo. They also found increases

in glycerol and free fatty acids with the placebo but, similar to the present study, a blunting effect with the carbohydrate meal until after 2 hours of cycling when FFA began to rise. Their RER values remained stable over the first two hours but began to decline after 2 hours as well. Like the results of the present study, lactate and heart rate both rose at the end of exercise but lactate rose then fell until it rose again at exhaustion. On carbohydrate feedings the riders were able to go significantly longer (33%) than on the placebo feedings. In the present study the riders were able to ride 20% longer after consuming carbohydrate than they could after consuming the placebo and 18% longer than they could after consuming the milk drink, however, these results were not statistically significant ($p = .654$).

Thomas et al., (1991) studied the effects of glycemic index on meals eaten before prolonged, strenuous exercise. In four different trials performance variables were studied in eight trained cyclists consuming isocaloric amounts (1 g/kg bw) of a low glycemic food (lentils), a high glycemic food (a potato), glucose, and water. Similar to the present study, glucose fell precipitously at the outset of exercise, free fatty acid response was blunted with carbohydrate, lactate rose significantly with exercise then fell gradually, and endurance time was longer with carbohydrate supplementation. In their study, the low glycemic supplement provided a significantly greater effect on endurance ($p < .05$) than the other supplements.

Kirwan et al., (1998) studied the effects of preexercise carbohydrate supplementation in six recreationally active college-aged women. The women ate 75 g of carbohydrate meals (sweetened rolled oats - SRO, sweetened oat flour - SOF) in water versus water alone. Meals were consumed 45 minutes prior to a semi-recumbent ride to exhaustion at 60% of VO_{2peak} . Similar to the present study in which free fatty acids were highest for the placebo ($p < .007$), FFA were significantly lower for both carbohydrate supplements. Glycerol concentrations were suppressed during the carbohydrate meals but rose gradually throughout the test for each of the meals. Similar to the present study where there was no significant difference between the carbohydrate drinks but there was a significant drop in glucose over time for the carbohydrate supplement ($p < .001$). There was also a significant interaction of drink by time ($p < .001$) with glucose dropping most for the carbohydrate meals compared to the placebo. The SRO meal was the only meal associated with an increased time to exhaustion, however, the difference between the means was not significant. Interestingly, the SRO meal also had the highest fiber content, 6.8 g versus 1.6 g for the SOF. Although the kilocaloric contents of the meals in the present study and the study by Kirwan et al. were close 300 Kcal. versus 200 Kcal., in the present study neither the glucola meal nor the milk meal provided any fiber.

Goodpaster et al. (1996) compared various types of starch (waxy and resistant) to glucose and placebo supplements in ten college-aged male competitive cyclists. As in the present study, the glucose supplement resulted in a significantly greater blood glucose response prior to the ride (at rest), then fell and leveled out for the remainder of the ride. The glucose supplement, approximately 75 g, and the waxy starch provided a significantly greater ergogenic effect ($p < .05$) than the placebo.

Sherman et al. (1991) studied the effects of two carbohydrate meals (low, 1.1 g/kg bw and high, 2.2 g/kg bw). Similar to the present study the meals were consumed prior to exercise (one hour for their study, 30 minutes for the present study), there were three trials, and there were three supplements (high carbohydrate, low carbohydrate, and a placebo). The subjects rode

for 90 minutes and then performed a time trial (for distance). In both cases, carbohydrate supplements provided a significant benefit for the time trial performance. Similar to the present study, the free fatty acid response was significantly blunted for each carbohydrate supplement and high for the placebo. Lactate also rose with exercise and fell gradually over time. Unlike the present study in which there was a main effect for time on RER but a non-significant ($p = .054$) interaction with RER (lower for the placebo), there was a treatment effect in the study by Sherman et al. with RER significantly higher for the carbohydrate supplements than for the placebo.

One final study providing supporting evidence for the effect of carbohydrate supplementation prior to exercise will be presented in support of the results of present study. Wright et al, 1991 compared carbohydrate feedings before, during, and in combination against a placebo beverage in nine well-trained cyclists. Similar to the present study, the carbohydrate feeding prior to exercise improved performance by 18% in a ride to exhaustion at 70% maximal oxygen consumption. In their study, the time to exhaustion following the carbohydrate meal was significantly greater than that of the placebo beverage (236 min vs. 201 min) but the meal consisted of 333 ± 6 g carbohydrate, considerably more than the meal in the present study at 50 g carbohydrate.

There were several studies related to the present investigation that did not show significant improvements in performance with carbohydrate ingestion, particularly when time to exhaustion was the major outcome measure. Cramp et al., (2004) studied the effects of a low carbohydrate (1 g/kg bm) meal to a high carbohydrate meal (3 g/kg bm) consumed 3 hours prior to a mountain bike performance trial in eight trained mountain bike cyclists. Though the nature of mountain biking is different from that of endurance road-cycling, it is still an endurance sport in that there are many peak periods, some higher than others, interspersed by just as many coasting periods ~ similar to riding in a piloton on a road race. Similar to the present study, serum glucose was highest at 30 minutes and fell to a steady state for the remainder of the ride. Free fatty acids rose for the low carbohydrate trial but were not significantly different while they were blunted for the high carbohydrate trial, again, similar to the present study ($p < .007$). Performance was better on the high carbohydrate meal than on the low carbohydrate meal, however, similar to the present study on glucola versus milk or a placebo on overall performance, the differences at just 3% were not significant. The authors do make the point, though, that an advantage of 3% could make the difference between winning and losing in mountain bike racing.

Foster et al., (1979) found that carbohydrate feedings demonstrated impaired free fatty acid mobilization with carbohydrate (glucose) feedings in endurance cycling. The glucose response in this study was similar to that of Foster et al (1979) who found a non-significant effect of a preexercise carbohydrate meal on time to exhaustion when compared to an isocaloric meal of whole milk or a placebo beverage. The carbohydrate meal in Foster's study was 75 g glucose (glucola in 300 ml water). Similar to the study by Foster et al, in the present study blood glucose fell significantly with the onset of exercise to reach a steady state level until the end of the ride.

The significant spike in glucose prior to exercise and the concomitant fall in glucose with exercise in the present study, and in Foster's study, can be explained by the fact that insulin

released with the glucose drink stimulated muscle glucose uptake with the glucose being rapidly absorbed by the exercising muscles by minute 30. The sharp rise in blood lactate in the present study was similar to the lactate response in the study by Sherman et al. (1991) who studied carbohydrate feedings in nine male cyclists one hour before exercise. In their study, lactate rose 15 minutes after exercise began, in the present study the lactate response was 30 minutes later (Figure 4.4). It is reasonable that the fall and leveling off of blood glucose and fall and leveling off in lactate and RER represent a period of adjustment, from rest, as the riders' physiological responses adapted to the energy demands of a prolonged, submaximal ride by shifting from a primarily glycolytic response in the first minutes of the ride to a more oxidative state.

In the present study, at minute 60 the milk drink showed an increase in blood glucose level that remained steadily above that of the glucose drink for the remainder of the long ride. It may be that it took time for the lactose in the milk to be digested, absorbed, and the glucose and galactose to be converted to glucose in the liver before it could be transported through the blood to the muscle. Leijssen, Saris, Jeukendrup, and Wagenmakers (1995) compared the oxidation rates of isotopically labeled glucose and galactose and found the latter was oxidized at half the rate of the former during a 120 minute cycling trial by eight highly trained male cyclists at 65% maximal oxygen consumption. Leijssen et al. also reported that galactose caused a small but significant increase in the rate of endogenous glucose oxidation starting 45 to 60 minutes after the start of exercise, which, if glycogen is being oxidized for exercise, could theoretically spare blood glucose. However, the authors suggested that this higher rate of glucose oxidation could have a paradoxical effect of increasing the rate of muscle glycogen oxidation, ultimately inducing fatigue, and limiting time to exhaustion. This could explain the results in time to exhaustion in the present study and that of Foster et al. (1979).

Febbraio and Stewart (1987) compared the effects of a low glycemic meal (lentils) to a high glycemic meal (mashed potato) and a placebo (diet jelly) consumed 45 minutes prior to cycling for 120 minutes at 70% $\text{VO}_{2\text{peak}}$ followed by a 15 minute peak performance ride in six endurance-trained men. Each carbohydrate test meal consisted of 1 g/kg bw carbohydrate. Dietary fiber was not considered. Similar to all of the studies reported so far as well as the present study, heart rate was not different between the treatments, glucose was significantly higher at rest with the meals but fell precipitously with the onset of exercise and leveled off, lactate rose immediately with the outset of exercise then fell and leveled off but were not different between the treatments, and free fatty acids were suppressed significantly with both carbohydrate meals. Most importantly, there was no difference on peak work rate between the meals on the 15 minute post-120 minute peak work period.

Hargreaves et al., (1987) investigated muscle glycogen utilization in six male subjects following preexercise meals of glucose (75 g) to fructose (75 g) and a flavored placebo, all in 350 ml of water, on a cycle ride to exhaustion at 75% $\text{VO}_{2\text{max}}$. No difference was found between the meals suggesting no advantage to consuming one form of monosaccharide over the other, comparing favorably with the study by Leijssen et al., (1995) who studied the uptake of the third monosaccharide, galactose, versus glucose during endurance exercise.

In a follow-up study on moderate glycemic response to endurance exercise in the same type of subjects, Kirwin et al., (2000) found that regular whole grain rolled oats consisting of 75 g carbohydrate, 15.8 g protein, 7.9 g fat, and 15.7 g fiber (dietary fiber 11.8 g, soluble fiber 3.9

g) did not exert a significant ergogenic effect on time to exhaustion at 60 % $\text{VO}_{2\text{peak}}$ compared to a placebo. In this study they used an isotopically labeled tracer, $[6,6-^2\text{H}]$ glucose. Similar to the present study, free fatty acids and glycerol were suppressed with the rolled oats during the ride and, at exhaustion, there was no difference between trials on glucose, free fatty acids, glycerol, RER, and other metabolites specific to their study (muscle glycogen, norepinephrine, and epinephrine).

Lactate is a by-product of the hydrolysis of glucose. The lactate response in this ride was similar to the response seen by others (Foster et al., 1979; Leijssen et al., 1995; Miller et al., 2002). Initially, lactate rose as carbohydrate was oxidized, then fell and leveled off till the end of exercise. The reason lactate fell was that glucose was not available from the diet and either muscle glycogen was meeting the demand of exercise or the demands of exercise were being met by free fatty acids from the diet or from lipolysis of adipose or intramuscular triglycerides.

Carbohydrate Coingested with Fat as a Preexercise Meal. The combination of carbohydrate and fat has received attention because of the obvious caloric density of fat and the possibility that, if ingested with carbohydrate, this may delay the metabolism of endogenous carbohydrate during endurance exercise (Foster et al., 1979; Jeukendrup et al., 1995; Massicotte et al., 1992; Miller et al., 2002; Van Zyl et al., 1996). The results have been equivocal.

Foster et al., (1979) compared the effects of a glucose meal (75 g) to an isocaloric carbohydrate and fat meal (whole milk) and a placebo to a high intensity ride (80% $\text{VO}_{2\text{max}}$) and a ride to exhaustion with 16 subjects (8 males, 8 females). While there were no significant differences on time to exhaustion between the drinks, glycerol and free fatty acid responses were depressed with the glucose and milk drinks.

Unlike Foster et al.'s study, glycerol in the present study spiked early at minute 30 for the glucose drink, fell to the levels of milk and the placebo at the next test point (60 minutes), and then, like Foster et al.'s study, glycerol values for all three supplements rose significantly until the end of the long ride. The differences in glycerol values in the present study were not significantly different. The early spike in glycerol for the glucose drink can be explained by the rapid drop in available energy supporting the outset of exercise (only 200 Kcal) in these moderately trained cyclists. With the depletion of glucose there would be a concomitant decrease in insulin and, with exercise demand, an increase in lipolysis (of triglyceride) to sustain exercise (Coyle et al., 1997). The reason that glycerol fell at minute 60 would be that there was either enough free fatty acid available to sustain exercise or the more slowly metabolized galactose from the milk was used to sustain exercise.

In the present study, free fatty acids remained level during the first 30 minutes then steadily rose throughout the long ride. In response to the lack of nutrients in the placebo drink, free fatty acids were significantly higher than for the carbohydrate drink and the milk drink. Foster et al. (1979) saw a similar response but free fatty acids first fell, then rose in their study. Similar to the present study, they were lowest for the milk and carbohydrate trial. Miller et al. (2002) showed the same results in runners fed similar exercise meals (170 Kcal). In their study, milk and carbohydrate meals resulted in significantly blunted free fatty acid responses compared to the placebo, even though the milk in their study was fat free. Miller et al. attributed the blunted response of free fatty acids with milk and carbohydrate feedings, compared to the placebo, to the availability of the nutrients in those drinks as opposed to the placebo with no

nutrients. Triglyceride derived free fatty acids are cleaved from their glycerol backbone to serve as an energy supply during prolonged exercise when there is little glucose available for exercising muscles.

Jeukendrup et al., (1995) examined the effect of medium-chain triglycerides (MCT) coingested with carbohydrate during endurance exercise in 8 well-trained athletes cycling at 50% of maximal oxygen consumption. They used an isotopically labeled tracer [1,1,1-¹³C] trioctanoate in the MCT oil. They confirmed the hypothesis that triglycerides, particularly medium chain triglycerides are oxidized during exercise when coingested with carbohydrate. In addition to short chain (7%) and long chain (73 – 78%) fatty acids, milk lipid is composed of 15 to 20% medium chain triglyceride (Hurley, 2000). However, like the study by Massicotte et al., (1992) who found no effect of isotopically labeled MCT on the oxidation of endogenous carbohydrate using 119 Kcal of MCT versus 140 Kcal of glucose in endurance cycling exercise, the supplements in the present study were too low in total kilocalories to significantly affect performance.

Van Zyl et al., (1996) found that a MCT / carbohydrate mixture improved time performance, however, in their study the supplements were administered at a rate of 100 ml every ten minutes following an 85 g carbohydrate breakfast. This is quite unlike the present study where subjects arrived following an overnight fast and consumed only 50 g carbohydrate prior to the ride. In both studies the subjects cycled for 2-hours at approximately the same percent VO_{2max} (60% and 55% respectively). In the present study it was theorized that the MCT / carbohydrate combination in milk would contribute to performance. In the present study, the free fatty acid response was significantly different between the whole milk and placebo supplements ($p < .030$), but was not significant between glucola and the placebo ($p = .065$). Free fatty acids were depressed during the milk and glucola trials.

Other Variables of Interest.

Heart Rate. Heart rate response was investigated in this study because it was believed to be a more objective measure of effort over the trials. Heart rate during submaximal work is fairly linear with oxygen consumption and, as such, provides another objective insight into the degree of labor required by the three drinks over the 2 hours of exercise. Heart rate rose steadily with the milk meal while it fell with the carbohydrate meal. This could be a result of the thermic effect of the protein in the milk however, this would be minimal because of the low protein content, about 10.6 g protein of the meal. Even though the riders in this study had free access to (bottled) water before and throughout the duration of each long ride, the volume of fluid consumed was not measured and very probably unequal between trials. Nevertheless, thirst is not an accurate indicator of fluid needed to replace water lost during prolonged work or exercise (Coyle, 2004). In this study, plasma volume and hematocrit were not measured, so there is no way to tell whether dehydration played a major role in the response of heart rate to prolonged exercise though it is a likely reason. Nevertheless, after 90 minutes heart rate rose for each of the meals until the end of exercise. Analysis was made from rest, immediately preceding exercise, through the last minute of the long ride.

Respiratory exchange ratio. RER represents the cellular metabolism of nutrients where fuel, oxygen, and temperature turn out ATP to drive exercise. In this study, as in the study by Miller et al. (2002), the carbohydrate and milk meals blunted the downward trend of RER. Milk and glucola both contain sugars, lactose and glucose respectively, which would raise (or maintain) RER for a given workload while the placebo, devoid of sugar, would stimulate lipolysis and lower RER. The galactose and glucose from milk may have caused RER to rise during the middle of the long ride compared to the other two drinks because it takes more time for the lactose to be digested to galactose and converted to glucose in the liver and then to be transported to the muscles (Leijssen et al. 1995). Toward the end of exercise, the glucose from the glucola drink appears to have been totally oxidized. Analysis was made from rest, immediately preceding exercise, through the last minute of the long ride.

Time to exhaustion. Even though the differences were not significant, $F(2, 52) = .428$, $p = .654$, the subjects in the glucose drink trial averaged approximately 18% longer at 80% VO_{2max} than the milk drink trial and nearly 20% longer than the placebo drink trial. The findings of the present study on time to exhaustion are contrary to the findings of Foster et al. (1979) who found that time to exhaustion was less for the glucose meal than for either the placebo or the milk (mixed) meal. However, the findings of the present study are similar for the milk trial in the study by Foster et al in that milk did not exert a significant influence on time to exhaustion. Mean glucose values at the end of the 80% ride were 75.2 mg/dl, 81.5 mg/dl, and 74.6 mg/dl for glucose, milk, and the placebo respectively and these values are within normal reference interval for blood glucose.

Cardiorespiratory and Blood Responses to High Intensity Exercise

There were no significant differences found on any of the cardiorespiratory or blood variables on the short, high intensity ride at 80% maximal oxygen consumption. This may be due to the low energy content of the test drinks (200Kcal). Although time to exhaustion for the glucose drink was about 20% longer than for the placebo drink and 18% longer than for the whole milk drink, time to exhaustion for the test drinks was not significantly different in this study. ANOVA summary tables for the short ride can be found in Appendix F, Table F2.

Hypotheses Tested. The following hypotheses were tested

Hypothesis 1: Glucose concentration will be significantly greater for the glucose polymer and for the whole milk supplement compared to the placebo treatment throughout the duration of the long cycling bout.

In this study, the means of the test drinks were not significantly different (glucose = $80.5 \text{ mg/dl} \pm 1.9$, milk = $79.3 \text{ mg/dl} \pm 5.1$, placebo = $75.2 \text{ mg/dl} \pm 2.4$), however, there was an effect for time, $F(4, 64) = 32.071$, $p < .001$, and a statistically significant interaction for drink and time on glucose, $F(8, 128) = 12.898$, $p < .001$.

Hypothesis 2: Glycerol concentration will be significantly greater for the whole milk supplement compared to either the glucose polymer or the placebo throughout the duration of the long cycling bout.

In this study the means of the tests drinks for glycerol concentration were not significantly different over the long ride (glucose = $0.170 \text{ mmol/L} \pm 0.026$, milk = $0.139 \text{ mmol/L} \pm .008$, placebo = $0.157 \text{ mmol/L} \pm 0.012$), however there was a statistically significant effect for time on glycerol, $F(4, 64) = 9.574$, $p < .001$.

Hypothesis 3: Free fatty acids will be significantly greater for the whole milk supplement compared to either the glucose polymer supplement or the placebo throughout the duration of the long cycling bout.

In this study the means of drinks for free fatty acids were significantly different from one another, $F(2, 32) = 5.916$, $p < .007$. However, the difference was greater for the placebo ($0.689 \text{ mmol/L} \pm 0.064$) than for the other two drinks ($0.506 \text{ mmol/L} \pm 0.052$ and $0.505 \text{ mmol/L} \pm 0.043$, glucose and milk respectively). There was a statistically significant effect for time and free fatty acids, $F(4, 64) = 43.146$, $p < .001$. There was no significant interaction between drink and time for free fatty acids.

Hypothesis 4: Plasma lactate will be significantly greater for either the glucose polymer supplement or the placebo supplement compared to the milk group throughout the duration of the long cycling bout.

In this study the means of the test drinks for lactate were not significantly different on the long ride (glucola = $2.68 \text{ mmol/L} \pm 0.127$, milk = $2.601 \text{ mmol/L} \pm 0.139$, placebo = $2.636 \text{ mmol/L} \pm 0.1$), however, there was an effect for time and lactate, $F(4, 64) = 10.646$, $p < .001$. There was no significant interaction between drink and time for lactate for the duration of the long ride.

Hypothesis 5: Respiratory exchange ratio (RER) will be significantly greater for either the glucose polymer supplement or the placebo supplement compared to the whole milk supplement for the duration of the cycling bout.

In this study the means of the test drinks for RER were not significantly different on the long ride (glucola = 0.95 , milk = 0.95 , placebo = 0.94). There was a statistically significant effect for time on RER, $F(8, 128) = 8.267$, $p < .001$. There was no statistically significant interaction between drink and time for RER for the duration of the long ride.

Hypothesis 6: Ratings of perceived exertion (RPE) will be significantly greater for either the placebo supplement or the glucose polymer supplement compared to the whole milk supplement for the duration of the short cycling bout.

In this study there was no significant difference between the drinks on RER for the short cycling bout, $F(2, 52) = .190$, $p = .828$.

Hypothesis 7: Time to exhaustion will be significantly greater for the milk supplement compared to either the glucose polymer supplement or the placebo supplement on the short cycling bout.

In this study there were no significant differences between the drinks on time to exhaustion on the short cycling bout, $F(2, 52) = .428$, $p = .654$.

Conclusions

This study replicated, in part, the landmark study by Foster, Costill, and Fink (1979) comparing isocaloric pre-exercise meals of liquid carbohydrate and whole milk to a placebo on

three long rides and three short rides. However, there were several major differences between that earlier study and the present study. First, though the earlier study used the same drinks as the present study, they used 300 Kcal in each of the two energy drinks instead of 200 Kcal in the present study. This could represent a significant difference in the metabolic responses and the conclusions that can be drawn from the present study in that the kilocaloric content in the present study was just too low. Second, the subjects in the earlier study were tested a total of six times with long, low intensity rides and short, high intensity rides separated by about a week. In the present study, subjects were tested only three times and performed both long, low intensity rides and short, high intensity rides on the same test day, back-to-back, with rides separated by only 30 minutes of rest. Thirdly, there was a notable difference between the short, high intensity rides between these studies. In Foster et al.'s study the short ride was set at a workload requiring 100% of VO_{2max} and only intended to last about 5 minutes. As opposed to the present study at 80% of VO_{2max} and following 2 hours of a low intensity ride at 55% of VO_{2max} , it would have been very difficult, if not impossible, for the subjects in Foster et al.'s study to have performed well after consuming a meal. Finally, the subjects in the earlier study pedaled the entire time at 80% and 100% of their maximal oxygen consumption while the subjects in the present study pedaled at rates corresponding to 55% and 80% of VO_{2max} for long and short rides respectively. Thus, a combination of issues including a lower energy test drink in terms of Kcal, different ride times, and different energy intensities may have negatively impacted the ability to draw comparisons between these two studies.

However, several strengths of the present study may make it significant in its own right. The subject population was more homogenous than the earlier study. The subjects in the earlier study by Foster et al. (1979) included 8 men and 8 women. The subjects in the present study were 18 men, making the population more homogenous and therefore, making it easier to draw conclusions about the effects of the same drinks on male cyclists with similar characteristics. In the earlier study, Sheffé post hoc analysis was performed while in the present study Bonferroni post hoc analyses were made. Bonferroni post hoc analyses may be a more conservative technique for reducing the chance of making a type I error. An additional strength of the present study could be that the effects of the drinks, though of lower kilocaloric content, were not contaminated by or washed out by time as in the earlier study where the subjects left after a long ride and returned another day for the short ride.

The conclusion to be drawn from the present study is that a mixed carbohydrate, fat, and protein meal, i.e., cow's milk, even though it contains all of the major energy producing nutrients, does not exert a greater influence over cardiorespiratory variables or substrate concentrations during exercise than does either glucose or a placebo. Since there were no lasting significant differences between the glucose drink used in this study and whole milk, some people may benefit from cow's milk consumption prior to moderate intensity exercise.

Recommendations for Future Research

One area of future research would be a closer examination of the effects of milk consumption on maintaining blood glucose values overnight during a relative fasting period, as in a last meal prior to an overnight fast that is followed by supplementation and work / exercise.

Since the galactose in milk is only slowly converted to glucose by the liver, it may be that milk consumption the night before exhaustive exercise may confer some benefit by maintaining blood glucose during the fasting period between dinner and breakfast.

APPENDIX A
HUMAN SUBJECTS APPROVAL

Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2742
(850) 644-8633 FAX (850) 644-4392

REAPPROVAL MEMORANDUM

Date: 9/28/2007

To:
Green Waggener III
Valdosta State University
Dept. of Kinesiology and Physical Education
Attn.: Green T Waggener III
1500 North Paterson St.
Valdosta GA 31698-0095

Dept.: NFMS

From: Thomas L. Jacobson, Chair

A handwritten signature in dark ink, appearing to read "Thomas Jacobson".

Re: **Reapproval of Use of Human subjects in Research:**
The Effects of Three Pre-exercise Meals on Long and Short-term Sub-maximal Cycling
Endurance Exercise

Your request to continue the research project listed above involving human subjects has been approved by the Human Subjects Committee. If your project has not been completed by 9/11/2008 please request renewed approval.

You are reminded that a change in protocol in this project must be approved by resubmission of the project to the Committee for approval. Also, the principal investigator must report to the Chair promptly, and in writing, any unanticipated problems involving risks to subjects or others.

By copy of this memorandum, the Chairman of your department and/or your major professor are reminded of their responsibility for being informed concerning research projects involving human subjects in their department. They are advised to review the protocols of such investigations as often as necessary to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

Cc: Emily Haymes
HSC No. 2007.701-R

Human Subjects Committee

Informed Consent Form

I HAVE BEEN INFORMED THAT:

1. **Green T. Waggener, a graduate student in the Department of Nutrition, Food, and Exercise Sciences, has requested my participation in a research study [The Effects of Three Pre-Exercise Meals on Long and Short-term Sub-maximal Cycling Endurance Exercise] at Florida State University.**
2. **The purpose of this research is to ascertain the effects of three different (liquid) meals on long and short-term sub-maximal cycling exercise.** In an early study, other researchers (Foster, Costill, and Fink, 1979) studied the same meals in 16 male and female subjects but their cycling routine was different, it was high intensity exercise and their results were somewhat ambiguous regarding two of the meals. It is believed the results may be different with lower intensity exercise. Twenty subjects will be recruited for this study and you have been recruited because, like the subjects in the earlier study, you are familiar with endurance cycling and considered to be highly trained. You must be at least 18 and not older than 35 years of age.
3. **My participation will involve** four separate cycling bouts. The first bout of exercise will be to determine my maximal oxygen consumption on a cycle ergometer. For the subsequent exercise bouts, I will cycle on a cycle ergometer and expired gas will be collected periodically throughout the test from a mouth piece and nose clip. During these brief periods (about 5 minutes for each 15 minutes) I will be breathing room air through my mouth only while my expired air will be collected and analyzed by a computerized gas analysis system, otherwise I will be breathing normally during your ride. The second, third, and fourth bouts of exercise will be performed at least a week apart and I am expected to continue my recreational / training cycling exercise. I will be urged to consume adequate carbohydrate (60% of the daily diet) at least two days prior to each test and a two-day food log will be kept and turned in to the Primary Investigator on the day of each test. After an overnight fast (consuming nothing but water after mid-night and no caffeine for 48 hours) I will report to the FSU Exercise Physiology Laboratory where a nurse or other clinically trained professional will fit me with a catheter in my arm and a blood sample drawn. I will then receive a liquid meal in an opaque container that has been numbered but, for purposes of equal treatment during the tests, blinded to both me and the Primary Investigator. After consuming the meal and immediately before the first cycling bout, a sample of my blood will be taken. I will cycle for 120 minutes at about 55% of my maximal ability (55% of maximal oxygen consumption) and blood samples will be drawn from me every 30 minutes (4 times). My heart rate will be monitored throughout the test by a Polar Heart Rate Monitor. After the long ride (120 minutes) I will rest for 30 minutes after which another blood sample will be taken, then ride again for time to exhaustion at 80% of my maximal oxygen consumption. I will be urged to ride as long as I can but I can quit at any time, however, there are discrete, clinical indications that I am nearing exhaustion and the test may be stopped before I am ready. A final blood sample will be taken at the conclusion of this ride.
4. **There are foreseeable risks or discomforts to me if I agree to participate in the study. The possible risks are** minimal (ACSM, 2000) but real. There is a slight risk of death during an exercise stress test (1 / 10,000 or 0.01%), however, every effort will be taken to maintain the highest degree of safety throughout the test including knowing when to not test, when to terminate the test and preparation for any emergencies that might arise. During the initial test for maximal oxygen consumption there is the possibility that I could become dizzy or nauseous from the effort. The use of an indwelling catheter to obtain blood samples will probably be uncomfortable at first but that discomfort usually quickly subsides as there is usually no pain after the initial application of the device. There is a risk of bruising at the site of the catheter (placed in a vein on the outer surface of either the arm or hand), however, I may receive a pack of ice in a plastic baggie to reduce any swelling after the test. A clinically trained and licensed professional will be present to set up, draw blood, and remove the catheter.
5. **Although there may be no direct benefits to me, the possible benefits of my participation in the research is** a clearer understanding of the dynamics of food energy usage during long and short term sub-maximal cycling exercise in men and women at least 18 years of age through 35 years of age.
6. **I understand that my participation is voluntary and that I may stop at any time. The results of this research study may be published, however, the I have been told that the researcher will do the following to maintain the confidentiality of my records:**
 1. Access to data forms will be limited (to the extent allowed by law) to the primary investigator and the thesis committee only during data analysis.
 2. A code will be used for identifying subjects with trials and will be kept in a locked filing cabinet separate from the data forms.
 3. The list linking names with the code will be destroyed by an automatic shredder after all data are collected.
 4. All data forms will be kept in a locked, secure filing cabinet in the office of the

The Effects of Three Pre-exercise Meals on Long and Short-term Sub-maximal Cycling Endurance Exercise

primary investigator at Valdosta State University.

5. All data will be analyzed and reported only in aggregate form.

6. All data files will be destroyed by automatic shredding by 2010.

7. In case of injury I expect to receive the following treatment or care which will be provided at my expense: treatment for any bruising at the catheter site at the VSU Human Performance Laboratory as well as first aid emergency assistance from the VSU Paramedics (911).

8. I will be paid for my participation as follows: after the initial test for maximal oxygen consumption for which I will not be paid, \$33 will be paid at the end of each of the next two bouts and \$34 at the end of the last bout (2 @ \$33, one @ \$34 = \$100).

I understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of benefits to which I may otherwise be entitled. In signing this consent form, I am not waiving any legal claims, rights or remedies.

9. Any questions I have concerning the research study of my participation in it, before or after my consent, will be answered by Green T. Waggener, Valdosta State University, 1500 N. Patterson St. Valdosta, GA 31698, (229) 249-4921, gtwaggen@valdosta.edu or Dr. Emily Haymes, Department of Nutrition, Food, and Exercise Sciences at Florida State University, (850) 644-4793, ehaymes@mailier.fsu.edu.

10. If I have questions about my rights as a subject/participant in this research, or if I feel that I have been placed at risk, I can contact the Chair of the Human Subjects Committee, Institutional Review Board, through the Office of the Vice President for Research, at (850) 644-8633.

11. The nature, demands, benefits and any risk of the project have been explained to me. I knowingly assume any risks involved.

I have read the above informed consent form. I understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of benefits to which I may otherwise be entitled. In signing this consent form, I am not waiving any legal claims, rights or remedies. A copy of this consent form will be given (offered) to me.

Subject's Signature

(Date)

Institutional Review for Human Subjects Research
Office of Grants and Contracts, Valdosta State University
Research Qualifying for Exemption from Federal Regulations
for the Protection of Human Subjects
 (Based on the Code of Federal Regulations, Title 45, Part 46.101.
 and the Valdosta State University Policy on Human Subjects)

University procedures provide for review of research involving human subjects that may be exempt under federal, state, and university regulations. The exempt categories and exceptions are described on the reverse of this form. Exempt research may be approved by the IRB Administrator provided it is in accord with the Code of Federal Regulations and the general principles stated in the VSU Policy on Human Subjects. This form, properly endorsed, certifies that the research described here qualifies for exemption.

Principal Investigator Green T. Waggener Academic Title Faculty
 Department/College Kinesiology and Physical Education / Education Telephone (229) 249-4921
 Project Title The Effects of Three Pre-Exercise Meals on Long and Short-Term Sub-Maximal Cycling Endurance Exercise
 E-mail gtwaggen@valdosta.edu
 Starting Date 02/23/04 Anticipated Termination Date 02/22/05
 If PI is a student, provide Faculty sponsor/mentor's name N/A
 Grant (if sponsored) Title (if applicable) N/A
 Funding Agency and application due date (if applicable) N/A

I. The category under which this research qualifies for exemption (categories are described on page 2) is circled:

1 (2) 3 4 5 6

II. ABSTRACT: Brief description of a) purpose of the research, b) what subjects will do (if applicable), c) the nature of the data to be obtained, and d) how anonymity or confidentiality will be maintained. Additional sheet may be attached.

Note: This section is obtained directly from the Application for Review completed by the PI

Valdosta State University (VSU) accepts the
 Florida State University (FSU) IRB Evaluation and Decision on
 the Above Project

Modification (02/23/04)

This file has been updated to indicate the changed participant pool. At this time your research will include 20 males, no females.
 No other changes are indicated at this time.

Summary

To ascertain the effects of three different (liquid) meals on long and short-term sub-maximal cycling exercise. In an early study, other researchers (Foster, Costill, and Fink, 1979) studied the same meals in 16 male and female subjects but their cycling routine was different, it was high intensity exercise and their results were somewhat ambiguous regarding two of the meals. It is believed the results will be different with lower intensity exercise. Twenty (20) subjects will be recruited for this study that are familiar with endurance cycling and considered to be highly trained.

III. Human Subjects (to be considered 'exempt' all of these responses must be answered "NO"):

	YES	NO
Are any subjects presumed to be not legally competent?	☐	☒
Are any subjects under 18 years of age?	☐	☒
Are any subjects confined in a correctional or detention facility?	☐	☒
Is pregnancy a prerequisite for serving as a subject?	☐	☒
Are fetuses <i>in utero</i> subjects in this research?	☐	☒
Are personal records (medical, academic, etc.) used without written consent?	☐	☒
Are data from subjects (responses, information, specimens) directly or indirectly identifiable?	☐	☒
Are data damaging to subjects' financial standing, employability or reputation?	☐	☒
Is material obtained at autopsy used in the research?	☐	☒

IV. The information provided above is based on the material provided in the Application for Review of Research presented to the Institutional Review Board of Valdosta State University dated (month, day and year) 02/23/04. Based on this application, this research is certified as exempt from federal regulations and is in accord with the general principles stated in the VSU Policy for the Protection of Human Subjects. Signed and sealed Greg A. Heath

V. IRB Signature _____ Date 02/24/04

cc: Faculty Advisor

Grants and Contracts

Address 1500 N. Patterson St. • Valdosta, Ga. 31698-0429
Phone 229-259-5045 • Fax 229-245-3853

Valdosta State
University®

September 20, 2007

Mr. Thomas Jacobson, Chair
Florida State University
Human Subjects Committee
Tallahassee, FL 32306-2742

Campus Mail Code: 2742

Re: FSU Protocol #2004.731-R

*The Effects of Three Pre-exercise Meals on Long and
Short-term Sub-maximal Cycling Endurance Exercise*
Green T. Waggener, III, Principal Investigator

Dear Mr. Jacobson:

It is my understanding that the above referenced protocol received continuation approval by the FSU Human Subjects Committee on September 12, 2007, pending confirmation of continuing approval of the protocol by Valdosta State University's Institutional Review Board.

Although VSU has accepted FSU's jurisdiction and HSC approval of this protocol, it appears that our IRB was using the exemption process to give VSU's concurrence to conduct of the research on our campus. Since approval of another IRB is not a federally identified criterion for exemption, we are discontinuing this practice. However, we will continue to accept FSU's review and approval of the research, and we will continue to give Dr. Waggener permission to conduct the study on the VSU campus.

If you have any questions about VSU's support of Dr. Waggener's research, please call our IRB Administrator, Barbara Gray, at 229-333-7837 or email her at bhgray@valdosta.edu.

Sincerely,

Hill L. Harper, Ph.D.
Chair
Institutional Review Board

cc: Emily M. Haymes, Ph.D., Chair, Department of NFES, FSU
Green T. Waggener, Ph.D., Department of Kinesiology and Physical Education, VSU
Barbara H. Gray, Office of Grants & Contracts, VSU

APPENDIX B
MEDICAL HISTORY FORM

Office of Research
Human Subjects Committee

Health History – Short Form

Please indicate whether any of the following apply to you. If so, please place a check in the blank beside the appropriate item. Thank you.

_____. Hypertension or high blood pressure.

_____. A personal OR family history of heart problems or heart disease

_____. Diabetes.

_____. Orthopedic problems.

_____. Cigarette smoking or other regular use of tobacco products.

_____. Asthma or other chronic respiratory problems.

_____. Recent illness, fever, or Gastrointestinal Disturbances (diarrhea, nausea, vomiting).

..... Any other medical or health related problems not listed above (Provide details below.)

List any prescription medications, vitamin/nutritional supplements or over-the-counter medications you routinely take or have taken in the last five days (including dietary / nutritional supplements, herbal remedies, cold or allergy medications, antibiotics, migraine/headache medicines, aspirin, ibuprofen, birth control pills, etc.).

I certify that my responses to the foregoing questionnaire are true, accurate, and complete.

Signature: _____ . Date: _____.

APPENDIX C
RECRUITMENT POSTER
INFORMATION LETTER FOR SUBJECTS

Distance Bikers!

Volunteers (♂18 ~ 35 yoa) Needed
for *VSU & FSU Study On*
Endurance-Meals

Up to \$100 CASH Paid!

Contact Dr. Green T. Waggener
Dept of Kinesiology & Physical Education
gtwaggen@valdosta.edu (229-249-4921)

For meeting time/place/details
@ VSU P.E. Complex

Subjects needed for VSU/FSU cycling-endurance study.

This study is totally voluntary for male subjects between 18 and 35 years of age with endurance-cycling experience!

1. This VSU/FSU study is on the effects of several simple dietary components (fat versus carbohydrate) and a placebo on an endurance-cycling bout.
2. Subjects should not have any dietary allergies (fruit, vegetable, or animal) that they are aware of. If they do, they should notify the investigator prior to the first test.
3. There will be FOUR tests (on four separate dates): the FIRST is a maximal O_2 consumption test for the purposes of determining resistance settings for the SECOND, THIRD, and FOURTH trials which are performed with a different dietary supplement each time. Each test is for 2 hours at about 55% VO_{2max} , followed by a 30 minute rest, and finally a brief high intensity (80% VO_{2max}) ride to exhaustion.
4. Total payment is \$100 (if you finish all four tests). While subjects may withdraw from the test/study at any time, however, they are only paid after the SECOND, THIRD, and FOURTH tests at \$33, \$33, and \$34 respectively.
5. Expired respiratory gas samples, Rating of Perceived Exertion, and heart rate will be measured throughout each test.
6. During the test bouts, in addition to the above respiratory and heart rate values, blood samples will be taken periodically and components (glucose, free fatty acids, glycerol, and lactate) will be measured. A certified nurse (infusion specialist), State of Georgia, will perform this. Samples will be refrigerated and analyzed at a later date.
7. Except for the initial max-test, subjects will be able to drink water throughout each test and will NOT have to wear the nose-clip the entire time, only periodically for gas sample measurement. Subjects may also use their own pedals on the cycle ergometer (Monark).
8. Specific precautions for subjects:
 - $\geq 60\%$ CHO for two days preceding 2nd, 3rd, and 4th tests; to ensure adequate muscle fuel during the placebo trial.
 - Abstention from caffeine / tobacco for two days preceding test; both stimulate fatty acid release.
 - Delivery by car, do not ride bike to test site; this alters hemodynamics such as plasma concentration.
 - With the possible exception of the VO_{2max} tests, all tests/trials will be done as early as possible in the day at VSU in the Human Performance Lab, Rm 142.

For further information, contact Dr. Green T. Waggener at Valdosta State University: gtwaggen@valdosta.edu, or by phone 229-249-4921.

APPENDIX D
CONTENT OF WHOLE MILK

Publix

whole

GRADE A MILK

Nutrition FactsServing Size 1 cup (240mL)
Servings Per Container about 8

Amount Per Serving

Calories 150 **Calories from Fat 70**

% Daily Value*

Total Fat 8g **12%****Saturated Fat 5g** **25%****Cholesterol 35mg** **11%****Sodium 120mg** **5%****Total Carbohydrate 12g** **4%****Dietary Fiber 0g** **0%****Sugars 12g****Protein 8g**

Vitamin A 6% • Vitamin C 4%

Calcium 30% • Iron 0%

Vitamin D 25% • Phosphorus 25%

* Percent Daily Values are based on a 2,000 calorie diet.

INGREDIENTS: GRADE A MILK, VITAMIN D3.

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APPENDIX E

RAW DATA

Table E1a. Glucose polymer drink, blood glucose concentration (mg/dl).

Subject	GGLUB	GGLUR	GGLU30	GGLU60	GGLU90	GGLU120	GGLUmx
1	77.80	143.80	122.70	67.50	60.90	62.20	56.70
2	76.70	145.00	56.30	65.20	67.20	71.90	88.70
3	87.70	84.20	53.40	77.30	81.00	73.00	69.90
4	88.80	115.00	70.30	75.30	84.10	83.20	84.00
5	83.90	140.10	53.70	51.00	49.50	49.40	57.10
6	78.70	113.90	74.00	74.20	81.00	75.40	82.90
7	86.60	103.30	77.50	78.70	71.70	72.10	66.50
8	70.70	84.00	69.30	65.70	69.00	66.30	73.10
9							
10	77.80	112.40	59.10	80.10	81.80	65.30	90.50
11	83.20	94.20	74.90	74.90	72.40	72.70	70.00
12	75.00	119.70	65.60	73.30	69.60	59.20	64.80
13	82.70	148.00	84.30	81.20	84.00	80.70	90.80
14	80.90	152.50	76.70	82.40	84.20	71.80	78.40
15	87.80	116.10	89.30	62.30	64.70	62.90	64.60
16	86.30	100.70	85.40	73.00	76.90	80.70	79.90
17	73.60	89.40	59.50	75.10	73.90	70.20	102.40
18	98.50	97.00	85.50	63.80	58.90	59.00	58.20
Mean	82.16	115.25	73.97	71.82	72.40	69.18	75.21
St.Dev.	6.86	23.11	17.11	8.20	10.05	8.87	13.42

Table E1b. Whole milk drink, blood glucose concentration (mg/dl).

Subject	MGLUB	MGLUR	MGLU30	MGLU60	MGLU90	MGLU120	MGLUmx
1	83.60	80.20	56.00	78.20	77.10	77.70	74.30
2	86.10	106.60	58.80	69.60	63.50	69.20	89.10
3	87.70	80.20	73.20	78.60	83.50	76.20	70.50
4	89.80	104.50	84.60	86.40	88.80	84.60	94.90
5	78.00	45.20	55.90	60.70	58.40	34.40	53.90
6	88.00	139.00	137.00	168.00	154.50	152.40	161.40
7	78.90	69.50	90.20	74.50	75.70	81.50	68.90
8	74.80	78.50	68.80	68.90	63.90	59.10	79.80
9	89.10	80.30	75.80	90.60	92.40	95.50	100.20
10	84.90	95.90	67.10	70.40	71.00	70.90	98.70
11	71.10	89.80	55.80	72.80	64.30	72.30	66.30
12	56.40	50.40	68.10	68.70	59.50	55.70	47.40
13	80.50	76.20	77.50	84.10	75.40	73.80	64.60
14	83.60	122.60	91.80	92.60	92.00	87.20	83.10
15	97.50	102.90	72.00	78.70	68.20	79.00	77.10
16	59.30	65.40	59.90	62.40	71.60	64.50	60.90
17	89.80	63.60	88.30	80.00	79.00	81.30	93.50
18	96.60	86.20	77.00	80.10	79.90	83.00	83.00
Mean	81.98	85.39	75.43	81.41	78.82	77.68	81.53
St.Dev.	11.10	23.87	19.37	23.34	21.58	23.18	25.01

Table E1c. Placebo drink, blood glucose concentration (mg/dl).

Subject	PGLUB	PGLUR	PGLU30	PGLU60	PGLU90	PGLU120	PGLUmx
1	95.00	76.00	69.00	83.00	79.00	77.00	80.00
2	80.60	69.20	76.60	73.10	66.00	66.70	94.40
3	115.20	62.20	68.20	84.50	77.00	74.00	74.00
4	79.90	75.40	72.20	76.50	78.30	74.90	69.10
5	60.30	62.90	52.20	53.60	57.40	57.20	54.50
6	93.20	101.60	82.90	88.40	85.80	91.60	89.10
7	72.10	82.10	77.50	134.70	74.00	67.50	82.20
8	77.90	77.20	66.00	63.70	67.60	67.20	66.20
9	59.50	82.00	141.50	75.70	69.70	130.90	74.60
10	68.00	87.00	80.00	84.50	66.40	59.90	94.50
11	69.90	73.70	56.70	62.50	63.80	51.80	52.80
12	81.30	101.50	77.70	77.70	83.70	66.80	78.50
13	72.80	72.70	74.80	81.00	63.70	73.20	70.00
14	86.90	94.40	94.50	102.20	91.90	84.80	89.00
15	85.00	79.50	72.60	78.00	74.70	75.20	72.00
16	79.90	74.70	63.70	61.60	65.30	58.50	52.30
17	89.70	75.80	79.00	88.70	86.60	83.30	89.70
18	70.30	92.80	64.70	69.30	70.20	58.60	59.30
Mean	79.86	80.04	76.10	79.93	73.39	73.28	74.57
St.Dev.	13.45	11.55	19.04	17.97	9.44	17.82	13.88

B= baseline, R= rest, 30= 30 min, 60= 60 min, 90= 90 min, 120= 120 min, mx= end ride.

Table E2a. Glucose polymer drink, blood glycerol concentration (mmol/l).

Subject	GGLYB	GGLYR	GGLY30	GGLY60	GGLY90	GGLY120	GGLYmx
1	0.07	0.09	0.26	0.18	0.24	0.24	0.23
2	0.10	0.51	0.09	0.14	0.17	0.22	0.30
3	0.05	0.05	0.06	0.10	0.16	0.23	0.23
4	0.05	0.08	0.07	0.09	0.10	0.14	0.22
5	0.14	0.03	0.13	0.14	0.14	0.12	0.09
6	0.10	0.09	0.09	0.22	0.32	0.37	0.29
7	0.15	0.28	0.11	0.05	0.08	0.13	0.10
8	0.08	0.08	0.10	0.14	0.19	0.23	0.28
9							
10	0.03	0.07	0.11	0.08	0.08	0.19	0.20
11	0.29	0.21	1.76	0.35	0.24	0.24	0.30
12	0.04	0.03	0.03	0.05	0.16	0.22	0.17
13	0.22	0.13	0.14	0.15	0.22	0.24	0.19
14	0.04	0.05	0.06	0.05	0.14	0.16	0.19
15	0.26	0.11	0.07	0.17	0.30	0.30	0.30
16	0.05	0.09	0.10	0.09	0.12	0.17	0.16
17	0.09	0.16	0.13	0.12	0.12	0.19	0.21
18	0.07	0.05	0.09	0.15	0.25	0.30	0.16
Mean	0.11	0.12	0.20	0.13	0.18	0.22	0.21
St.Dev.	0.08	0.12	0.41	0.07	0.07	0.07	0.07

B=baseline, R=rest, 30=30 min, 60=60 min, 90=90 min, 120=120 min, mx= end ride.

Table E2b. Whole milk drink, blood glycerol concentration (mmol/l).

Subject	MGLYB	MGLYR	MGLY30	MGLY60	MGLY90	MGLY120	MGLYmx
1	0.04	0.04	0.05	0.09	0.16	0.20	0.17
2	0.04	0.04	0.05	0.31	0.16	0.19	1.27
3	0.05	0.05	0.06	0.08	0.12	0.17	0.23
4	0.06	0.07	0.10	0.10	0.10	0.11	0.19
5	0.00	0.06	0.04	0.07	0.15	0.12	0.12
6	0.14	0.12	0.14	0.14	0.15	0.24	0.38
7	0.03	0.13	0.05	0.13	0.10	0.05	0.17
8	0.12	0.08	0.10	0.16	0.23	0.38	0.41
9	0.08	0.07	0.15	0.25	0.21	0.31	0.16
10	0.12	0.06	0.11	0.18	0.19	0.25	0.47
11	0.07	0.08	0.09	0.14	0.22	0.23	0.19
12	0.07	0.11	0.09	0.19	0.12	0.33	0.16
13	0.07	0.23	0.09	0.13	0.15	0.27	0.17
14	0.09	0.09	0.12	0.12	0.20	0.23	0.25
15	0.14	0.04	0.11	0.08	0.11	0.15	0.20
16	0.07	0.09	0.08	0.10	0.16	0.26	0.13
17	0.10	0.18	0.09	0.11	0.18	0.28	0.19
18	0.11	0.12	0.16	0.22	0.15	0.26	0.25
Mean	0.08	0.09	0.09	0.14	0.16	0.22	0.28
St.Dev.	0.04	0.05	0.03	0.06	0.04	0.08	0.26

B= baseline, R= rest, 30= 30 min, 60= 60 min, 90= 90 min, 120= 120 min, mx= end ride.

Table E2c. Placebo drink, blood glycerol concentration (mmol/l).

Subject	PGLYB	PGLYR	PGLY30	PGLY60	PGLY90	PGLY120	PGLYmx
1	0.09	0.06	0.10	0.08	0.13	0.19	0.28
2	0.10	0.09	0.14	0.17	0.16	0.26	0.33
3	0.10	0.08	0.05	0.10	0.15	0.16	0.21
4	0.06	0.05	0.14	0.13	0.15	0.09	0.17
5	0.08	0.07	0.05	0.03	0.11	0.14	0.13
6	0.10	0.07	0.14	0.18	0.14	0.29	0.10
7	0.06	0.08	0.13	0.07	0.14	0.17	0.20
8	0.07	0.09	0.09	0.18	0.29	0.34	0.28
9	0.03	0.06	0.11	0.15	0.29	0.32	0.25
10	0.09	0.08	0.23	0.10	0.15	0.15	0.23
11	0.05	0.10	0.17	0.27	0.31	0.40	0.27
12	0.09	0.07	0.12	0.16	0.31	0.48	0.29
13	0.05	0.10	0.07	0.07	0.13	0.19	0.16
14	0.05	0.06	0.05	0.12	0.18	0.25	0.34
15	0.05	0.05	0.11	0.19	0.24	0.39	0.78
16	0.04	0.06	0.07	0.13	0.19	0.23	0.22
17	0.15	0.24	0.19	0.21	0.22	0.34	0.22
18	0.08	0.05	0.11	0.24	0.26	0.32	0.20
Mean	0.07	0.08	0.11	0.14	0.20	0.26	0.26
St.Dev.	0.03	0.04	0.05	0.06	0.07	0.11	0.15

B= baseline, R= rest, 30= 30 min, 60= 60 min, 90= 90 min, 120= 120 min, mx= end ride.

Table E3a. Glucose polymer drink, free fatty acid concentration (mEq/L)).

Subject	GFFAB	GFFAR	GFFA30	GFFA60	GFFA90	GFFA120	GFFAMx
1	1.08	0.52	0.24	0.37	1.47	1.07	0.95
2	0.39	0.36	0.30	0.55	1.61	1.53	0.92
3	0.09	0.32	0.31	0.54	1.01	1.15	1.28
4	0.41	0.33	0.36	0.29	0.41	0.58	0.90
5	0.28	0.18	0.20	0.23	0.23	0.46	0.57
6	0.46	0.21	0.30	0.45	0.58	0.86	0.50
7	0.23	0.15	0.15	0.23	0.20	0.51	0.50
8	0.21	0.17	0.22	0.21	0.56	0.62	0.87
9							
10	0.31	0.24	0.21	0.25	0.24	0.50	0.70
11	0.45	0.50	0.27	0.45	0.35	0.52	1.17
12	0.67	0.28	0.18	0.49	1.20	1.68	0.79
13	0.23	0.19	0.19	0.37	0.44	1.18	0.41
14	0.38	0.24	0.16	0.29	0.47	0.54	0.72
15	0.63	0.64	0.26	0.62	1.71	1.42	1.01
16	0.23	0.16	0.15	0.16	0.57	0.81	0.77
17	0.31	0.18	0.31	0.63	0.48	0.73	1.43
18	0.54	0.23	0.30	0.62	0.83	0.73	0.34
Mean	0.41	0.29	0.24	0.40	0.73	0.88	0.81
St.Dev.	0.23	0.14	0.07	0.16	0.49	0.39	0.30

B= baseline, R= rest, 30 = 30 min, 60= 60 min, 90= 90 min, 120=120 min, mx= end ride.

Table E3b. Whole milk drink, free fatty acid concentration (mEq/L).

Subject	MFFAB	MFFAR	MFFA30	MFFA60	MFFA90	MFFA120	MFFAMx
1	0.43	0.43	0.38	0.49	0.96	0.97	0.73
2	0.45	0.34	0.27	0.45	1.01	1.08	1.41
3	0.36	0.24	0.24	0.27	0.52	0.73	0.71
4	0.41	0.40	0.23	0.43	0.40	0.99	1.06
5	0.24	0.23	0.23	0.31	0.36	0.59	0.68
6	0.34	0.28	0.18	0.47	0.40	0.58	0.48
7	0.16	0.09	0.24	0.29	0.29	0.49	0.52
8	0.62	0.39	0.56	0.86	1.21	1.21	1.01
9	0.24	0.21	0.22	0.46	0.54	0.55	0.96
10	0.17	0.20	0.18	0.21	0.46	0.66	0.85
11	0.27	0.31	0.27	0.37	0.54	0.55	0.53
12	0.32	0.41	0.29	0.45	0.84	1.68	0.73
13	0.59	0.27	0.58	0.82	0.68	1.13	0.83
14	0.61	0.25	0.26	0.40	0.64	0.70	1.17
15	1.47	0.34	0.33	0.51	0.86	1.57	1.33
16	0.30	0.26	0.27	0.35	0.66	1.09	0.90
17	0.19	0.22	0.20	0.39	0.43	0.90	0.89
18	0.37	0.19	0.20	0.33	0.30	0.32	0.38
Mean	0.42	0.28	0.28	0.44	0.62	0.88	0.84
St.Dev.	0.30	0.09	0.11	0.17	0.26	0.37	0.28

B= baseline, R= rest, 30= 30 min, 60= 60 min, 90= 90 min, 120= 120 min, mx= end ride.

Table E3c. Placebo drink, free fatty acid concentration (mEq/L).

Subject	PFFAB	PFFAR	PFFA30	PFFA60	PFFA90	PFFA120	PFFAMx
1	0.24	0.26	0.24	0.39	0.56	0.75	1.09
2	0.59	0.53	0.49	0.90	1.08	1.41	1.26
3	0.28	0.24	0.25	0.38	0.36	0.64	0.60
4	0.50	0.90	0.53	0.64	0.72	1.20	0.79
5	0.24	0.24	0.26	0.25	0.59	1.06	0.89
6	0.38	0.38	0.37	0.48	0.37	0.56	0.43
7	0.92	0.75	0.83	1.47	0.98	1.26	1.22
8	0.24	0.42	0.53	0.71	1.21	1.64	1.12
9	0.73	0.52	0.76	1.19	1.41	1.44	0.92
10	0.29	0.23	0.21	0.27	0.33	0.34	0.62
11	0.26	0.32	0.45	0.55	1.24	1.11	0.56
12	1.31	0.94	0.91	0.96	0.84	1.71	1.02
13	0.20	0.22	0.21	0.31	0.56	1.05	0.57
14	0.32	0.30	0.26	0.35	0.91	0.57	0.90
15	0.21	0.30	0.56	1.15	1.12	1.95	1.17
16	0.64	0.38	0.55	1.02	1.18	1.66	1.04
17	0.43	0.70	0.48	0.87	0.48	0.40	1.08
18	0.35	0.28	0.42	0.81	1.55	0.76	0.37
Mean	0.45	0.44	0.46	0.71	0.86	1.08	0.87
St.Dev.	0.29	0.23	0.21	0.36	0.38	0.49	0.28

B= baseline, R= rest, 30=30 min, 60= 60 min, 90= 90 min, 120= 120 min, mx= end ride.

Table E4a. Glucose polymer drink, heart rate ($\text{b}\cdot\text{min}^{-1}$).

Subject	GHRr	GHR15	GHR30	GHR45	GHR60	GHR75	GHR90	GHR105	GHR120	GHRmx
1	67	132	125	123	120	114	130	128	125	155.9
2	88	117	115	114	116	121	123	123	123	164.2
3	85	122	116	114	115	116	113	116	124	158.2
4	63	132	119	125	127	129	122	120	133	161.3
5	92	128	149	144	138	137	135	153	157	164.97
6	93	154	150	148	152	157	159	157	160	181.68
7	68	125	125	122	123	122	123	104	123	135.4
8	91	138	141	151	149	153	147	147	151	175.73
9										
10	68	117	118	121	122	122	120	127	125	159.13
11	58	124	137	138	136	132	95	137	140	166.57
12	61	145	129	148	132	133	133	131	133	174.31
13	76	123	125	138	139	136	135	137	141	159.89
14	62	135	132	123	121	125	125	132	128	168.89
15	75	97	97	95	99	100	104	106	108	134.26
16	75	155	155	149	149	139	136	145	143	186.66
17	99	135	135	137	134	129	130	133	134	172.98
18	65	131	129	137	140	140	134	140	136	170.54
Mean	75.647	130	129.24	131	130.12	129.71	127.29	131.53	134.35	164.15
St.Dev.	13.153	14.04	14.635	15.532	14.124	13.972	14.987	14.904	13.416	13.861

R=rest, 15, 30, 45, 60, 75, 90, 105, 120 = min; mx= end ride.

Table E4b. Whole milk drink, heart rate ($\text{b} \cdot \text{min}^{-1}$).

Subject	MHRr	MHR15	MHR30	MHR45	MHR60	MHR75	MHR90	MHR105	MHR120	MHRmx
1	58	119	119	123	124	120	125	127	134	153.92
2	85	122	121	118	118	160	161	167	166	172.7
3	77	115	107	113	111	120	122	120	117	156.75
4	71	145	141	142	141	123	139	140	153	175.14
5	66	132	141	141	136	133	131	137	130	161.67
6	93	129	155	141	146	149	151	158	163	191.6
7	92	111	120	111	114	115	117	114	119	158.36
8	90	145	150	152	159	159	150	158	165	180.38
9	63	139	140	142	141	144	145	157	154	179.25
10	63	123	130	124	127	130	128	135	131	165.91
11	70	129	129	132	131	134	134	142	142	164.51
12	61	115	149	152	138	153	159	152	156	186.39
13	66	136	141	146	135	141	142	146	143	162
14	59	120	123	121	128	128	122	127	126	167.42
15	57	101	103	102	97	102	104	102	102	137.05
16	62	132	140	136	149	137	143	153	155	175.17
17	61	145	145	140	142	143	145	137	144	177.86
18	76	146	141	140	144	146	146	153	154	174.32
Mean	70.556	128	133.06	132	132.28	135.39	136.89	140.28	141.89	168.91
St.Dev.	12.147	13.222	14.826	14.685	15.285	15.692	15.161	17.299	18.253	13.039

R=rest, 15, 30, 45, 60, 75, 90, 105, 120 = min; mx= end ride.

Table E4c. Placebo drink, heart rate ($\text{b} \cdot \text{min}^{-1}$).

Subject	PHRr	PHR15	PHR30	PHR45	PHR60	PHR75	PHR90	PHR105	PHR120	PHRmx
1	78	131	128	142	109	131		121	128	155.63
2	79	125	123	128	131	123	122	118	143	175.48
3	61	112	107	110	110	110	112	114	133	153.13
4	65	117	114	112	116	124	118	123	126	152.86
5	84	142	135	139	139	136	135	134	133	161.39
6	102	154	140	138	148	138	133	143	145	183.21
7	81	121	127	126	126	124	121	124	122	168.53
8	71	148	141	152	142	144	146	156	158	182.41
9	77	141	144	128	132	143	143	142	142	172.64
10	68	120	121	142	140	141	138	130	128	169.67
11	94	131	137	137	147	139	141	142	151	163.51
12	74	133	139	148	142	147	131	126	129	174.5
13	79	115	118	117	127	123	133	136	134	154.87
14	67	129	124	129	125	133	130	127	126	186.77
15	66	100	81	103	112	110	113	115	137	140
16	92	146	146	136	134	138	138	144	145	171.77
17	77	158	156	149	151	150	151	160	165	179.87
18	72	135	140	147	152	145	147	148	144	172.63
Mean	77.056	131	128.94	132.39	132.39	133.28	132.47	133.5	138.28	167.72
St.Dev.	10.806	15.431	17.309	14.39	14.009	11.96	11.849	13.721	11.791	12.632

R=rest, 15, 30, 45, 60, 75, 90, 105, 120 = min; mx= end ride.

Table E5a. Glucose polymer drink, respiratory exchange ratio.

Subject	GRRr	GRR15	GRR30	GRR45	GRR60	GRR75	GRR90	GRR105	GRR120	GRRmx
1	0.8	1.04	0.96	0.97	0.93	0.9	1	0.94	0.83	0.99
2	0.95	0.98	0.97	0.96	0.94	0.89	0.87	0.87	0.87	0.99
3	0.94	0.97	0.92	0.95	0.93	0.99	0.86	0.89	0.83	1.07
4	0.93	1.07	1.01	1.02	0.95	1.09	0.99	0.99	0.82	1
5	0.84	1	1	0.98	1	1.04	1	1.21	0.9	1.01
6	0.86	0.93	0.92	0.81	0.88	0.92	0.86	0.88	0.88	1.03
7	1.02	1.08	1.07	1.03	1.01	1.01	1	1.07	0.98	1.04
8	1	1.05	0.99	0.97	0.95	0.93	0.91	0.9	0.82	1.02
9										
10	0.95	1.04	0.91	0.91	1	1.02	0.9	0.95	0.9	1.09
11	0.96	0.91	0.98	0.9	0.89	0.92	0.91	0.89	0.92	1.05
12	0.86	1.02	1	0.99	0.92	0.98	0.89	0.89	0.99	1.19
13	0.97	1.17	1.03	1.05	1.03	1.02	1.01	1.04	1.06	1.1
14	0.93	1	0.98	0.85	0.91	0.91	0.91	0.94	0.93	1.04
15	0.9	0.92	0.94	0.94	0.81	0.86	0.85	0.8	0.84	0.98
16	0.96	1.09	1.02	0.97	0.94	0.95	0.93	0.94	0.96	1.18
17	0.88	0.94	0.95	0.92	0.91	0.87	0.87	0.84	0.83	1
18	0.91	1	0.91	0.96	0.96	0.9	0.87	0.89	0.88	1.31
Mean	0.92	1.01	0.97	0.95	0.94	0.95	0.92	0.94	0.9	1.06
St.Dev.	0.06	0.07	0.05	0.06	0.05	0.07	0.06	0.1	0.07	0.09

R=rest, 15, 30, 45, 60, 75, 90, 105, 120 = min; mx= end ride.

Table E5b. Whole milk drink, respiratory exchange ratio.

Subject	MRERr	MRER15	MRER30	MRER45	MRER60	MRER75	MRER90	MRER105	MRER120	MRERmx
1	0.79	0.95	0.93	0.92	0.83	0.91	0.93	0.94	0.93	1.052
2	0.88	0.94	0.9	0.85	1.13	1.15	1.18	1.15	1.02	1.02
3	0.89	0.95	0.92	0.9	0.89	0.94	0.9	0.86	0.9	1.07
4	0.94	1.04	1.02	0.96	1.02	0.99	0.97	1.05	0.93	1.05
5	1.13	1.04	0.91	0.98	0.92	0.93	0.93	0.94	0.87	1.06
6	0.89	0.9	0.91	0.93	0.91	0.93	0.92	0.97	0.87	1.08
7	0.95	0.95	0.97	0.96	0.93	1.04	1.05	1.03	0.98	1.05
8	1.07	1.03	0.95	0.93	0.96	0.94	0.87	0.93	0.92	1.09
9	0.94	0.92	0.96	0.91	0.97	0.96	0.99	0.99	0.96	1.14
10	0.92	0.95	0.99	0.93	0.98	1.02	0.9	0.91	0.9	1.07
11	0.9	0.94	0.91	0.89	0.9	0.88	0.87	0.89	0.88	1.10
12	0.88	0.99	0.99	0.96	0.94	0.95	0.98	0.91	0.99	1.18
13	1.18	1.05	0.96	1	0.95	0.97	0.95	1	1.04	1.18
14	0.86	0.97	0.95	0.91	0.9	0.88	0.88	0.9	0.91	1.05
15	1.08	0.9	0.96	0.91	0.94	0.91	0.94	0.9	0.88	1
16	0.99	1.01	0.96	0.89	0.92	0.92	0.89	0.9	0.89	1.14
17	0.96	0.96	0.96	0.95	0.96	0.95	0.95	0.88	0.91	1.08
18	0.93	1.05	0.96	0.9	0.95	0.93	0.93	1	0.96	1.13
Mean	0.95	0.97	0.95	0.93	0.94	0.96	0.95	0.95	0.93	1.09
St.Dev.	0.10	0.05	0.03	0.04	0.062	0.06	0.07	0.07	0.05	0.05

R=rest, 15, 30, 45, 60, 75, 90, 105, 120 = min; mx= end ride.

Table E5c. Placebo drink, respiratory exchange ratio measure.

Subj	PRRr	PR15	PR30	PR45	PR60	PR75	PR90	PR105	PR120	PRmx
1	0.88	1.04	0.96	1.01	0.92	0.98	0.89	0.9	0.98	1.08
2	0.88	0.92	0.96	0.89	0.9	0.91	0.89	0.89	0.7	1.10
3	0.95	0.96	0.92	1	0.95	0.96	0.95	0.91	0.99	1.09
4	0.98	1.07	0.97	0.99	0.92	1	1.1	1.09	1.05	1.04
5	1.14	1.07	0.98	0.97	0.92	0.92	0.94	0.86	0.88	1.01
6	0.83	0.9	0.85	0.79	0.87	0.91	0.88	0.87	0.87	1.07
7	0.93	0.97	0.88	0.94	0.86	0.85	0.91	0.93	1.06	1.03
8	0.92	0.99	0.93	0.91	0.93	0.91	0.89	0.91	0.86	1.03
9	0.8	0.94	0.91	0.88	0.87	0.83	0.81	0.84	0.82	1.03
10	0.89	0.95	0.92	0.97	0.93	0.92	0.96	0.93	0.92	1.09
11	0.69	0.93	0.86	0.88	0.88	0.83	0.83	0.85	0.87	1.07
12	0.8	1	1.01	0.93	0.98	0.93	0.88	0.85	0.93	1.25
13	1.03	1.06	0.96	1	1.02	0.99	1	1.01	0.92	1.09
14	0.72	0.93	0.9	0.85	0.93	0.95	0.95	0.92	0.93	1.02
15	0.89	0.92	0.92	0.88	0.89	0.86	0.87	0.91	0.99	1
16	1.04	1.12	1.13	0.96	0.98	1.1	1.01	1	0.99	1.12
17	0.88	1.09	0.93	0.91	0.89	0.92	0.9	0.84	0.94	1.09
18	0.8	0.95	0.92	0.91	0.9	0.87	0.87	0.89	0.86	1.29
Mean	0.89	0.99	0.94	0.93	0.92	0.92	0.92	0.91	0.92	1.08
St.Dev.	0.11	0.07	0.06	0.07	0.04	0.07	0.07	0.07	0.09	0.08

R=rest, 15, 30, 45, 60, 75, 90, 105, 120 = min; mx= end ride.

Table E6a. Glucose polymer drink, lactate concentration (mmol/L).

Subject	GLACb	GLACr	GLAC30	GLAC60	GLAC90	GLAC120	GLACmx
1	1.7	2	3.3	3	2.5	2.6	4.3
2	1.9	2.1	1.7	2.4	2	1.9	7.5
3	1.7	2.7	2.4	2.7	2.2	2.1	9.2
4	2.1	2.4	2.4	2.9	2.9	2.5	4.3
5	2.4	2.6	5.2	3.9	3.5	4	4.7
6	2.4	2.3	2.1	1.8	2.4	2.4	7.2
7	2.6	3.3	2.9	2.4	2.4	2.4	4.7
8	1.9	2.9	4.6	4.1	2.6	2.3	4.6
9							
10	2.4	2.4	2.7	3	2.4	2.7	8.6
11	2.2	3	3.5	3.4	2.7	3.1	5
12	2.1	2.4	3.3	2.9	3	3	8.6
13	2.7	3.2	4.5	3.1	2.8	2.9	7.7
14	2.2	2.6	2.4	1.8	2.1	1.5	4.9
15	2.8	2.4	2.4	2.4	2.1	2	3.2
16	2.4	2.4	2.4	2.4	2.6	2.1	11.2
17	1.9	2	2.4	2.1	1.6	1.8	4.9
18	2.6	2.8	3.9	3.3	2.6	2.6	8.7
Mean	2.24	2.56	3.06	2.80	2.49	2.46	6.43
St.Dev.	8.00	4.40	6.40	0.60	0.43	1.47	12.36

B = baseline, R=rest, 30= 30 min, 60=60 min, 90=90 min, 120=120 min, mx= end ride.

Table E6b. Whole milk drink, lactate concentration (mmol/L).

Subject	MLACb	MLACr	MLAC30	MLAC60	MLAC90	MLAC120	MLACmx
1	1.7	2.1	3.3	2.9	2.1	2.6	5
2	1.4	2	2	3.8	1.2	1.4	8.7
3	2.4	2.6	3.2	2.1	1.9	2.4	8.2
4	1.9	2	3	2.3	2.6	2.2	4.7
5	2.5	2.6	4.1	3.7	2.9	3	3.9
6	2.7	2.4	2.4	2.5	2.4	2.4	7.8
7	2.7	2.6	3	1.9	1.8	2.4	3.2
8	2	2.5	4.3	4	2.8	3	6.7
9	2.2	2.5	2.2	2.2	2.1	1.9	6.7
10	2.3	4.3	2.4	1.8	1.8	1.7	6
11	2.4	2.4	3.3	2.6	2.2	2.4	5.2
12	2.4	2.9	5.4	3.2	3.6	3.7	8.2
13	2.4	3	4	3	3	3	9
14	2	2.2	1.9	1.7	1.5	1.8	3.7
15	1.6	2	1.5	1.6	1.8	2.1	3.4
16	2.3	2.6	2.6	1.8	1.9	1.7	5.2
17	2.4	2.5	2.1	2.6	2.3	2.1	6.9
18	2.4	3	4.4	3.1	3	3.2	8.2
Mean	2.21	2.57	3.06	2.60	2.27	2.39	6.15
St.Dev.	5.04	5.34	0.23	0.14	0.074	0.16	0.49

B = baseline, R=rest, 30= 30 min, 60=60 min, 90=90 min, 120=120 min, mx= end ride.

Table E6c. Placebo drink, lactate concentration (mmol/L).

Subject	PLACb	PLACr	PLAC30	PLAC60	PLAC90	PLAC120	PLACmx
1	2.3	1.8	3.6	3.1	2.2	2.4	4.5
2	1.8	1.7	1.9	1.7	1.3	1.5	8.4
3	2.5	3	2.4	2.4	2.3	2.2	7.9
4	2.2	3	3.2	2.9	2.4	2.4	5.9
5	2.4	3	3.4	3	2.8	2.7	4.9
6	2.4	2.4	2.1	2.1	2.4	2.4	8.9
7	2.8	3	2.7	2.1	2.4	2.1	4.1
8	2	2.4	3.7	3	2.7	3.1	6.7
9	2.2	2.2	2.4	2	1.8	2.7	4
10	2.4	2.6	3.6	3	2.6	2.4	7.4
11	2.4	2.2	3	3.3	3.3	3.2	5.1
12	2.5	2.4	4.9	3.7	2.6	2.4	10
13	2.4	2.6	3.2	2.4	3	3	7.2
14	2.3	2.4	2.2	2.3	2.3	2.1	4.9
15	2.3	2.6	2.6	2.4	2.4	2.4	4.1
16	2.4	2.4	2.4	2.4	2.6	2.1	11.2
17	2.4	2.2	3.6	1.4	2.2	2.4	7
18	2.7	2.8	3.2	3.7	3.6	3.1	8.7
Mean	2.36	2.48	3.01	2.61	2.49	2.48	6.72
St.Dev.	0.30	5.34	0.30	0.09	0.11	0.17	0.26

B = baseline, R=rest, 30= 30 min, 60=60 min, 90=90 min, 120=120 min, mx= end ride.

Table E7. Time to exhaustion; glucola, whole milk, placebo (min).

Subject	GTTEmx	MTTEmx	PTTEmx
1	16.5	13	11.18
2	27.16	20.6	18.14
3	16.72	18.13	15.85
4	26.63	22.32	20.4
5	3	3.99	7.79
6	14.18	11.58	13.19
7	9.41	25.88	19.96
8	15.98	8.09	18.84
9		10.07	12.05
10	34.53	22.57	20.19
11	22.65	8.83	3.69
12	0.89	3.18	4.66
13	11.49	2.93	9.02
14	19.75	16.49	21.33
15	5.47	8.12	10.12
16	1	1.16	0.34
17	13.49	13.65	3.66
18	0.42	3.25	0.43
Mean	14.07	11.88	11.71
St.Dev.	10.08	7.70	7.20

GTTEmx = glucola, MTTEmx = whole milk, PTTEmx = placebo.

APPENDIX F
ANOVA TABLE FOR SHORT RIDE

Table F1. ANOVA summary table for baseline, pretest values for variables in the study

Variable		Sum of Squares	df	Mean Square	F	P	P < 0.05
FFA	Group	0.021	2	0.011	0.136	0.873	
	Error	3.851	50	0.077			
	Total	3.872	52				
Glucose	Group	58.192	2	29.096	0.246	0.783	
	Error	5919.389	50	118.388			
	Total	5977.581	52				
Glycerol	Group	0.012	2	0.006	2.045	0.518	
	Error	0.141	50	0.003			
	Total	0.153	52				
Heart Rate	Group	419.408	2	209.704	1.444	0.546	
	Error	7261.271	50	145.225			
	Total	7680.679	52				
Lactate	Group	0.226	2	0.113	1.132	0.330	
	Error	4.993	50	0.100			
	Total	5.219	52				
RER	Group	0.036	2	0.018	2.004	0.146	
	Error	0.443	50	0.009			
	Total	0.479	52				

Table F2. ANOVA summary table for maximal (80% $\text{VO}_{2\text{max}}$) values for variables in the study.

Variable		Sum of Squares	df	Mean Square	F	P	P < 0.05
FFA	Group	0.027	2	0.014	0.163	0.850	
	Error	4.190	50	0.084			
	Total	4.217	52				
Glucose	Group	530.215	2	265.108	0.789	0.460	
	Error	16793.789	50	335.876			
	Total	17324.005	52				
Glycerol	Group	0.043	2	0.028078	0.666	0.518	
	Error	1.623	50	0.032			
	Total	1.666	52				
Heart Rate	Group	212.642	2	106.321	0.613	0.546	
	Error	8677.166	50	173.543			
	Total	8889.808	52				
Lactate	Group	2.890	2	1.445	0.317	0.730	
	Error	228.085	50	4.562			
	Total	230.975	52				
RER	Group	0.005	2	0.002	0.462	0.633	
	Error	0.270	50	0.005			
	Total	0.275	52				
RPE	Group	0.641	2	0.320	0.190	0.828	
	Error	84.311	50	1.686			
	Total	84.951	52				
TTE	Groups	60.174	2	30.087	0.428	0.654	
	Error	3515.285	50	70.306			
	Total	3575.459	52				

APPENDIX G
GENERAL LINEAR MODELS SUMMARY

Table G.1 Blood glucose values by drink and by time; ANOVA GLM Summary Table.

Source Within	df	Mean Square	F	Partial Eta Squared	P	P < 0.05
Drink	2	670.564	1.066	.062	.356	
Error (Drink)	32	629.236				
Time	4	3937.428	32.071	.667	.001	*
Error (Time)	64	122.771				
Drink x Time	8	1586.543	12.898	.446	.001	*
Error (Drink x Time)	128	123.003				

Table G.2 Blood glycerol values by drink and by time; ANOVA GLM Summary Table.

Source Within	df	Mean Square	F	Partial Eta Squared	P	P < 0.05
Drink	2	.021	1.131	.066	.335	
Error (Drink)	32	.019				
Time	4	.128	9.574	.374	.001	*
Error (Time)	64	.013				
Drink x Time	8	.015	1.164	.068	.326	
Error (Drink x Time)	128	.013				

Table G.3 Blood free fatty acid values by drink and by time; ANOVA GLM Summary Table.

Source Within	df	Mean Square	F	Partial Eta Squared	Sig.	P < 0.05
Drink	2	.953	5.916	.270	.007	*
Error (Drink)	32	.161				
Time	4	3.622	43.146	.729	.001	*
Error (Time)	64	.084				
Drink x Time	8	.028	.881	.052	.534	
Error (Drink x Time)	128	.032				

Table G.4 Blood lactate values by drink and by time; ANOVA GLM Summary Table.

Source Within	df	Mean Square	F	Partial Eta Squared	P	P < 0.05
Drink	2	.121	.394	.024	.678	
Error (Drink)	32	.306				
Time	4	3.524	10.646	.400	.001	*
Error (Time)	64	.331				
Drink x Time	8	.103	.650	.039	.734	
Error (Drink x Time)	128	.158				

Table G.5 Respiratory Exchange Ratio values by drink and by time; ANOVA GLM Summary Table.

Source Within	df	Mean Square	F	Partial Eta Squared	P	P < 0.05
Drink	2	.013	1.273	.041	.294	
Error (Drink)	32	.010				
Time	8	.026	8.267	.420	.001	*
Error (Time)	128	.003				
Drink x Time	16	.004	1.665	.099	.054	
Error (Drink x Time)	256	.003				

Table G.6 Heart rate values by drink and by time; ANOVA GLM Summary Table.

Source Within	df	Mean Square	F	Partial Eta Squared	P	P < 0.05
Drink	2	354.675	1.180	.069	.320	
Error (Drink)	32	300.657				
Time	8	19276.532	225.075	.934	.001	*
Error (Time)	128	85.645				
Drink x Time	16	118.945	2.074	.107	.115	*
Error (Drink x Time)	256	57.343				

APPENDIX H

BONFERRONI POST HOC ANALYSES TABLES

Table H1. Free Fatty Acid Data, Bonferroni post hoc test. (Main Effect: Time x Condition)

Free Fatty Acids: Long Ride Means of Drinks

Drink	Mean	Std. Error	95% Confidence Interval – Lower Boundary	95% Confidence Interval – Upper Boundary
(1) Glucola	.506	.052	.397	.616
(2) Milk	.505	.043	.415	.596
(3) Placebo	.689	.064	.554	.825

Free Fatty Acids: Long Ride Means of Drinks at Specific Time Points

Time	Mean	Std. Error	95% Confidence Interval – Lower Boundary	95% Confidence Interval – Upper Boundary
Rest	.336	.025	.283	.390
30 Minutes	.325	.018	.287	.362
60 Minutes	.503	.035	.430	.577
90 Minutes	.726	.069	.579	.872
120 Minutes	.945	.087	.760	1.130

Free Fatty Acids: Long Ride Main Effect of Time

(I)Time (J)Time	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval – Lower	95% Confidence Interval – Upper
Rest to 30 min	.011	.019	1.000	-.049	.072
Rest to 60 min	*-.167*	.032	.001	-.271	-.064
Rest to 90 min	*-.389*	.063	.001	-.594	-.185
Rest to 120 min	*-.609*	.076	.001	-.855	-.363
30 to Rest	-.011	.019	1.000	-.072	.049
30 to 60 min	*-.179*	.023	.001	-.252	-.105
30 to 90 min	*-.401*	.062	.001	-.603	-.198
30 to 120 min	*-.620*	.076	.001	-.867	-.373
60 to Rest	*.167*	.032	.001	.064	.271
60 to 30 min	*.179*	.023	.001	.105	.252
60 to 90 min	*-.222*	.056	.001	-.403	-.041
60 to 120 min	*-.442*	.071	.001	-.672	-.211
90 to Rest	*.389*	.063	.001	.185	.594
90 to 30 min	*.401*	.062	.001	.198	.603
90 to 60 min	*.222*	.056	.001	.041	.403
90 to 120 min	*-.219*	.060	.001	-.414	-.025
120 to Rest	*.609*	.076	.001	.363	.855
120 to 30 min	*.620*	.076	.001	.373	.867
120 to 60 min	*.442*	.071	.001	.211	.672
120 to 90 min	*.219*	.060	.001	.025	.414

Based on estimated marginal means. * The mean difference is significant at the .05 level. Bonferroni.

Table H2. Glucose Data, Bonferroni post hoc test. (Main Effect: Time x Condition, Interaction: Drink x Time x Condition).

Glucose: Long Ride Means of Drinks

Drink	Mean	Std. Error	95% Confidence Interval – Lower Boundary	95% Confidence Interval – Upper Boundary
(1) Glucola	80.525	1.882	76.534	84.515
(2) Milk	79.324	5.116	68.478	90.169
(3) Placebo	75.172	2.372	70.143	80.201

Glucose: Long Ride Means of Drinks at Specific Time Points

Time	Mean	Std. Error	95% Confidence Interval – Lower Boundary	95% Confidence Interval – Upper Boundary
Rest	93.622	3.355	86.509	100.734
30 Minutes	73.878	2.541	68.491	79.266
60 Minutes	77.622	3.124	70.999	84.244
90 Minutes	74.676	2.771	68.802	80.551
120 Minutes	71.902	2.951	65.647	78.157

Glucose: Long Ride Main Effect of Time

(I)Time (J)Time	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval - Lower	95% Confidence Interval – Upper
Rest to 30 min	*19.473*	2.629	.001	11.193	28.294
Rest to 60 min	*16.000*	3.156	.001	5.736	26.264
Rest to 90 min	*18.945*	2.997	.001	9.200	28.691
Rest to 120 min	*21.720*	3.016	.001	11.913	31.527
30 to Rest	*-19.743*	2.626	.001	-28.294	-11.193
30 to 60 min	-3.743	1.625	.350	-9.027	1.541
30 to 90 min	-.798	1.658	1.000	-6.191	4.595
30 to 120 min	1.976	1.573	1.000	-3.139	7.092
60 to Rest	*-16.000*	3.156	.001	-26.264	-5.736
60 to 30 min	3.743	1.625	.350	-1.541	9.027
60 to 90 min	2.945	1.441	.577	-1.739	7.630
60 to 120 min	*5.720*	1.505	.016	.824	10.615
90 to Rest	*-18.945*	2.997	.001	-26.691	-9.200
90 to 30 min	.798	1.658	1.000	-4.595	6.191
90 to 60 min	-2.945	1.441	.577	-7.630	1.739
90 to 120 min	2.775	.994	.131	-.459	6.008
120 to Rest	*-21.720*	3.016	.001	-31.527	-11.913
120 to 30 min	-1.720	1.573	1.000	-7.092	3.139
120 to 60 min	-5.720	1.505	.016	-10.615	-.824
120 to 90 min	-2.775	.994	.131	-6.008	.459

Based on estimated marginal means. * The mean difference is significant at the .05 level. Bonferroni.

Table H2-Continued. Glucose: Long Ride Estimates of Means, Drink by Time

Drink by Time		Mean	Std. Error	95% Confidence Interval – Lower	95% Confidence Interval - Upper
Glucola	Rest	115.253	5.606	103.369	127.137
	30 min	73.971	4.149	65.175	82.767
	60 min	71.824	1.989	67.608	76.040
	90 min	72.400	2.436	67.235	77.565
	120 min	69.176	2.150	64.618	73.735
Milk	Rest	85.688	5.960	73.054	98.323
	30 min	75.824	4.843	65.145	85.678
	60 min	80.865	5.806	68.556	93.174
	90 min	78.018	5.323	66.723	89.313
	120 min	76.635	5.688	64.577	88.038
Placebo	Rest	79.924	2.885	73.809	86.038
	30 min	72.253	2.453	67.053	77.453
	60 min	80.176	4.485	70.668	89.685
	90 min	73.612	2.359	68.631	78.592
	120 min	69.894	2.631	64.316	75.472

Glucose: Long Ride Drink by Time Interaction – Glucola Effect

Drink x Time (I) x Time (J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval – Lower	95% Confidence Interval - Upper
Glucola x Rest X 30 min	*41.282*	6.108	.001	21.418	61.146
Glucola x Rest x 60 min	*43.429*	6.099	.001	23.595	63.263
Glucola x Rest x 90 min	*42.853*	6.292	.001	22.391	63.315
Glucola x Rest x 120 min	*46.076*	6.204	.001	25.902	66.251
Glucola x 30 min x Rest	*-41.282*	6.108	.001	-61.146	-21.418
Glucola x 30 min x 60 min	2.147	4.620	1.000	-12.877	17.171
Glucola x 30 min x 90 min	1.571	5.122	1.000	-15.085	18.266
Glucola x 30 min x 120 min	4.794	4.609	1.000	-10.196	19.784
Glucola x 60 min x Rest	*-43.429*	6.099	.001	-63.263	-23.595
Glucola x 60 min x 30 min	-2.147	4.620	1.000	-17.171	12.877
Glucola x 60 min x 90 min	-.576	1.088	1.000	-4.113	2.960
Glucola x 60 min x 120 min	2.647	1.632	1.000	-2.661	7.955
Glucola x 90 min x Rest	*-42.853*	6.292	.001	-63.315	-22.391
Glucola x 90 min x 30 min	-1.571	5.122	1.000	-18.226	15.085
Glucola x 90 min x 60 min	.576	1.088	1.000	-2.960	4.113
Glucola x 90 min x 120 min	3.224	1.392	.342	-1.304	7.751
Glucola x 120 min x Rest	*-46.076	6.204	.001	-66.251	-25.902
Glucola x 120 min x 30 min	-4.794	4.609	1.000	-19.784	10.196
Glucola x 120 min x 60 min	-2.647	1.632	1.000	-7.955	2.661
Glucola x 120 min x 90 min	-3.224	1.392	.342	-7.751	1.304

Based on estimated marginal means. * The mean difference is significant at the .05 level. Bonferroni.

Table H2-Continued. Glucose: Long Ride Drink by Time Interaction – Milk Effect

Drink x Time (I) x Time (J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval – Lower	95% Confidence Interval - Upper
Milk x Rest X 30 min	10.276	5.106	.613	-6.327	26.880
Milk x Rest x 60 min	4.824	4.555	1.000	-9.989	19.636
Milk x Rest x 90 min	7.671	4.537	1.000	-7.085	22.426
Milk x Rest x 120 min	9.053	4.001	.379	-3.958	22.064
Milk x 30 min x Rest	-10.276	5.106	.613	-26.880	6.327
Milk x 30 min x 60 min	-5.453	2.602	.523	-13.913	3.008
Milk x 30 min x 90 min	-2.606	2.296	1.000	-10.074	4.862
Milk x 30 min x 120 min	-1.224	2.754	1.000	-10.178	7.731
Milk x 60 min x Rest	-4.824	4.555	1.000	-19.636	9.989
Milk x 60 min x 30 min	5.453	2.602	.523	-3.008	13.913
Milk x 60 min x 90 min	2.847	1.452	.676	-1.875	7.570
Milk x 60 min x 120 min	4.229	2.015	.521	-2.324	10.783
Milk x 90 min x Rest	-7.671	4.537	1.000	-22.426	7.085
Milk x 90 min x 30 min	2.606	2.296	1.000	-4.862	10.074
Milk x 90 min x 60 min	-2.847	1.452	.676	-7.570	1.875
Milk x 90 min x 120 min	1.382	1.912	1.000	-4.836	7.600
Milk x 120 min x Rest	-9.053	4.001	.379	-22.064	3.958
Milk x 120 min x 30 min	1.224	2.754	1.000	-7.731	10.178
Milk x 120 min x 60 min	-4.229	2.015	.521	-10.783	2.324
Milk x 120 min x 90 min	-1.382	1.912	1.000	-7.600	4.836

Based on estimated marginal means. * The mean difference is significant at the .05 level. Bonferroni.

Table H2-Continued. Glucose: Long Ride Drink by Time Interaction – Placebo Effect

Drink x Time (I) x Time (J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval – Lower	95% Confidence Interval - Upper
Placebo x Rest X 30 min	7.671	2.454	.065	-.309	15.651
Placebo x Rest x 60 min	-.253	4.493	1.000	-14.865	14.359
Placebo x Rest x 90 min	6.312	2.480	.216	-1.752	14.375
Placebo x Rest x 120 min	10.029	3.265	.073	-.589	20.647
Placebo x 30 min x Rest	-7.671	2.454	.065	-15.651	.309
Placebo x 30 min x 60 min	-7.924	3.340	.306	-18.786	2.939
Placebo x 30 min x 90 min	-1.359	1.760	1.000	-7.081	4.364
Placebo x 30 min x 120 min	2.359	1.959	1.000	-4.011	8.728
Placebo x 60 min x Rest	.253	4.493	1.000	-14.359	14.865
Placebo x 60 min x 30 min	7.924	3.340	.306	-2.939	18.786
Placebo x 60 min x 90 min	6.565	3.794	1.000	-5.772	18.902
Placebo x 60 min x 120 min	10.282	3.979	.200	-2.658	23.223
Placebo x 90 min x Rest	-6.312	2.480	.216	-14.375	1.752
Placebo x 90 min x 30 min	1.359	1.760	1.000	-4.364	7.081
Placebo x 90 min x 60 min	-6.565	3.794	1.000	-18.902	5.772
Placebo x 90 min x 120 min	3.718	1.570	.308	-1.389	8.824
Placebo x 120 min x Rest	-10.029	3.265	.073	-20.647	.589
Placebo x 120 min x 30 min	-2.359	1.959	1.000	-8.728	4.011
Placebo x 120 min x 60 min	-10.282	3.979	.200	-23.223	2.658
Placebo x 120 min x 90 min	-3.718	1.570	.308	-8.824	1.389

Based on estimated marginal means. * The mean difference is significant at the .05 level. Bonferroni.

Table H3. Glycerol Data, Bonferroni post hoc test (Main Effect :Time x Condition).

Glycerol: Long Ride Means of Drinks

Drink	Mean	Std. Error	95% Confidence Interval – Lower Boundary	95% Confidence Interval – Upper Boundary
(1) Glucola	.170	.026	.114	.226
(2) Milk	.139	.008	.121	.157
(3) Placebo	.157	.012	.131	.184

Glycerol: Long Ride Means of Drinks at Specific Time Points

Time	Mean	Std. Error	95% Confidence Interval – Lower Boundary	95% Confidence Interval – Upper Boundary
Rest	.099	.012	.073	.125
30 Minutes	.134	.034	.062	.207
60 Minutes	.138	.012	.133	.162
90 Minutes	.175	.010	.153	.197
120 Minutes	.231	.017	.195	.267

Glycerol: Long Ride Main Effect of Time

(I)Time (J)Time	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval - Lower	95% Confidence Interval – Upper
Rest to 30 min	-.035	.034	1.000	-.146	.076
Rest to 60 min	-.038	.014	.121	-.083	.006
Rest to 90 min	*-.076*	.016	.003	-.129	-.022
Rest to 120 min	*-.132*	.021	.001	-.199	-.065
30 to Rest	.035	.034	1.000	-.076	.146
30 to 60 min	-.003	.028	1.000	-.095	.088
30 to 90 min	-.041	.030	1.000	-.139	.058
30 to 120 min	-.097	.034	.121	-.208	.015
60 to Rest	.038	.014	.121	-.006	.083
60 to 30 min	.003	.028	1.000	-.088	.095
60 to 90 min	*-.037*	.008	.001	-.062	-.013
60 to 120 min	*-.093*	.013	.001	-.135	-.052
90 to Rest	*.076*	.016	.003	.022	.129
90 to 30 min	.041	.030	1.000	-.058	.139
90 to 60 min	*.037*	.008	.001	.013	.062
90 to 120 min	*-.056*	.009	.001	-.087	-.026
120 to Rest	*.132*	.021	.001	.065	.199
120 to 30 min	.097	.034	.121	-.015	.208
120 to 60 min	*.093*	.013	.001	.052	.135
120 to 90 min	*.056*	.009	.001	.026	.087

Based on estimated marginal means. * The mean difference is significant at the .05 level. Bonferroni.

Table H4. Lactate Data, Bonferroni post hoc test (Main Effect: Time x Condition).

Lactate: Long Ride Means of Drinks

Drink	Mean	Std. Error	95% Confidence Interval – Lower Boundary	95% Confidence Interval – Upper Boundary
(1) Glucola	2.676	.127	2.408	2.945
(2) Milk	2.601	.139	2.307	2.895
(3) Placebo	2.636	.100	2.424	2.849

Lactate: Long Ride Means of Drinks at Specific Time Points

Time	Mean	Std. Error	95% Confidence Interval – Lower Boundary	95% Confidence Interval – Upper Boundary
Rest	2.543	.080	2.373	2.713
30 Minutes	3.073	.199	2.650	3.495
60 Minutes	2.688	.137	2.399	2.978
90 Minutes	2.437	.109	2.207	2.668
120 Minutes	2.449	.114	2.208	2.690

Lactate: Long Ride Main Effect of Time

(I)Time (J)Time	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval - Lower	95% Confidence Interval – Upper
Rest to 30 min	-.529	.181	.100	-1.119	.060
Rest to 60 min	-.145	.144	1.000	-.615	.325
Rest to 90 min	.106	.097	1.000	-.209	.420
Rest to 120 min	.094	.105	1.000	-.249	.437
30 to Rest	.529	.181	.100	-.060	1.119
30 to 60 min	*.384*	.110	.029	.028	.741
30 to 90 min	*.635*	.119	.001	.248	1.022
30 to 120 min	*.624*	.107	.001	.275	.972
60 to Rest	.145	.144	1.000	-.325	.615
60 to 30 min	*-.384*	.110	.029	-.741	-.028
60 to 90 min	.251	.097	.194	-.063	.565
60 to 120 min	.239	.084	.115	-.033	.512
90 to Rest	-.106	.097	1.000	-.420	.209
90 to 30 min	*-.635*	.119	.001	-1.022	-.248
90 to 60 min	-.251	.097	.194	-.565	.063
90 to 120 min	-.012	.040	1.000	-.143	.120
120 to Rest	-.094	.105	1.000	-.437	.249
120 to 30 min	*-.624*	.107	.001	-.972	-.275
120 to 60 min	-.239	.084	.115	-.512	.033
120 to 90 min	.012	.040	1.000	-.120	.143

Based on estimated marginal means. * The mean difference is significant at the .05 level. Bonferroni.

Table H5. Heart Rate Data, Bonferroni post hoc test (Main Effect: Time x Condition; Interaction: Drink x Time x Condition).

Heart Rate: Long Ride Means of Drinks

Drink	Mean	Std. Error	95% Confidence Interval – Lower Boundary	95% Confidence Interval – Upper Boundary
(1) Glucola	124.320	2.966	118.033	130.607
(2) Milk	127.327	3.180	120.585	134.068
(3) Placebo	126.242	2.847	120.206	132.278

Heart Rate: Long Ride Means of Drinks at Specific Time Points

Time	Mean	Std. Error	95% Confidence Interval – Lower Boundary	95% Confidence Interval – Upper Boundary
Rest	74.569	2.125	70.064	79.073
15 minutes	129.255	2.985	122.927	135.583
30 minutes	129.980	3.499	122.563	137.398
45 minutes	131.686	3.302	124.686	138.687
60 minutes	131.431	3.261	124.518	138.345
75 minutes	132.431	2.997	126.079	138.784
90 minutes	131.843	2.751	126.012	137.675
105 minutes	134.608	3.235	127.749	141.466
120 minutes	137.863	2.910	131.694	144.031

Table H5-Continued. Heart Rate: Long Ride Main Effect of Time

(I)Time (J)Time	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval – Lower	95% Confidence Interval – Upper
Rest to 15 min	*-54.686*	2.759	.001	-65.335	-44.038
Rest to 30 min	*-55.412*	3.118	.001	-67.443	-43.380
Rest to 45 min	*-57.118*	3.316	.001	-69.914	-44.321
Rest to 60 min	*-56.863*	2.971	.001	-68.327	-45.399
Rest to 75 min	*-57.863*	2.734	.001	-68.415	-47.311
Rest to 90 min	*-57.275*	2.514	.001	-66.976	-47.573
Rest to 105 min	*-60.039*	2.822	.001	-70.928	-49.151
Rest to 120 min	*-63.294*	2.301	.001	-72.173	-54.415
15 min to Rest	*54.686*	2.759	.001	44.038	65.335
15 min to 30 min	-.725	1.130	1.000	-5.088	3.637
15 min to 45 min	-2.431	1.598	1.000	-8.597	3.734
15 min to 60 min	-2.176	1.388	1.000	-7.532	3.179
15 min to 75 min	-3.176	1.613	1.000	-9.401	3.048
15 min to 90 min	-2.588	1.494	1.000	-8.352	3.175
15 min to 105 min	-5.353	1.572	.130	-11.419	.713
15 min to 120 min	*-8.608*	1.567	.002	-14.654	-2.562
30 min to Rest	*55.412*	3.118	.001	43.380	67.443
30 min to 15 min	.725	1.130	1.000	-3.637	5.088
30 min to 45 min	-1.706	1.211	1.000	-6.380	2.968
30 min to 60 min	-1.451	1.141	1.000	-5.855	2.953
30 min to 75 min	-2.451	1.558	1.000	-8.463	3.561
30 min to 90 min	-1.863	1.773	1.000	-8.706	4.980
30 min to 105 min	-4.627	1.628	.423	-10.909	1.654
30 min to 120 min	*-7.882*	1.926	.031	-15.313	-.451
45 min to Rest	*57.118*	3.316	.001	44.321	69.914
45 min to 15 min	2.431	1.598	1.000	-3.734	8.597
45 min to 30 min	1.706	1.211	1.000	-2.968	6.380
45 min to 60 min	.255	1.190	1.000	-4.339	4.849
45 min to 75 min	-.745	1.243	1.000	-5.541	4.051
45 min to 90 min	-.157	1.526	1.000	-6.047	5.734
45 min to 105 min	-2.922	1.582	1.000	-9.025	3.181
45 min to 120 min	-6.176	1.906	.184	-13.532	1.179
60 min to Rest	*56.863*	2.971	.001	45.399	68.327
60 min to 15 min	2.176	1.388	1.000	-3.179	7.532
60 min to 30 min	1.451	1.141	1.000	-2.953	5.855
60 min to 45 min	-.255	1.190	1.000	-4.849	4.339
60 min to 75 min	-1.000	1.077	1.000	-5.158	3.158
60 min to 90 min	-.412	1.539	1.000	-6.349	5.526
60 min to 105 min	-3.176	1.060	.308	-7.268	.915
60 min to 120 min	*-6.431*	1.472	.017	-12.111	-.751

Based on estimated marginal means. * The mean difference is significant at the .05 level. Bonferroni.

Table H5-Continued. Heart Rate: Long Ride Main Effect of Time

(I)Time (J)Time	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval - Lower	95% Confidence Interval - Upper
75 min to Rest	*57.863*	2.734	.001	47.311	68.415
75 min to 15 min	3.176	1.613	1.000	-3.048	9.401
75 min to 30 min	2.451	1.558	1.000	-3.561	8.463
75 min to 45 min	.745	1.243	1.000	-4.051	5.541
75 min to 60 min	1.000	1.077	1.000	-3.158	5.158
75 min to 90 min	.588	.973	1.000	-3.166	4.343
75 min to 105 min	-2.176	1.040	1.000	-6.189	1.836
75 min to 120 min	*-5.431*	1.263	.020	-10.306	-.557
90 min to Rest	*57.275*	2.514	.001	47.573	66.976
90 min to 15 min	2.588	1.494	1.000	-3.175	8.352
90 min to 30 min	1.863	1.773	1.000	-4.980	8.706
90 min to 45 min	.157	1.526	1.000	-5.734	6.047
90 min to 60 min	.412	1.539	1.000	-5.526	6.349
90 min to 75 min	-.588	.973	1.000	-4.343	3.166
90 min to 105 min	-2.765	1.318	1.000	-7.853	2.323
90 min to 120 min	*-6.020*	1.381	.018	-11.348	-.691
105 min to Rest	*60.039*	2.822	.001	49.151	70.928
105 min to 15 min	5.353	1.572	.130	-.713	11.419
105 min to 30 min	4.627	1.628	.423	-1.654	10.909
105 min to 45 min	2.922	1.582	1.000	-3.181	9.025
105 min to 60 min	3.176	1.060	.308	-.915	7.268
105 min to 75 min	2.176	1.040	1.000	-1.836	6.189
105 min to 90 min	2.765	1.318	1.000	-2.323	7.853
105 min to 120 min	-3.255	.987	.163	-7.062	.553
120 min to Rest	*63.294*	2.301	*.001*	54.415	72.173
120 min to 15 min	*8.608*	1.567	*.002*	2.562	14.654
120 min to 30 min	*7.882*	1.926	*.031*	.451	15.313
120 min to 45 min	6.176	1.906	.184	-1.179	13.532
120 min to 60 min	*6.431*	1.472	*.017*	.751	12.111
120 min to 75 min	*5.431*	1.263	*.020*	.557	10.306
120 min to 90 min	*6.020*	1.381	*.018*	.691	11.348
120 min to 105 min	3.255	.987	.163	-.553	7.062

Based on estimated marginal means. * The mean difference is significant at the .05 level. Bonferroni.

Table H5-Continued. Heart Rate: Long Ride Estimates of Means, Drink by Time

Drink by Time		Mean	Std. Error	95% Confidence Interval – Lower	95% Confidence Interval – Upper
Glucola	Rest	75.647	3.190	68.885	82.410
	15 min	130.000	3.405	122.781	137.219
	30 min	129.235	3.550	121.711	136.760
	45 min	131.000	3.767	123.014	138.986
	60 min	130.118	3.426	122.856	137.379
	75 min	129.706	3.389	122.522	136.890
	90 min	127.294	3.635	119.589	134.999
	105 min	131.529	3.615	123.866	139.193
	120 min	134.353	3.254	127.455	141.251
Milk	Rest	71.000	3.000	64.640	77.360
	15 min	127.353	3.233	120.498	134.208
	30 min	132.647	3.681	124.843	140.451
	45 min	131.412	3.618	123.742	139.081
	60 min	131.765	3.782	123.747	139.783
	75 min	134.882	3.886	126.644	143.121
	90 min	136.412	3.756	128.449	144.375
	105 min	139.294	4.197	130.397	148.192
	120 min	141.176	4.500	131.636	150.716
Placebo	Rest	77.059	2.701	71.332	82.786
	15 min	130.412	3.807	122.341	138.482
	30 min	128.059	4.224	119.104	137.013
	45 min	132.647	3.587	125.043	140.251
	60 min	132.412	3.502	124.988	139.836
	75 min	132.706	2.928	126.499	138.912
	90 min	131.824	2.797	125.893	137.754
	105 min	133.000	3.389	125.816	140.184
	120 min	138.059	2.939	131.829	144.289

Table H5-Continued. Heart Rate: Long Ride Drink by Time Interaction – Glucola Effect

Drink x Time (I) x Time (J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval – Lower	95% Confidence Interval – Upper
Glucola x Rest x 15 min	-*54.353*	4.429	.001	-71.445	-37.261
Glucola x Rest x 30 min	-*53.588*	4.095	.001	-69.389	-37.788
Glucola x Rest x 45 min	-*55.353*	4.498	.001	-72.709	-37.997
Glucola x Rest x 60 min	-*54.471*	4.080	.001	-70.216	-38.725
Glucola x Rest x 75 min	-*54.059*	3.933	.001	-69.235	-38.882
Glucola x Rest x 90 min	-*51.647*	3.572	.001	-65.430	-37.864
Glucola x Rest x 105 min	-*55.882*	3.930	.001	-71.049	-40.715
Glucola x Rest x 120 min	*58.706*	3.576	.001	-72.504	-44.908
Glucola x 15 min x Rest	*54.353*	4.429	.001	37.261	71.445
Glucola x 15 min x 30 min	.765	2.062	1.000	-7.194	8.724
Glucola x 15 min x 45 min	-1.000	2.208	1.000	-9.520	7.520
Glucola x 15 min x 60 min	-.118	2.236	1.000	-8.746	8.510
Glucola x 15 min x 75 min	.294	2.419	1.000	-9.040	9.629
Glucola x 15 min x 90 min	2.706	2.669	1.000	-7.593	13.005
Glucola x 15 min x 105 min	-1.529	2.898	1.000	-12.712	9.653
Glucola x 15 min x 120 min	-4.353	2.675	1.000	-14.674	5.969
Glucola x 30 min x Rest	*53.588*	4.095	.001	37.788	69.389
Glucola x 30 min x 15 min	-.765	2.062	1.000	-8.724	7.194
Glucola x 30 min x 45 min	-1.765	1.777	1.000	-8.623	5.093
Glucola x 30 min x 60 min	-.882	1.689	1.000	-7.399	5.635
Glucola x 30 min x 75 min	-.471	2.142	1.000	-8.737	7.796
Glucola x 30 min x 90 min	1.941	3.181	1.000	-10.336	14.218
Glucola x 30 min x 105 min	-2.294	1.976	1.000	-9.918	5.329
Glucola x 30 min x 120 min	-5.118	1.723	.325	-11.768	1.532
Glucola x 45 min x Rest	*55.353*	4.498	.001	37.997	72.709
Glucola x 45 min x 15 min	1.000	2.208	1.000	-7.520	9.520
Glucola x 45 min x 30 min	1.765	1.777	1.000	-5.093	8.623
Glucola x 45 min x 60 min	.882	1.153	1.000	-3.568	5.333
Glucola x 45 min x 75 min	1.294	1.631	1.000	-5.000	7.588
Glucola x 45 min x 90 min	3.706	3.045	1.000	-8.044	15.455
Glucola x 45 min x 105 min	-.529	2.102	1.000	-8.642	7.584
Glucola x 45 min x 120 min	-3.353	1.784	1.000	-10.238	3.532

Based on estimated marginal means. * The mean difference is significant at the .05 level. Bonferroni.

Table H5-Continued. Heart Rate: Long Ride Drink by Time Interaction – Glucola Effect

Drink x Time (I) x Time (J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval – Lower	95% Confidence Interval - Upper
Glucola x 60 min x Rest	*54.471*	4.080	.001	38.725	70.216
Glucola x 60 min x 15 min	.118	2.236	1.000	-8.510	8.746
Glucola x 60 min x 30 min	.882	1.689	1.000	-5.635	7.399
Glucola x 60 min x 45 min	-.882	1.153	1.000	-5.333	3.568
Glucola x 60 min x 75 min	.412	1.004	1.000	-3.462	4.286
Glucola x 60 min x 90 min	2.824	2.758	1.000	-7.818	13.465
Glucola x 60 min x 105 min	-1.412	1.881	1.000	-8.669	5.846
Glucola x 60 min x 120 min	-4.235	1.392	.279	-9.607	1.136
Glucola x 75 min x Rest	*54.059*	3.933	.001	38.882	69.235
Glucola x 75 min x 15 min	-.294	2.419	1.000	-9.629	9.040
Glucola x 75 min x 30 min	.471	2.142	1.000	-7.796	8.737
Glucola x 75 min x 45 min	-1.294	1.631	1.000	-7.588	5.000
Glucola x 75 min x 60 min	-.412	1.004	1.000	-4.286	3.462
Glucola x 75 min x 90 min	2.412	2.500	1.000	-7.236	12.059
Glucola x 75 min x 105 min	-1.824	1.948	1.000	-9.342	5.695
Glucola x 75 min x 120 min	-4.647	1.328	.107	-9.773	.479
Glucola x 90 min x Rest	*51.647*	3.572	.001	37.864	55.430
Glucola x 90 min x 15 min	-2.706	2.669	1.000	-13.005	7.593
Glucola x 90 min x 30 min	-1.941	3.181	1.000	-14.218	10.336
Glucola x 90 min x 45 min	-3.706	3.045	1.000	-15.455	8.044
Glucola x 90 min x 60 min	-2.824	2.758	1.000	-13.465	7.818
Glucola x 90 min x 75 min	-2.412	2.500	1.000	-12.059	7.236
Glucola x 90 min x 105 min	-4.235	2.971	1.000	-15.701	7.230
Glucola x 90 min x 120 min	-7.059	2.779	.786	-17.784	3.666
Glucola x 105 min x Rest	*55.882*	3.930	.001	40.715	71.049
Glucola x 105 min x 15 min	1.529	2.898	1.000	-9.653	12.712
Glucola x 105 min x 30 min	2.294	1.976	1.000	-5.329	9.918
Glucola x 105 min x 45 min	.529	2.102	1.000	-7.584	8.642
Glucola x 105 min x 60 min	1.412	1.881	1.000	-5.846	8.669
Glucola x 105 min x 75 min	1.824	1.948	1.000	-5.695	9.342
Glucola x 105 min x 90 min	4.235	2.971	1.000	-7.230	15.701
Glucola x 105 min x 120 min	-2.824	1.463	1.000	-8.471	2.824
Glucola x 120 min x Rest	*55.706*	3.576	.001	44.908	72.504
Glucola x 120 min x 15 min	4.353	2.675	1.000	-5.969	14.674
Glucola x 120 min x 30 min	5.118	1.723	.325	-1.532	11.768
Glucola x 120 min x 45 min	3.353	1.784	1.000	-3.532	10.238
Glucola x 120 min x 60 min	4.235	1.392	.279	-1.136	9.607
Glucola x 120 min x 75 min	4.647	1.328	.107	-.479	9.773
Glucola x 120 min x 90 min	7.059	2.779	.786	-3.666	17.784
Glucola x 120 min x 105 min	2.824	1.463	1.000	-2.824	8.471

Based on estimated marginal means. * The mean difference is significant at the .05 level. Bonferroni.

Table H5-Continued. Heart Rate: Long Ride Drink by Time Interaction – Milk Effect

Drink x Time (I) x Time (J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval – Lower	95% Confidence Interval – Upper
Milk x Rest x 15 min	-*56.353*	4.005	.001	-72.000	-40.706
Milk x Rest x 30 min	-*61.647*	4.279	.001	-78.159	-45.135
Milk x Rest x 45 min	-*60.412*	4.566	.001	-78.031	-42.793
Milk x Rest x 60 min	-*60.765*	4.417	.001	-77.810	-43.719
Milk x Rest x 75 min	-*63.882*	3.962	.001	-79.172	-48.593
Milk x Rest x 90 min	-*65.412*	4.016	.001	-80.908	-49.916
Milk x Rest x 105 min	-*68.294*	4.229	.001	-84.612	-51.976
Milk x Rest x 120 min	-*70.176*	4.368	.001	-87.030	-53.322
Milk x 15 min x Rest	*56.353*	4.055	.001	40.706	72.000
Milk x 15 min x 30 min	-5.294	2.572	1.000	-15.220	4.632
Milk x 15 min x 45 min	-4.059	2.423	1.000	-13.409	5.292
Milk x 15 min x 60 min	-4.412	2.086	1.000	-12.463	3.640
Milk x 15 min x 75 min	-7.529	3.451	1.000	-20.848	5.790
Milk x 15 min x 90 min	-9.059	3.293	.511	-21.765	3.647
Milk x 15 min x 105 min	-11.941	3.400	.104	-25.063	1.181
Milk x 15 min x 120 min	-13.824	3.429	.035	-27.056	-.591
Milk x 30 min x Rest	*61.647*	4.279	.001	45.135	78.159
Milk x 30 min x 15 min	5.294	2.572	1.000	-4.632	15.220
Milk x 30 min x 45 min	1.235	1.276	1.000	-3.690	6.160
Milk x 30 min x 60 min	.882	1.472	1.000	-4.800	6.565
Milk x 30 min x 75 min	-2.235	2.870	1.000	-13.312	8.841
Milk x 30 min x 90 min	-3.765	2.653	1.000	-14.004	6.475
Milk x 30 min x 105 min	-6.647	2.937	1.000	-17.980	4.686
Milk x 30 min x 120 min	-8.529	2.906	.349	-19.742	2.683
Milk x 45 min x Rest	*60.412*	4.566	.001	42.793	78.031
Milk x 45 min x 15 min	4.059	2.423	1.000	-5.292	13.409
Milk x 45 min x 30 min	-1.235	1.276	1.000	-6.160	3.690
Milk x 45 min x 60 min	-.353	1.606	1.000	-6.552	5.846
Milk x 45 min x 75 min	-3.471	2.928	1.000	-14.770	7.829
Milk x 45 min x 90 min	-5.000	2.683	1.000	-15.354	5.354
Milk x 45 min x 105 min	-7.882	3.024	.687	-19.553	3.788
Milk x 45 min x 120 min	-9.765	3.062	.206	-21.583	2.053
Milk x 60 min x Rest	*60.765*	4.417	.001	43.719	77.810
Milk x 60 min x 15 min	4.412	2.086	1.000	-3.640	12.463
Milk x 60 min x 30 min	-.882	1.472	1.000	-6.565	4.800
Milk x 60 min x 45 min	.353	1.606	1.000	-5.846	6.552
Milk x 60 min x 75 min	-3.118	3.027	1.000	-14.798	8.562
Milk x 60 min x 90 min	-4.647	2.959	1.000	-16.066	6.772
Milk x 60 min x 105 min	-7.529	2.923	.731	-18.810	3.751
Milk x 60 min x 120 min	-9.412	2.817	.149	-20.282	1.458

Based on estimated marginal means. * The mean difference is significant at the .05 level. Bonferroni.

Table H5-Continued. Heart Rate: Long Ride Drink by Time Interaction – Milk Effect

Drink x Time (I) x Time (J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval – Lower	95% Confidence Interval – Upper
Milk x 75min x Rest	*63.882*	3.962	.001	48.593	79.172
Milk x 75 min x 15 min	7.529	3.451	1.000	-5.790	20.848
Milk x 75 min x 30 min	2.235	2.870	1.000	-8.841	13.312
Milk x 75 min x 45 min	3.471	2.928	1.000	-7.829	14.770
Milk x 75 min x 60 min	3.118	3.027	1.000	-8.562	14.798
Milk x 75 min x 90 min	-1.529	1.301	1.000	-6.549	3.490
Milk x 75 min x 105 min	-4.412	1.500	.345	-10.201	1.377
Milk x 75 min x 120 min	-6.294	2.097	.304	-14.384	1.796
Milk x 90min x Rest	*65.412*	4.016	.001	49.916	80.908
Milk x 90 min x 15 min	9.059	3.293	.511	-3.647	21.765
Milk x 90 min x 30 min	3.765	2.653	1.000	-6.475	14.004
Milk x 90 min x 45 min	5.000	2.683	1.000	-5.354	15.354
Milk x 90 min x 60 min	4.647	2.959	1.000	-6.772	16.066
Milk x 90 min x 75 min	1.529	1.301	1.000	-3.490	6.549
Milk x 90 min x 105 min	-2.882	1.331	1.000	-8.018	2.253
Milk x 90 min x 120 min	-4.765	1.518	.229	-10.624	1.094
Milk x 105 min x Rest	*68.294*	4.229	.001	51.976	84.612
Milk x 105 min x 15 min	11.941	3.400	.104	-1.181	25.063
Milk x 105 min x 30 min	6.647	2.937	1.000	-4.686	17.980
Milk x 105 min x 45 min	7.882	3.024	.687	-3.788	19.553
Milk x 105 min x 60 min	7.529	2.923	.731	-3.751	18.810
Milk x 105 min x 75 min	4.412	1.500	.345	-1.377	10.201
Milk x 105 min x 90 min	2.882	1.331	1.000	-2.253	8.018
Milk x 105 min x 120 min	-1.882	1.230	1.000	-6.630	2.866
Milk x 120 min x Rest	*70.176*	4.368	.001	53.322	87.030
Milk x 120 min x 15 min	*13.824*	3.429	.035	.591	27.056
Milk x 120 min x 30 min	8.529	2.906	.349	-2.683	19.742
Milk x 120 min x 45 min	9.765	3.062	.206	-2.053	21.583
Milk x 120 min x 60 min	9.412	2.817	.149	-1.458	20.282
Milk x 120 min x 75 min	6.294	2.097	.304	-1.796	14.384
Milk x 120 min x 90 min	4.765	1.518	.229	-1.094	10.624
Milk x 120 min x 105 min	1.882	1.230	1.000	-2.866	6.630

Based on estimated marginal means. * The mean difference is significant at the .05 level. Bonferroni.

Table H5-Continued. Heart Rate: Long Ride Drink by Time Interaction – Placebo Effect

Drink x Time (I) x Time (J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval – Lower	95% Confidence Interval – Upper
Placebo x Rest x 15 min	-.53.353*	3.169	.001	-65.583	-41.123
Placebo x Rest x 30 min	-.51.000*	3.565	.001	-64.755	-37.245
Placebo x Rest x 45 min	-.55.588*	3.681	.001	-69.794	-41.382
Placebo x Rest x 60 min	-.55.353*	3.224	.001	-67.796	-42.910
Placebo x Rest x 75 min	-.55.647*	3.236	.001	-68.134	-43.160
Placebo x Rest x 90 min	-.54.765*	3.118	.001	-66.798	-42.731
Placebo x Rest x 105 min	-.55.941*	3.359	.001	-68.903	-42.979
Placebo x Rest x 120 min	-.61.000*	3.266	.001	-73.605	-48.395
Placebo x 15 min x Rest	.53.353*	3.169	.001	41.123	65.583
Placebo x 15 min x 30 min	.2.353	1.693	1.000	-4.181	8.887
Placebo x 15 min x 45 min	-.2.235	2.319	1.000	-11.185	6.715
Placebo x 15 min x 60 min	-.2.000	2.769	1.000	-12.687	8.687
Placebo x 15 min x 75 min	-.2.294	2.263	1.000	-11.029	6.440
Placebo x 15 min x 90 min	-.1.412	2.463	1.000	-10.917	8.093
Placebo x 15 min x 105 min	-.2.588	2.309	1.000	-11.498	6.322
Placebo x 15 min x 120 min	-.7.647	3.016	.793	-19.285	3.991
Placebo x 30 min x Rest	.51.000*	3.565	.001	37.245	64.755
Placebo x 30 min x 15 min	-.2.353	1.693	1.000	-8.887	4.181
Placebo x 30 min x 45 min	-.4.588	2.142	1.000	-12.855	3.678
Placebo x 30 min x 60 min	-.4.353	2.728	1.000	-14.879	6.173
Placebo x 30 min x 75 min	-.4.647	2.198	1.000	-13.128	3.834
Placebo x 30 min x 90 min	-.3.765	2.514	1.000	-13.466	5.937
Placebo x 30 min x 105 min	-.4.941	2.630	1.000	-15.089	5.207
Placebo x 30 min x 120 min	-.10.000	3.689	.556	-24.236	4.236
Placebo x 45 min x Rest	.55.588*	3.681	.001	41.382	69.794
Placebo x 45 min x 15 min	.2.235	2.319	1.000	-6.715	11.185
Placebo x 45 min x 30 min	.4.588	2.142	1.000	-3.678	12.855
Placebo x 45 min x 60 min	.2.35	2.488	1.000	-9.364	9.834
Placebo x 45 min x 75 min	-.059	1.332	1.000	-5.201	5.083
Placebo x 45 min x 90 min	.824	1.871	1.000	-6.398	8.045
Placebo x 45 min x 105 min	-.353	2.775	1.000	-11.060	10.354
Placebo x 45 min x 120 min	-.5.412	3.503	1.000	-18.930	8.107
Placebo x 60 min x Rest	.55.353*	3.224	.001	42.910	67.796
Placebo x 60 min x 15 min	.2.000	2.769	1.000	-8.687	12.687
Placebo x 60 min x 30 min	.4.353	2.728	1.000	-6.173	14.879
Placebo x 60 min x 45 min	-.235	2.488	1.000	-9.834	9.364
Placebo x 60 min x 75 min	-.294	1.886	1.000	-7.572	6.984
Placebo x 60 min x 90 min	.588	2.063	1.000	-7.374	8.551
Placebo x 60 min x 105 min	-.588	2.181	1.000	-9.005	7.829
Placebo x 60 min x 120 min	-.5.647	2.904	1.000	-16.854	5.559

Based on estimated marginal means. * The mean difference is significant at the .05 level. Bonferroni.

Table H5-Continued. Heart Rate: Long Ride Drink by Time Interaction – Placebo Effect

Drink x Time (I) x Time (J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval – Lower	95% Confidence Interval – Upper
Placebo x 75min x Rest	*55.647*	3.236	.001	43.160	68.134
Placebo x 75 min x 15 min	2.294	2.263	1.000	-6.440	11.029
Placebo x 75 min x 30 min	4.647	2.198	1.000	-3.834	13.128
Placebo x 75 min x 45 min	.059	1.332	1.000	-5.083	5.201
Placebo x 75 min x 60 min	.294	1.886	1.000	-6.984	7.572
Placebo x 75 min x 90 min	.882	1.300	1.000	-4.135	5.899
Placebo x 75 min x 105 min	-.294	2.152	1.000	-8.598	8.010
Placebo x 75 min x 120 min	-5.353	3.046	1.000	-17.108	6.402
Placebo x 90min x Rest	*54.768*	3.118	.001	42.731	66.798
Placebo x 90 min x 15 min	1.412	2.463	1.000	-8.093	10.917
Placebo x 90 min x 30 min	3.765	2.514	1.000	-5.937	13.466
Placebo x 90 min x 45 min	-.824	1.871	1.000	-8.045	6.398
Placebo x 90 min x 60 min	-.588	2.063	1.000	-8.551	7.374
Placebo x 90 min x 75 min	-.882	1.300	1.000	-5.899	4.135
Placebo x 90 min x 105 min	-1.176	1.463	1.000	-6.824	4.171
Placebo x 90 min x 120 min	-6.235	2.459	.794	-15.725	3.255
Placebo x 105 min x Rest	*55.941*	3.359	.001	42.979	68.903
Placebo x 105 min x 15 min	2.588	2.309	1.000	-6.322	11.498
Placebo x 105 min x 30 min	4.941	2.630	1.000	-5.207	15.089
Placebo x 105 min x 45 min	.353	2.775	1.000	-10.354	11.060
Placebo x 105 min x 60 min	.588	2.181	1.000	-7.829	9.005
Placebo x 105 min x 75 min	.294	2.152	1.000	-8.010	8.598
Placebo x 105 min x 90 min	1.176	1.463	1.000	-4.471	6.824
Placebo x 105 min x 120 min	-5.059	2.141	1.000	-13.321	3.204
Placebo x 120 min x Rest	*61.000*	3.266	.001	48.395	73.605
Placebo x 120 min x 15 min	7.647	3.016	.793	-3.991	19.285
Placebo x 120 min x 30 min	10.000	3.689	.556	-4.236	24.236
Placebo x 120 min x 45 min	5.412	3.503	1.000	-8.107	18.930
Placebo x 120 min x 60 min	5.647	2.904	1.000	-5.559	16.854
Placebo x 120 min x 75 min	5.353	3.046	1.000	-6.402	17.108
Placebo x 120 min x 90 min	6.235	2.459	.794	-3.255	15.725
Placebo x 120 min x 105 min	5.059	2.141	1.000	-3.204	13.321

Based on estimated marginal means. * The mean difference is significant at the .05 level. Bonferroni.

Table H6. Respiratory Exchange Ratio Data, Bonferroni post hoc test (Main Effect: Time x Condition).

Respiratory Exchange Ratio: Long Ride Means of Drinks

Drink	Mean	Std. Error	95% Confidence Interval – Lower Boundary	95% Confidence Interval – Upper Boundary
(1) Glucola	.945	.012	.920	.970
(2) Milk	.948	.009	.928	.967
(3) Placebo	.931	.013	.904	.958

Respiratory Exchange Ratio: Long Ride Means of Drinks at Specific Time Points

Time	Mean	Std. Error	95% Confidence Interval – Lower Boundary	95% Confidence Interval – Upper Boundary
Rest	.925	.017	.888	.961
15 Minutes	.994	.013	.967	1.022
30 Minutes	.955	.009	.937	.973
45 Minutes	.936	.011	.913	.959
60 Minutes	.935	.009	.916	.953
75 Minutes	.946	.010	.924	.968
90 Minutes	.929	.011	.907	.952
105 Minutes	.934	.014	.905	.963
120 Minutes	.917	.011	.894	.939

Table H6-Continued. Respiratory Exchange Ratio: Long Ride Main Effect of Time

(I)Time (J)Time	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval - Lower	95% Confidence Interval - Upper
Rest to 15 min	*-.070*	.014	.005	-.124	-.015
Rest to 30 min	-.031	.015	1.000	-.090	.029
Rest to 45 min	-.012	.014	1.000	-.066	.042
Rest to 60 min	-.010	.015	1.000	-.067	.047
Rest to 75 min	-.022	.015	1.000	-.081	.038
Rest to 90 min	-.005	.016	1.000	-.066	.056
Rest to 105 min	-.010	.015	1.000	-.068	.048
Rest to 120 min	.008	.018	1.000	-.061	.076
15 min to Rest	*.070*	.014	.005	.015	.124
15 min 30 min	*.039*	.008	.006	.008	.070
15 min to 45 min	*.058*	.008	.001	.028	.088
15 min to 60 min	*.060*	.010	.001	.020	.099
15 min to 75 min	*.048*	.010	.009	.008	.088
15 min to 90 min	*.065*	.011	.001	.024	.106
15min to 105 min	*.060*	.012	.004	.015	.105
15 min to 120 min	*.077*	.012	.001	.032	.122
30 min to Rest	.031	.015	1.000	-.029	.090
30 min to 15 min	*-.039*	.008	.006	-.070	-.008
30 min to 45 min	-.019	.008	1.000	-.014	.052
30 min to 60 min	.021	.008	.996	-.012	.053
30 min to 75 min	-.009	.009	1.000	-.024	.042
30 min to 90 min	.026	.009	.324	-.008	.059
30 min to 105 min	.021	.012	1.000	-.026	.068
30 min to 120 min	*.038*	.009	.016	.005	.072
45 min to Rest	.012	.014	1.000	-.042	.066
45 min to 15 min	*-.058*	.008	.001	-.088	-.028
45 min to 30 min	-.019	.008	1.000	-.052	.014
45 min to 60 min	-.002	.009	1.000	-.035	.038
45 min to 75 min	-.010	.009	1.000	-.046	.026
45 min to 90 min	.007	.009	1.000	-.027	.041
45 min to 105 min	.002	.011	1.000	-.042	.046
45 min to 120 min	.019	.009	1.000	-.017	.056
60 min to Rest	.010	.015	1.000	-.047	.067
60 min to 15 min	*-.060*	.010	.001	-.099	-.020
60 min to 30 min	-.021	.008	.996	-.053	.012
60 min to 45 min	.002	.009	1.000	-.038	.035
60 min to 75 min	.012	.006	1.000	-.037	.013
60 min to 90 min	.005	.008	1.000	-.026	.037
60 min to 105 min	.001	.011	1.000	-.041	.041
60 min to 120 min	.018	.011	1.000	-.026	.062

Based on estimated marginal means. * The mean difference is significant at the .05 level. Bonferroni.

Table H6-Continued. Respiratory Exchange Ratio: Main Effect of Time

(I)Time (J)Time	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval – Lower	95% Confidence Interval – Upper
75 min to Rest	.022	.015	1.000	-.038	.081
75 min to 15 min	*-.048	.010	.009	-.088	-.008
75 min to 30 min	-.009	.009	1.000	-.042	.024
75 min to 45 min	.010	.009	1.000	-.026	.046
75 min to 60 min	.012	.006	1.000	-.013	.037
75 min to 90 min	.017	.006	.498	-.007	.040
75 min to 105 min	.012	.009	1.000	-.024	.047
75 min to 120 min	.029	.012	.786	-.015	.074
90 min to Rest	.005	.016	1.000	-.056	.066
90 min to 15 min	*-.065*	.011	.001	-.106	-.008
90 min to 30 min	-.026	.009	.324	-.059	.024
90 min to 45 min	-.007	.009	1.000	-.041	.046
90 min to 60 min	-.005	.008	1.000	-.037	.037
90 min to 75 min	-.017	.006	.498	-.040	.040
90 min to 105 min	-.005	.006	1.000	-.030	.047
90 min to 120 min	.012	.011	1.000	-.028	.074
105 min to Rest	.010	.015	1.000	-.048	.066
105 min to 15 min	*.060*	.012	.004	-.105	-.024
105 min to 30 min	-.021	.012	1.000	-.068	.008
105 min to 45 min	-.002	.011	1.000	-.046	.027
105 min to 60 min	.001	.011	1.000	-.041	.026
105 min to 75 min	-.012	.009	1.000	-.047	.007
105 min to 90 min	.005	.006	1.000	-.019	.019
105 min to 120 min	.017	.013	1.000	-.034	.053
120 min to Rest	-.008	.018	1.000	-.076	.061
120 min to 15 min	*-.077*	.012	.001	-.122	-.032
120 min to 30 min	*-.038*	.009	.016	-.072	-.005
120 min to 45 min	-.019	.009	1.000	-.056	.017
120 min to 60 min	-.018	.011	1.000	-.062	.026
120 min to 75 min	-.029	.012	.786	-.074	.015
120 min to 90 min	-.012	.011	1.000	-.053	.028
120 min to 105 min	-.017	.013	1.000	-.069	.034

Based on estimated marginal means. * The mean difference is significant at the .05 level. Bonferroni.

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BIOGRAPHICAL SKETCH

I was born in Tullahoma, Tennessee. My father was from Mississippi and was a civil engineer for the U.S. Army Corps of Engineers. My mother was from Louisiana and was a school teacher. Both grew up during the Great Depression and World War II.

My early education was parochial after which I graduated from the University of South Alabama with a bachelor's degree in Geography and immediately obtained another bachelor's degree in Education. I taught various subjects in middle schools in Alabama for several years before starting graduate school at the United States Sports Academy where I earned a M.S.S. in Fitness Management (and should have received a concurrent M.S.S. in Sports Medicine). My doctoral work was at the University of Southern Mississippi where I earned advanced degrees in Exercise Physiology and Public Health. I came to Florida State University to culminate my formal education in Sport Nutrition.

My teaching experiences include the American Red Cross in the Mobile, AL Chapter and the Lowcountry Chapter (South Carolina) where I taught many swimming and First aid courses. I taught for several years at one of the oldest African-American schools in Alabama, Mobile County Training School, where I taught 7th and 8th grade reading, math, and science. I also taught reading and social studies at Scott School in Birmingham, AL. After my graduate education I taught at the College of Charleston in Charleston, SC for a number of years where I was assigned to teach health education and some exercise physiology. While pursuing the graduate degree at Florida State University I taught as an adjunct at FSU and Tallahassee Community College. I have also taught karate (Shotokan style) as an adjunct professor at the University of South Alabama, Spring Hill College, University of Alabama at Birmingham, University of Southern Mississippi, the College of Charleston, and at Valdosta State University.

My work experience outside of academia includes throwing newspapers, interior and exterior painting, lifeguarding, concession sales, histological lab work, and experience as a diamond drill (U.S. Army Corps of Engineers) core drill operator/helper on the Tennessee Tombigbee Waterway and the Santee-Cooper River Re-diversion Projects. As a supervisor for a geotechnical testing company I performed subsurface soil (drilling) inspection, concrete inspection, dam impoundment inspection (Brookwood, AL), and high-rise steel inspection (Birmingham).

I have actively participated in karate training since 1969. My teachers have included Mr. Takayuki Mikami and Mr. Shigeru Takashina, and many other Senior Instructors of the Japan Karate Association. I have earned a fourth dan rank and have successfully earned Instructor status with the Japan Karate Association of Tokyo, Japan.

I have a brother who is FAA Inspector certified and who keeps helicopters flying. I have a younger sister who is a Navy Captain and who also has a terminal degree and several master's degrees. My older sister loves me unconditionally and has two wonderful daughters (nieces). My wife is a native Japanese nurse. She loves to cook, read, and do karate with me (she can beat me up).

I have traveled to many places by auto, train, plane, and by thumb and foot. I have met many wonderful people and some very strange ones. I intend to meet many more and have many more adventures. My motto is from *Seven Pillars of Wisdom* by Thomas Edward Lawrence, "All men dream, but not equally. Most men dream in the dusty recesses of their minds and wake to find their dreams but vanity, but, some men dream with their eyes open. These are dangerous men for they are awake to see their dreams come true. This I did."