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## **The Effect of a Low Glycemic vs. High Glycemic Pre-Exercise Meal in Recreationally Trained Endurance Cyclists**

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<sup>1</sup>University of West Florida, Exercise Science and Health Promotion, Pensacola, FL, USA, <sup>2</sup>Valdosta State University, Department of Psychology, Valdosta, GA, USA, <sup>3</sup>University of North Florida, Department of Nursing, Jacksonville, FL, <sup>4</sup>Florida State University, Department of Nutrition, Food, and Exercise Science, Tallahassee, Florida, USA

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### **ABSTRACT**

**Waggener GT, Kwon I, Wiley L, Lee Y, Nichols IH, Haymes, E.** The Effect of a Low Glycemic vs. High Glycemic Pre-Exercise Meal in Recreationally Trained Endurance Cyclists. **JEP**online 2016;19 (2):91-98. The purpose of this study was to examine the effects of two iso-kilocaloric (837.2 kJ) pre-exercise meals: a low glycemic meal (LGM) vs. a high glycemic meal (HGM) and a placebo meal in recreational cyclists on endurance cycling. After a 2-d high carbohydrate diet and abstention from exercise, 18 healthy recreationally trained male subjects aged 18 to 35 yrs with a  $\text{VO}_2$  max of  $3.94 \pm 0.6 \text{ L}\cdot\text{min}^{-1}$  participated in this within-subject design study. Each of three rides consisted of 2 hr of cycling exercise at 55%  $\text{VO}_2$  max followed by a brief 30 min rest and a moderately high intensity ride to exhaustion at 80%  $\text{VO}_2$  max. The LGM did not exert a greater ergogenic effect in this study when compared to the iso-kilocaloric HGM. While the effect was not statistically significant, the HGM meal outperformed the LGM and the placebo on time to exhaustion. A fiber-free, glucose-derived meal may be superior to a low glycemic fiber-free whole meal in supporting moderately high intensity exercise in some highly motivated recreationally trained endurance athletes.

**Key Words:** Whole Milk, Pre-Exercise Meals, High Glycemic, Low Glycemic, Fiber-Free.

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## INTRODUCTION

The major carbohydrate in milk is the disaccharide lactose (4.8% cow's milk) made from the monosaccharides D-glucose and D-galactose. Lactose is cleaved by the enzyme lactase in the small intestine to form glucose and galactose, both simple sugars. Other nutrients found in low concentrations in cow milk include some free galactose, neutral and acid oligosaccharides, sugar phosphates, and nucleotide sugars (10). 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 to 78%) fatty acids. Of the nearly 400 different fatty acid derivatives found in whole milk most are saturated (65%) while the other fats are monounsaturated (32%) and polyunsaturated (3%). Milk proteins, at 3.2 to 3.8% per volume measure, consist primarily of casein at 80% and whey at 20% (8). The dominant protein, casein, 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, 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. Milk is a significant source of calcium and phosphorus, which are found in milk but primarily associated with the casein protein (4). Whole milk, at a glycemic index of 41, is a low glycemic food (7). With all these nutritive and ergogenic components, it would follow that milk, or a milk-derived supplement, should contribute to endurance exercise.

Only a small number of studies have examined the use of milk: whole, low fat or fat free, as a pre-exercise meal in endurance exercise (2,6,11,13,14). The results have been equivocal, most likely due to methodological differences. In a study on the effects of a low glycemic meal (LGM) on endurance cycling and cycling to exhaustion by DeMarko et al. (2), milk with banana and cornflakes was one of the components of the high glycemic meal (identified as HGM). In their study, the HGM did not contribute to maximal performance following endurance performance as well as the LGM meal that consisted of All-bran, apple, and unsweetened yogurt. They attributed the difference to the effect of fiber.

Completely lacking fiber, whole milk still has potential ergogenic effects. In the present study it was hypothesized that a low glycemic (LGM) pre-exercise meal of whole milk, (GI = 41), would equal or surpass the effects of an iso-kilocaloric, high glycemic (HGM) pre-exercise meal of glucose, (GI = 100), versus an artificially flavored placebo on selected hemodynamic and respiratory variables during a 2-hr submaximal steady state ride at 55% of  $\text{VO}_2$  max, followed by brief rest, and then time to exhaustion (TTE) at 80% of  $\text{VO}_2$  max.

## METHODS

### Subjects

Eighteen subjects (male, mean age 26.7 yrs) from a local cycling club, a local military base, a local regional university, and the general community in a Southern semi-rural community in the USA, volunteered to participate in this study. All subjects claimed to be recreationally trained cyclists or better. The study was approved by the Institutional Review Board. A medical history and an informed consent was administered and signed by each subject. Anyone indicating a positive personal, family history of disease, or an allergy to cow's milk was excluded from participation. The subjects were informed that milk would be one of the

test meals and discouraged from discussing the contents of any of the meals prior to and during the rides.

The subjects were recreationally trained cyclists when compared to more elite riders (3-5). The rather wide range of relative  $\text{VO}_2$  max values of the subjects in this study were indicative of the range of talent found in a semi-rural setting in the South. Notwithstanding, each subject in this study was able to finish each of the three rides (Table 1).

### **Procedures**

Preliminary maximal oxygen consumption for each subject was obtained using a continuous cycling protocol on a Monark 819 Cycle Ergometer at least 1 wk prior to the first ride. The initial resistance was set at 0 and increased 30 watts every 3 min until exhaustion (5). Zero resistance was set for the rider to accustom themselves to the Monark. When a steady state  $\text{VO}_2$  was achieved at each stage and maintained for 1 min, resistance was increased.  $\text{VO}_2$  max was determined when absolute  $\text{VO}_2$  plateaued, when lactate concentration reached  $8.0 \text{ mmol}\cdot\text{L}^{-1}$ , when RER exceeded 1.15, and when the subject indicated a RPE at 17 or above.

To ensure glycogen stores were optimal for the long ride, dietary intakes of the subjects in this study were recorded for a 2-d period prior to each ride. Each subject was instructed to consume a diet high ( $\geq 60\%$ ) in complex carbohydrates for 2 d prior to each test and to keep a written record of what was consumed. The mean caloric intake of the subjects in this study was  $13,914 \text{ kJ} \pm 883 \text{ kJ}$ . The subjects reported a daily 60.5% total carbohydrate intake ( $8,419.7 \text{ kJ} \pm 433.3 \text{ kJ}$ ). On the day of the test, each subject arrived by automobile at 6 am in a fasting state (nothing but water consumed after dinner the previous night). The subjects turned in their 2-d diet record for validation of the minimum carbohydrate intake. Each trial was performed in the same environment at the same time of the morning to minimize the effects of circadian rhythms.

Similar to the procedures of Leijssen, Saris, Jeukendrup, and Wagenmakers (12) where eight volunteers rode for 2 hrs at 65% of work max, rested for 60 min, then rode a second time at 60% of work max for 30 min, our riders rode for 2 hrs at 55% of the previously determined  $\text{VO}_2$  max, rested for 30 min, then rode to exhaustion at 80 to 85%  $\text{VO}_2$  max.

Thirty-five minutes prior to the ride each trial subjects were weighed and seated. A registered nurse fitted each subject with an indwelling catheter in a vein located in the forearm for blood collection throughout the test. After a baseline measure was drawn the subjects consumed one of the drinks, chilled and delivered in an opaque container to hide the identity of the drink from both the subject and the tester. Subjects were discouraged from discussing the contents of the meal with personnel collecting data. Each subject then rested quietly for 30 min in a chair and allowed to drink water to encourage gastric emptying and absorption.

The test drinks in this study consisted of whole cow's milk (837.2 kJ / 320 ml fluid volume: 16 g carbohydrate, 10.7 g fat, and 10.7 g protein; Publix, Inc.) and two contrast drinks, one consisting of glucose polymer drink iso-kilocaloric to the whole milk supplement (837.2 kJ / 300 ml fluid volume: 50 g carbohydrate, 0 g fat, and 0 g protein; Cardinal Health, McGraw Park, IL) and a placebo/control drink (water). The placebo was an artificially flavored, unsweetened beverage (2 g of NutraSweet in 300 ml bottled water; Merisant, US, Inc., Chicago).

Blood measurements were made at baseline prior to consumption of the test drink, after resting 30 min, every 30 min during the steady state ride, and at the end of the time to exhaustion ride (TTE). All blood samples were kept 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 vacutainer with antiglycolytic sodium fluoride and into an untreated vacutainer. Blood samples were coded, cooled in a refrigerator for at least 15 min, and centrifuged for 20 min at 3260 rev·min<sup>-1</sup> 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. All hematological assays, with the exception of lactate, were performed in duplicate.

Lactates from each sampling were analyzed immediately in the 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 using a glucose (oxidase) reagent (#23666287). The glucose oxidase reagent and a glucose standard (#23666277) were purchased from Fischer Scientific Company, P. O. Box 4829, Norcross, GA, 30091, USA. Glycerol was measured using GPO (glucose peroxidase) trinder reagent (#A FG0100). Glycerol, and the glycerol standard (#G 1394), were purchased from Sigma, P. O. Box 14508, St. Louis, MO, 63178-9916, USA. Glucose and glycerol were analyzed using a spectrophotometer (Beckman DU640) Corona, CA. Free fatty acids were measured 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.

Cardiovascular measurements were taken at rest, at 15-min intervals throughout the long ride, and continuously during the short ride. Oxygen consumption measures were obtained with the subject 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) was 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, high intensity ride.

For the steady state ride (120 min), the exercise intensity was set at 55% of VO<sub>2</sub> max. During the steady state ride, VO<sub>2</sub>, respiratory exchange ratios (RER), and heart rates (HR) were measured every 15 min. Blood was sampled every 30 min. Cool water *ad libitum* was provided to maintain plasma volume. Temperature in the laboratory remained fairly constant between 20° and 27° C and the subjects were fan cooled. Each of the three trials was separated from the others by 1 to 2 wks to ensure adequate recovery time and to minimize any learning effect on subsequent trials. There were no hematological or cardiorespiratory differences between the trials on cycling loads, thus indicating the subjects were continuing

their riding activities between the trials. All testing protocols occurred in the morning between 6 and 11 am to minimize the effects of circadian rhythms. For maximum subject comfort, the cycle was fitted with Aero-bars. Most subjects brought their own pedals and clip-on shoes. Personal pedals were fitted to the cycle ergometer by the tester while the subject rested quietly.

Following the 120 min steady state ride, each subject rested in a chair for 30 min during which no measurements were taken. After the 30 min rest the subject then began riding at a speed  $\geq 60$  RPM at a resistance equal to  $80\% \pm 5\%$  of their previously determined  $\text{VO}_2$  max. Subjects could not consume water during the ride because they were fitted with a one-way breathing valve for  $\text{O}_2$  measurement. TTE was measured after the subject attained at least two consecutive measurements  $\geq 80\%$   $\text{VO}_2$  max to the point where the subject either voluntarily stopped, or the subject could not maintain a pedaling rate required to remain a  $\text{VO}_2$  equal to or greater than  $80\%$  of their  $\text{VO}_2$  max. Measurements of oxygen uptake, RER, and RPE were taken each minute. A final blood sample was drawn at exhaustion and, then, the subject was allowed to cool down. Upon completing each ride, subjects were fed a high carbohydrate diet and scheduled for their next ride.

**Table 1. Subject Characteristics: Demographic, Cardiovascular, and Hematologic Variables (Mean  $\pm$  SD).**

Variable	
Age (yrs)	26.7 $\pm$ 5.7
Height (cm)	182 $\pm$ 5.3
Weight (kg)	78.2 $\pm$ 8.7
$\text{VO}_2$ max (mL $\cdot$ kg $^{-1}$ $\cdot$ min $^{-1}$ )	50.8 $\pm$ 8.0
$\text{VO}_2$ max (L $\cdot$ min $^{-1}$ )	3.94 $\pm$ 0.6
HR max (beats $\cdot$ min $^{-1}$ )	181 $\pm$ 12
RER max	1.2 $\pm$ 0.1
Lactate max (mmol $\cdot$ L $^{-1}$ )	10.1 $\pm$ 1.5
Calculated 55% $\text{VO}_2$ (mL $\cdot$ kg $^{-1}$ $\cdot$ min $^{-1}$ )	28.0 $\pm$ 4.4
Calculated 80% $\text{VO}_2$ (mL $\cdot$ kg $^{-1}$ $\cdot$ min $^{-1}$ )	40.7 $\pm$ 6.4

### Statistical Analysis

The data were analyzed using repeated measures two-way analysis of variance (general linear model) to test for differences between the means, for main effects, and for interactions. Bonferonni analysis was used for *post hoc* analyses. The alpha level was set at  $P < 0.05$  for all statistical tests. Statistical procedures were performed using a Statistical Program for Social Sciences (SPSS 21) software. Values are reported as means  $\pm$  SD. Eighteen subjects were chosen to participate to double the potential of the study since most other studies in the literature had half that number.

## RESULTS

The means of the test drinks on blood glucose were not significantly different though there was a significant effect for time and meal by time as glucose initially rose then fell. Similarly, glycerol was not different between the meals but rose over time. During the ride the means of the FFA for the iso-kilocaloric meals (LGM and HGM) were significantly lower than the mean of the placebo. The means of the FFA and the glycerol for the three meals increased significantly, in parallel fashion, over time to the end of the ride, which suggested that fats were being used during the ride. The means of the test drinks on lactate and for RER fell significantly in parallel fashion over time. The difference in TTE was not statistically significant, but TTE for HGM was 17% greater than the placebo and 15.6% greater than LGM. TTE for LGM was only 2% greater than the placebo.

**Table 2. Repeated Measures Two-Way Analysis of Variance (P<0.05).**

Variables	HGM	LGM	Placebo	Meal Sig	Time Sig	M x T Sig	P
<b>Glucose</b> (mg)	80.5 ± .13	79.3 ± .22	75.2 ± .15	NS	Sig	Sig	.001
<b>Glycerol</b> (mmol)	0.17 ± .15	0.14 ± .05	0.16 ± .07	NS	Sig	NS	.001
<b>FFA</b> (mmol)	0.51 ± .25	0.51 ± .20	0.69 ± .34	Sig	Sig	NS	.001
<b>Lactate</b> (mmol)	2.7 ± .61	2.6 ± .71	2.6 ± .50	NS	Sig	NS	.001
<b>RER</b>	0.95 ± .07	0.95 ± .06	0.94 ± .07	NS	Sig	NS	.001
<b>TTE</b> (min)	14.1 ± 10.1	11.9 ± 7.7	11.7 ± 7.2	NS			

## DISCUSSION

Few studies have used a low glycemic meal such as whole milk as a pre-exercise meal with the intent of determining its effect on endurance exercise capacity (6,11,13). An early study where a carbohydrate supplement was matched against a non-caloric placebo and a mixed meal of whole cow's milk, suggested that the effect of whole milk was similar to that of carbohydrate at moderate and high intensity exercise in men and women and that both were no better than a placebo (6). The authors concluded that lipid mobilization was impeded by both the carbohydrate and milk meals and that this negatively influenced time to exhaustion by drawing on endogenous carbohydrate reserves.

In the present study, LGM and HGM equally dampened the FFA response during the long ride. However, the significant interaction over time showed that fats were recruited to sustain the moderately high intensity ride (Table 2). Also, while the differences were not significantly

different, the HGM resulted in a 17% longer ride than the placebo and the LGM meal was 16% longer than the placebo. It is likely that the amount of kJ supplementation used in our study may not have been enough to sustain the moderately high intensity ride for very long, 837.2 kJ vs. 1255.8 kJ in the Foster et al. study (6).

Lee and colleagues (11) investigated the effect of milk-based products on exercise capacity in eight healthy males, comparing a carbohydrate-electrolyte solution to 0.1% fat milk, 0.1% fat milk with added glucose, to a placebo (water), on four separate occasions. Unlike the present study where the subjects consumed their meal prior to exercise and diluted it with water *ad libitum*, Lee et al. (11) administered 1.5 mL·kg<sup>-1</sup> body mass of a test drink to their subjects before, and every 10-min during, cycling to volitional exhaustion at 70% VO<sub>2</sub> peak. Not surprisingly, they did not find any significant differences between the drinks because the high nutrient content of the meals most likely impeded gastric emptying, as suggested by Foster and colleagues (6), reducing nutrient uptake and energy replacement.

Similar to the present study where the effects of pre-exercise meals were compared on two cycling bouts, long and short term, Okano et al. (14) investigated the effects of an iso-kilocaloric meal of fat compared to a carbohydrate meal (4877 kJ) on a 2-hr ride (65% of VO<sub>2</sub> max) followed by a time to exhaustion ride (78% of VO<sub>2</sub> max). Assuming blood FFA from a meal consumed prior to exercise might contribute to the exercise they found no significant differences in time to exhaustion between the two meals. Their subjects were fed a breakfast of 2490 kJ (55% CHO, 31% fat, and 11% protein), and their subjects waited 4.5 hrs for the meal to digest. They were then fed either the FM or the CHO meal and waited another 4 hrs before their endurance ride. They found no significant differences in time to exhaustion between the two meals.

The subjects in our study arrived by car at 6 am fasted and only consumed water after dinner the previous night. Our subjects were fed their test meal and rested for 30 min, ample time for the test-meal to clear the stomach. In addition, they were encouraged to consume water while they waited to ride and during the long ride. During the ride the means of the FFA for the iso-kilocaloric meals (HGM vs. LGM) were significantly lower than the mean of the placebo. However, the means of the FFA and the glycerol for all three meals increased significantly, in parallel fashion, over time to the end of the ride suggesting that fats were being recruited and used during the ride. The subjects' RER rose initially (min 30) then fell over time (to min 120), thus corroborating the use of fatty acids for energy. Energy for the long ride most likely came from endogenous adipose tissue of the subjects and may have conserved carbohydrate usage as evidenced in the results of the ride to exhaustion where the TTE for HGM exceeded the LGM and placebo meals. Although differences in the TTE were not statistically significant,  $F(2, 52) = .428, P=.654$ , when inability to work as hard or harder than the opponent, e.g., exhaustion is the unintended outcome measure, small differences may be significant. Mean blood glucose concentrations at the end of the 80% ride were close to normal, 75.2 mg·dL<sup>-1</sup>, 81.5 mg·dL<sup>-1</sup>, and 74.6 mg·dL<sup>-1</sup> for HGM, LGM, and the placebo trials.

The HGM supplement did not result in a statistically significant advantage in TTE. Yet, the subjects were still able to ride somewhat longer than the placebo following the HGM supplement, unlike the results of Foster et al. (6). In the present study, the subjects were able to ride 17% longer after consuming carbohydrate (HGM) than they could on the placebo,

and 15.6% longer than after consuming the milk (LGM) drink, but because the variances in our study were so great these results were not statistically significant.

In this study, as in the study by Miller et al. (13), the HGM and LGM blunted the decrease in RER. Milk (LGM) and glucola (HGM) both contain sugars, lactose and glucose, respectively, which would raise RER for a given workload while the placebo, devoid of carbohydrate, would stimulate lipolysis and lower RER. The contents from the HGM and glucose and lactose derived from LGM may have caused RER to rise briefly during the middle of the long ride compared to the placebo because of the relatively fast absorption of glucose in the duodenum and delayed absorption of lactose in the duodenum and jejunum (1,12).

This study replicated, in part, the landmark studies by Foster et al. (6) and that of Okano et al. (14). Although the earlier study by Foster et al. (6) used the same meals, they used higher energy intakes (1255.8 kJ) in each of the two energy drinks compared to the 837.2 kJ used in the present study. This may represent a significant difference in the metabolic responses and the conclusions that can be drawn. The subjects in the Foster et al. (6) study were tested six times with long, low intensity rides and short, high intensity rides separated by about a week. In the present study, the subjects were tested three times and performed long, low intensity rides and short, high intensity rides on the same test day, back-to-back, with long rides and TTE rides separated by 30 min of rest. There was a notable difference in intensity between Foster's study and our study. In the Foster et al. (6) study, the short ride was set at a workload requiring 100% of  $\text{VO}_2$  max and intended to only last about 5 min. Finally, Foster and colleagues' riders pedaled the entire time at 80% and 100% of their maximal oxygen consumption while the subjects in the present study pedaled at less intense rates that correspond to 55% and 80% of  $\text{VO}_2$  max for long and short rides, respectively.

## CONCLUSIONS

We propose several factors that may have contributed to our results (9). First, the pre-exercise meal may not have been high enough in nutrients to off-set the catabolism of glycogen occurring between the previous night's meal to the early morning ride. Lack of adequate phosphocreatine (Pcr) could have played a role in the lack of significance between the meals on the long ride and TTE. We did not measure muscle glycogen. It is likely that muscle or liver glycogen from the previous 2 d may have been used as a fuel earlier in the ride than anticipated even though the subjects abstained from exercise and consumed high carbohydrate meals 2 d prior to each trial. The blunted FFA responses during the long ride suggest muscle glycogen mobilization. An accumulation of  $\text{H}^+$  may have contributed to the subjects' fatigue. Even though lactate measures rose briefly to minute 30, they fell gradually to near beginning values by the end of the long ride at minute 120. This suggests a balance between lactate production and clearance. Finally, impaired relaxation could have contributed to the brevity of the TTE. Even though the cyclists used a cycle-saddle, 'Aero bars', and their own pedals for comfort, the Monark 819 cycle ergometer is still relatively cramped compared to the bicycles the subjects normally ride. A cramped ride could have caused co-contraction of antagonist muscles, resulting in reduced perfusion of tissue with oxygen and increased feelings of fatigue that resulted in early termination of the ride.

The short coming of the present study was that we did not measure how much water each subject consumed during the 2-hr ride. Hence, we do not know whether more water was



consumed with one meal or the other or the effect that may have had on the results of the current study. We would suggest that, when examining the effect of isolated nutrients against one another in exhaustive exercise, future clinical studies should include the measurement of *ad libitum* water consumption in the protocol where dehydration is not an intended outcome measure and that this water, however much it is, should be considered in the results that follow.

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