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The Effect of Various Carbohydrate Supplements on Postprandial Blood Glucose Response in Female Soccer Players

Nina Pannoni

University of South Florida, soccerbean02@cox.net

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The Effect of Various Carbohydrate Supplements on Postprandial Blood Glucose
Response in Female Soccer Players

by

Nina S. Pannoni

A thesis submitted in partial fulfillment
of the requirements for the degree of
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Department of Physical Education
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Major Professor: William Campbell, Ph.D.
Candi Ashley, Ph.D.
Marcus Kilpartick, Ph.D.

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Abstract

PURPOSE: The purpose of this study is to examine the effects of different types of carbohydrates on blood glucose response in collegiate soccer athletes at rest. This will help to determine the effectiveness of a carbohydrate supplement in providing sustained energy and maintained performance if ingested prior to a soccer match. **METHODS:** In a cross-over design, 10 female collegiate soccer players ($n= 10$, age $20.10 \pm .99$ years, height 65.55 ± 2.77 inches, weight 64.12 ± 8.36 kilograms) from the University of South Florida reported to the laboratory on five separate occasions after an overnight fast. Once a baseline blood glucose measurement was obtained, subjects ingested one of four different carbohydrate beverages (dextrose, maltodextrin, Vitargo®, and waxy maize) and a control (water). Each subject consumed 1 gram of carbohydrate per kilogram body weight in a 7% solution. Order of carbohydrate and control supplements was randomly assigned for each participant. After the subject ingested one of the test beverages blood glucose measurements were taken at the 30, 45, 60, 90, 120, and 180 minute time points (a total of three hours). The same procedures took place during each subject's visit. A series of one-way analysis of variance (ANOVA) were performed using SPSS 19 to determine differences in the blood glucose response at each time point between the carbohydrate supplements. **RESULTS:** No significant difference existed between treatments for blood glucose levels at baseline. At 30, 45, and 60 minutes, blood glucose concentrations following dextrose, maltodextrin, and Vitargo® ingestion were

significantly higher as compared to the placebo ingestion. No significant difference was observed between waxy maize and placebo at these time points. At ninety minutes the blood glucose concentrations for dextrose and Vitargo® were significantly higher than placebo, and at 120 minutes only Vitargo® was significantly higher than the placebo. Finally, at 180 minutes, the blood glucose concentration for waxy maize was significantly higher than all other treatments. CONCLUSION: The main finding of this study was that waxy maize does not observe a sharp increase in blood glucose response following ingestion but maintains an elevated blood glucose concentration over an extended period of time. All other treatments (maltodextrin, dextrose, and Vitargo®) resulted in a significant rise in blood glucose within the first thirty minutes following ingestion.

Chapter 1: Introduction

Athletes are always looking for ways to improve performance and obtain a competitive advantage over their competitors. This is especially true for endurance athletes and athletes who perform high-intensity, intermittent activities, such as soccer. Research suggests that the availability of carbohydrates becomes a limiting factor in prolonged sessions lasting more than 90 minutes of intermittent high-intensity exercise (Burke, Kiens, & Ivy, 2004). The major function of carbohydrates is to provide energy and act as a source of fuel to the working body (Smolin & Grosvenor, 2003). Consequently, it is important to maximize carbohydrate stores prior to exercise in order to minimize the potential effects of carbohydrate depletion, which could negatively affect energy availability and fatigue (Hargreaves, et al., 2004). Carbohydrate ingestion prior to activity has been shown to delay the onset of fatigue and may be responsible for improved performance in the later portions of a match or session (Ostojic & Mazic, 2002). In theory, carbohydrates have the potential to impact the performance of an individual during high-intensity, intermittent activities of long duration. Achieving such improved performance and sustained energy could be as simple as knowing the correct fuel to ingest prior to a match or bout of exercise. This knowledge would benefit elite athletes who are trying to gain an edge over their competition. Most researchers agree that carbohydrate ingestion prior to endurance and high-intensity, intermittent activities will help to sustain energy, maintain glucose levels, and improve performance. Further

research is needed to determine which type of carbohydrate would best sustain blood glucose, energy production, and improve performance for such athletes.

Purpose

The purpose of this study is to examine the effects of different carbohydrates on blood glucose response in collegiate soccer athletes at rest. This will help to determine the effectiveness of a carbohydrate supplement in providing sustained energy and maintained performance if ingested prior to a soccer match.

Study Variables

The independent variable, or treatments, in this investigation is the pre-exercise carbohydrate supplement given to the participants. There are five levels of the independent variable, all of which are commercially available: a waxy maize starch (sold as GlycoCharge®), dextrose, maltodextrin, barley starch (sold as Vitargo®), and a water control (which will be similar in volume to the other ingested beverages) (See Table 1 for treatment descriptions). The four carbohydrate supplements were chosen based off previous research and the theoretical established rate of digestion for each type of carbohydrate. Rate of digestion ranges from fast to slow and has implications to be beneficial in various circumstances. The dependent variables will include blood glucose response at 7 time points (baseline and 30, 45, 60, 90, 120, and 180 minutes following ingestion).

Treatment	Description	Rate of Digestion
Waxy Maize	A starched derived from corn that has naturally high levels of amylopectin	Slow
Glucose	Most common monosaccharide	Moderate
Maltodextrin	Rapidly absorbed polysaccharide	Fast
Vitargo	Vitargo® (barley starch) is a patented carbohydrate with unique properties, specially formulated for athletes to give an effective loading of easily accessible muscle energy (glycogen) in the body.	Fast
Water	Control	Control

Table 1. Treatments

Hypotheses

Ho₁: There will be no difference in blood glucose levels at baseline.

Ho₂: There will be no difference between the five treatments in relation to blood glucose 30 minutes after ingestion.

Ho₃: There will be no difference between the five treatments in relation to blood glucose 45 minutes after ingestion.

Ho₄: There will be no difference between the five treatments in relation to blood glucose 60 minutes after ingestion.

Ho₅: There will be no difference between the five treatments in relation to blood glucose 90 minutes after ingestion.

Ho₆: There will be no difference between the five treatments in relation to blood glucose 120 minutes after ingestion.

Ho₇: There will be no difference between the five treatments in relation to blood glucose 180 minutes after ingestion.

Limitations

The limitations of this study relate mainly to the chosen sample. For this study, physically active females were recruited from the University of South Florida women's Varsity soccer team. Because of the homogenous sample, it may not sufficiently represent the larger population of female soccer players. Since the sample may not accurately represent the population, the significance and generalizability of the results may be hindered. There is also a limitation in the participant's adherence to the pre-testing requirements of an eight-hour, overnight fast and refraining from strenuous exercise the day before testing. If participants are not capable of following these requirements the results may be altered.

Delimitations

The delimitations or specific limitations that were imposed in this research design deal with the sample chosen and the supplements chosen. As mentioned before, the participants were physically active females from the University of South Florida women's Varsity soccer team and were chosen to represent the larger female soccer players population. These participants ranged in age, height, weight, and body composition, which may increase generalizability. Additionally, there is delimitation in the carbohydrate beverages chosen for this study. The carbohydrate supplements were chosen based off previous research and the theoretical established rate of digestion for each type of carbohydrate. If the carbohydrates do not represent their theoretical rate of digestions the results of this study may be inaccurate.

Chapter 2: Review of Literature

Introduction

Over the years, researchers have developed many studies that assess the postprandial metabolic responses to carbohydrate ingestion. Early researchers studied this subject in depth to apply their results to diabetes, improving glucose tolerance and reducing insulin resistance (Hallfrisch & Behall, 2000; Macdonald, Kesyer, & Pacy, 1978; Behall, Scholfield, & Canary, 1988, Lehmann & Robin, 2007). Recent studies have examined blood glucose response to carbohydrate ingestion with a focus on its application to endurance events (Sparks, Selig, & Febbraio, 1998; DeMarco, Sucher, Cisar, & Butterfield, 1999). The major function of carbohydrates in the body is to provide energy and act as a fuel for the working body (Smolin & Grosvenor, 2003). Therefore, a carbohydrate that has the ability to provide sustained energy and maintain blood glucose might be ideal. This can be assessed by applying the theory of the glycemic index to timing of carbohydrate ingestion. The glycemic index ranks foods based on their glycemic response (DeMarco et.al., 1999). Glycemic response is defined by Smolin and Grosvenor (2003) as the postprandial rate, magnitude, and duration of the rise in blood glucose. Generally, foods that rank lower in the glycemic index have a slower increase in blood glucose after a meal and sustained blood glucose levels over time when compared to foods that have a high glycemic ranking (Smolin & Grosvenor, 2003; Lehmann & Robin, 2007).

Carbohydrates have been separated into three major categories based on digestion and glycemic response; rapidly digestible, slowly digestible, and resistant (Sands, Leidy, Hamaker, Maguire, & Campbell, 2009). Rapidly digestible carbohydrates are generally digested within 20 minutes while slowly digested carbohydrates can take between 20 and 120 minutes (Sands et al., 2009; Lehmann & Robin, 2007). Resistant carbohydrates, such as some legumes, consist of those that are not digested or absorbed in the small intestines (Sands et al., 2009). The glycemic response of foods is often affected by the composition of the food or meal being ingested (Smolin & Grosvenor, 2003).

Digestion and Absorption of Carbohydrates

The average adult diet contains at least 50% of the total calorie intake from carbohydrates (Holmes, 1971). In general, carbohydrates cannot be absorbed in their natural form and therefore must be digested to become useful (Guyton & Hall, 2000). The basic process in carbohydrate digestion is considered to be hydrolysis (Holmes, 1971; Guyton & Hall, 2000). The majority of carbohydrates in the diet are polysaccharides and disaccharides (Guyton & Hall, 2000). Through the process of hydrolysis these larger carbohydrates are broken down to the smaller final product, monosaccharides (Guyton & Hall, 2000). The three most common monosaccharides are glucose, fructose, and galactose (Smolin & Grosvenor, 2003). Monosaccharides and disaccharides (composed of two monosaccharides) are both considered simple sugars. Common disaccharides include maltose, sucrose, and lactose (Smolin & Grosvenor, 2003). Complex carbohydrates, polysaccharides and oligosaccharides are made up of many monosaccharides linked together. Complex carbohydrates include glycogen, starch, and fiber (Smolin & Grosvenor, 2003).

Carbohydrate digestion begins in the mouth when food is ingested. As food is chewed, it is mixed with the enzyme salivary α - amylase (Guyton & Hall, 2000; Smolin & Grosvenor, 2003). This begins the process of hydrolysis; however, only about 5% of the carbohydrates that are eaten are hydrolyzed before they are swallowed (Guyton & Hall, 2000). Digestion of carbohydrates slows as the food enters the stomach and is mixed with its acidic secretions (Guyton & Hall, 2000). A large amount of carbohydrate digestion occurs in the small intestines through the action of the pancreatic enzyme α -amylase and enzymes that are attached to the brush border of the intestinal villi (Smolin & Grosvenor, 2003; Guyton & Hall, 2000). The final product of all carbohydrate digestion is monosaccharides.

Carbohydrates are generally absorbed as monosaccharides (Guyton & Hall, 2000; Smolin & Grosvenor, 2003). More than 80% of all carbohydrates are absorbed as glucose, which is the final digestive product of the most common carbohydrates - starches (Guyton & Hall, 2000). Galactose and Glucose absorption occurs in a co-transport mode with the active transport of sodium (Guyton & Hall, 2000). The active transport of sodium through the membranes of epithelial cells provides the driving force to also move glucose through the membranes (Guyton & Hall, 2000). Fructose, the other monosaccharide, is converted to glucose as it enters the epithelial cell by facilitated diffusion; it is then transported as glucose into the paracellular space (Guyton & Hall, 2000). The monosaccharides are then absorbed and transported to the liver via the hepatic portal circulation system (Smolin & Grosvenor, 2003).

Effects of Carbohydrate Ingestion on Blood Glucose Response

Researchers have been examining the effects of the ingestion of different carbohydrates on blood glucose or glycemic response for some time. Glycemic response is the postprandial rate, magnitude, and duration of the rise in blood glucose (Smolin & Grosvenor, 2003). Foods that have a slower increase in blood glucose after a meal are considered low glycemic index foods and may maintain blood glucose levels over time when compared to foods that have a high glycemic index ranking (Smolin & Grosvenor, 2003; Lehmann & Robin, 2007). Foods that have a high glycemic index tend to have a quick rise and fall in blood glucose after a meal (Lehmann & Robin, 2007).

Sands, Leidy, Hamaker, Maguire, and Campbell (2009) examined the blunted plasma glucose response to the slow digesting starch waxy maize. It is said that this slow digestion and subsequent blunted plasma glucose response may lead to prolonged energy availability when compared to a more rapidly digested starch. This study recruited twelve physically fit subjects (six male and six female) through advertisements in local newspapers, businesses, and in buildings on the Purdue University Campus. The study was a randomized, crossover study consisting of three treatments conducted on three separate days over five weeks with one or more days between testing days. Subjects arrived to the laboratory after a ten hour fast and laid supine as a catheter was placed in their non-dominant arm to take blood samples measuring blood glucose and insulin. The subjects consumed 50 grams of carbohydrate from one of three experimental treatments, white bread control, maltodextrin, or waxy maize. Over the next four hours blood sampling, appetite and mood questionnaires, and resting energy expenditure were measured.

Results showed the blood glucose response of the white bread control to be similar to that of waxy maize. Both had a gradual increase in plasma glucose to 60 minutes and a gradual lowering over the four-hour period (Sands et al., 2009). The blood glucose response from maltodextrin was higher and faster and had a more drastic decline after peak. The blood glucose response of waxy maize suggests that it may be a more suitable carbohydrate if a slower and prolonged release of energy is desired (Sands et al., 2009).

The different blood glucose response to different carbohydrates inspired some researchers to look at what could cause such responses. Behall, Scholfield, and Canary (1988) looked at how the structure of starches affected postprandial metabolic responses. Twenty-five healthy volunteers (12 women and 13 men) were given two treatment meals, fed in a crossover design, separated by two weeks (Subjects came in on test days after a ten hour fast; blood was drawn at baseline and at 30, 60, 120, and 180 minutes after the meal was ingested. The meals contained a food grade cornstarch mixture that was either 70% amylose and 30% amylopectin or 30% amylose and 70% amylopectin (Behall, Scholfield, & Canary, 1988). Amylose and amylopectin differ in structure based on their type of glucose linkages. Amylose only has α -1,4 glucose linkages while amylopectin has α -1,4 and α -1,6 glucose linkages.

Thirty minutes after ingestion, the meal with high amylose showed significantly lower plasma glucose levels than after the meal high in amylopectin (Behall, Scholfield, & Canary, 1988). The mean glucose level over the three-hour assessment after both meals was higher in the meal high in amylose. The high amylose meal also resulted in lower peak plasma glucose levels and less variation from fasting values (Behall,

Scholfield, & Canary, 1988). These results showed that the composition of starches plays a role in blood glucose response; foods that are high in amylose appear to have the desired glucose response endurance athletes would look for in a pre-exercise meal (i.e., slow digesting carbohydrates or low glycemic foods which will have a blunted response in blood glucose levels after ingestion of food.)

Another study examined the effect that different loads of carbohydrates would have on serum glucose levels (Macdonald, Keyser, & Pacy, 1978). The carbohydrates that were examined in this study included glucose, fructose, sucrose, and sorbitol. Sorbitol is a sugar alcohol that the human body metabolizes slowly and is often marketed as a sugar substitute and provides 2.6 kilocalories per gram. Four doses of each carbohydrate, except for sorbitol, which only had three doses, were given to each of the nine subjects in a random order. The nine subjects that participated in this study were all male and were either medical or dental students (Macdonald, Keyser, & Pacy, 1978). The doses of each carbohydrate were 0.25, 0.5, 0.75, and 1.0 gram per kilogram body weight (sorbitol was not given in 1.0 gram dose due to negative side effects). Each solution was taken after a twelve hour fast and blood measures were taken at 15, 30, 60, and 90 minutes after ingestion (Macdonald, Keyser, & Pacy, 1978).

The serum glucose levels were similar at all dose levels of glucose, and, although levels of serum glucose increased with each dose the differences were not significant (Macdonald, Keyser, & Pacy, 1978). The increase in blood glucose following ingestion of fructose was only significant with 0.5 and 0.75 gram per kilogram of bodyweight doses and there was no significant increase in blood glucose with the different doses of sorbitol. The mean increase in serum glucose after sucrose ingestion was slightly less

than glucose, but not significantly different (Macdonald, Keyser, & Pacy, 1978).

Therefore, the amount of glucose, sorbitol, and sucrose ingested does not significantly alter the serum glucose.

Impact of Carbohydrate Digestion on Endurance Performance

There is a great deal of research that supports the claim that declines in blood glucose and muscle glycogen play an important role in fatigue development during prolonged exercise (Massicotte, Peronnet, Allah, Hillaire-Marcel, Ledoux, & Brisson, 1986). It is also widely accepted that maintaining a constant blood glucose level is key in performing long-lasting and intense exercise (Brouns, Rehrer, Saris, Beckers, Menheere, & Hoor, 1989; Sparks, Selig, & Febbraio, 1998; DeMarco et al., 1999; Hargreaves, Hawley, & Jeukendrup, 2004). It is believed that the fatigue associated with declines in blood glucose and muscle glycogen can be prevented during endurance type activities if an ideal pre-exercise food (carbohydrate) is consumed. Numerous studies agree that a pre-exercise meal consisting of a low-glycemic or slow digesting carbohydrate will have a positive effect on performance during prolonged exercise (DeMarco et al., 1999; Sands et al., 2009). Limited research has investigated the effects of carbohydrate ingestion on resistance training performance. Results of this research still appear to remain unclear. The ingestion of carbohydrates before resistance training may have some ergogenic benefits when combined with high volume (hypertrophic) resistance training programs (Haff, Lehmkuhl, McCoy, & Stone, 2003).

Comparing the postprandial metabolic responses to pre-exercise meals of different glycemic indices, DeMarco and colleagues (1999) discovered that a pre-exercise meal with a low glycemic index may have a positive effect on performance in endurance

or sustained exercise. Ten trained, male cyclists were recruited from cycling teams for this study. Each subject participated in three exercise trials, randomly consuming one of three meals at each trial. The control meal included only water. The high glycemic index meal (Glycemic Index (GI) = 69.3) consisted of Kellogg's Cornflakes, a banana, and milk; the low glycemic index meal (GI= 36) consisted of Kellogg's All-Bran, an apple, and unsweetened yogurt. After an overnight fast, each of the cyclists would consume one of the three test meals 30 minutes before their bout of sustained exercise (DeMarco et al., 1999). The exercise bout was performed at 70% of the cyclist's maximum oxygen uptake (VO_{2max}) and was maintained for two hours, followed by cycling to exhaustion at 100% VO_{2max} . Blood samples were taken to measure plasma insulin and glucose and ratings of perceived exertion (RPE), respiratory exchange ratios (RER), and time to exhaustion were also compared (DeMarco et al., 1999).

Results showed a more favorable plasma glucose response to the low glycemic index meal when compared to the control and high glycemic index meals. Plasma glucose levels were significantly higher in the low glycemic index and high glycemic index groups than the control (DeMarco et al., 1999). The high glycemic index meal showed a greater glycemic response before exercise and had the greatest absolute decline during the first 20 minutes of exercise. The low glycemic index meal displayed a gradual rise and fall in plasma glucose when compared to the high glycemic index meal (DeMarco et al., 1999). Between minutes 40 and 100 of the exercise, there was no significant difference between the plasma glucose levels for the three trials; however, at minute 120, the plasma glucose levels of the control and high glycemic index meals had significantly decreased while the plasma glucose of the low glycemic index meal was still being

maintained. Ratings of perceived exertions generally seemed to be lower for the low glycemic index trial than the high glycemic index trial. Finally, time to exhaustion was significantly longer in the low glycemic index trial than the high glycemic index or control trial (DeMarco et al., 1999). Overall, a pre-exercise meal with a low glycemic index may help to maintain plasma glucose levels throughout prolonged exercise and could result in improved performance and time to exhaustion.

Taking a slightly different approach to this research, Masicotte et al. (1986) examined the metabolic response to carbohydrate ingestion during exercise. Specifically they looked at the effects of glucose, fructose, or water on blood glucose response and other metabolic measures. Seven healthy male subjects performed three series of cycling bouts lasting 180 minutes every seven days. Each series of exercise was performed at a constant workload (about 50% of VO_{2max}) and was also conducted in the morning following a 12 hour overnight fast followed by a light breakfast ingested two hours before exercise. During the exercise series, subjects ingested 2 grams per kilogram of body weight of glucose, fructose, or water. The solutions were divided into nine equal volumes to be ingested every 20 minutes during the 180 minute exercise series.

The results of this study showed that the plasma glucose concentrations significantly decreased over time with the water only ingestion (Masicotte et al., 1986). However, plasma glucose remained stable throughout the exercise series with both glucose and fructose ingestion (Masicotte et al., 1986). This study illustrates that carbohydrate ingestion during exercise can help to maintain plasma glucose levels which can be beneficial in endurance activities.

Stephens, Roig, Armstrong, and Greenhaff (2008) examined the affect of post-exercise carbohydrate ingestion on a subsequent bout of cycling exercise. Eight healthy men reported to the laboratory on three randomized days that were separated by at least a week. On each visit, the participants would cycle to exhaustion at 73% of their maximal oxygen uptake. Exhaustion was determined when the participant could not maintain a pedaling cadence of 70 revolutions per minute for more than two minutes. Immediately following the exercise, participants rested in a semi-supine position on a bed for two hours and consumed one of three one liter solutions (Stephens et al., 2008). The three solutions that were consumed by each participant throughout each of their three visits were; a sugar free flavored water (control), 100 grams of a low molecular weight glucose polymer derived from hydrolyzed corn starch (Maxijul), or 100 grams of a very high molecular weight glucose polymer derived from corn starch (Vitargo®). Two hours after the consumption of the drink participants were asked to perform a 15 minute time trial on a cycle ergometer to measure work output. Blood samples were collected every ten minutes during the recovery after the carbohydrate solution had been ingested to assess blood glucose (Stephens et al., 2008).

Results showed that blood glucose remained unchanged upon consumption of the sugar-free flavored water control (Stephens et al., 2008). The blood glucose response occurred at a significantly faster rate in the high molecular weight as compared to the low molecular weight. Work output during the fifteen minute time trial was 10% higher after consumption of the high molecular weight than the low molecular weight. This positive performance factor was observed in all participants. This study shows that carbohydrate ingestion after glycogen depleting exercise, particularly a high molecular weight solution

(Vitargo®), has the capability to provide better re-synthesis of this muscle glycogen and results in improved performance on subsequent exercise bouts (Stephens et al., 2008).

Influence of Carbohydrate Ingestion on High-Intensity Intermittent Exercise Performance

High-intensity intermittent exercise involves running and walking at varying speeds, intensity, and direction and mimics the movement pattern of many sports (Nicholas, Tsintzas, Boobis, & Clyde, 1999). During prolonged high-intensity intermittent exercise, fatigue and decrements in performance are associated with reduced blood glucose concentrations, reduced and/or depleted muscle glycogen, and dehydration (Ostojic & Mazic, 2002). Specifically, during soccer, such events generally occur towards the end of a match and often result in mental fatigue, technical errors, drop in skill level, and ultimately lead to goals being scored at the end of the match (Ostojic & Mazic, 2002). The importance of carbohydrate ingestion to high-intensity intermittent exercise performance has been made clear through research (Little, Chilibeck, Ciona, Vandenberg, & Zello, 2009). Research has also suggested that the ingestion of a carbohydrate fluid before and during exercise may prevent these occurrences and have positive effects on performance (Ostojic & Mazic, 2002; Nicholas, Tsintzas, Boobis, & Clyde, 1999; Little, Chilibeck, Ciona, Vandenberg, & Zello, 2009).

The glycemic index of a pre-exercise meal has been shown to affect performance during continuous exercise. Little, Chilibeck, Ciona, Vandenberg, and Zello (2009) investigated the effects of low and high glycemic index foods on high-intensity intermittent exercise. Seven male athletes participated in three experimental trials that were separated by seven days. The three trials consisted of the ingestion of a high-glycemic food, a low-glycemic food, and a control food followed by 90 minutes of

intermittent treadmill running, simulating the activities of soccer. The foods were consumed three hours prior to and halfway through the 90 minute exercise period.

Performance was assessed by the distance that was covered in five, one minute sprints during the last 15 minutes of exercise days (Little, Chilibeck, Ciona, Vandenberg, & Zello, 2009). The mean difference in total distance covered between the low-glycemic food and the control showed an 81% chance that the low-glycemic food improved performance. The high-glycemic food showed a 76% chance against the control to also improve performance. Overall, low and high glycemic foods both improved performance when compared to a fasting control with no significant difference between the two (Little, Chilibeck, Ciona, Vandenberg, & Zello, 2009). These results show that carbohydrate ingestion in general has positive effects on performance, regardless of glycemic index.

To examine the effects of a carbohydrate-electrolyte beverage on soccer specific tests and performance, Ostojic and Mazic (2002) assessed 22 volunteer professional male soccer players during the trial. The players were divided into two teams to complete this study. The experimental design involved three phases; a soccer match, soccer -specific tests, and a relaxation-recovery phase. The soccer match consisted of two 45 minute halves with a 15 minute break in between. The second phase was completed immediately after the soccer match and consisted of four soccer- specific skills tests; dribble test, precision test, coordination test, and power test. The third and final phase was the relaxation and recovery phase. The recovery phase lasted for an hour and involved the changing of clothes, rest, and massage . To ensure that all participants had similar glycogen stores before the study, all subjects consumed the same standard diet for seven days prior to the experiment (Ostojic & Mazic, 2002).

On the day of the study, subjects consumed a standard breakfast four hours before the trial and drank only water (Ostojic & Mazic, 2002). One team was the control and ingested the placebo (water) beverage and the other team ingested the carbohydrate-electrolyte. Both teams consumed the fluid immediately before (5ml/kg body mass) the trial and every 15 minutes during the 90 minute soccer match (2 ml/kg body mass). Heart rate was monitored throughout the study and blood analysis was performed at the end of the first half of the match, upon completion of the match, and after the one hour relaxation phase (Ostojic & Mazic, 2002). Blood analysis measured blood glucose, blood lactate, plasma free fatty acids, plasma glycerol, serum sodium, potassium, and chloride.

Results from this study showed a significantly higher blood glucose concentration at the end of the first half and at the end of the second half of the match ($p < 0.05$) for the carbohydrate-electrolyte group when compared to the control (Ostojic & Mazic, 2002). Precision test scores were significantly higher and the dribble test was completed faster in the carbohydrate- electrolyte group ($p < 0.05$) than in the control group (Ostojic & Mazic, 2002). These findings support ingestion of a carbohydrate-electrolyte supplement prior to and during a soccer match to aid in improved blood glucose levels, as well as soccer performance.

Another study similarly examined the effects of carbohydrate-electrolyte ingestion during intermittent high-intensity running (Nicholas, Tsintzas, Boobis, & Clyde, 1999). This study assessed six soccer, hockey, or rugby players during two exercise trials completed seven days apart. Each exercise trial was comprised of six, 15 minute periods separated by three minutes of recovery. The 15 minute exercise period consisted of continuous 20 meter shuttles run at varying speeds in a fixed pattern that was

designed to match the activity pattern of. During this double-blind study, subjects consumed either the carbohydrate-electrolyte solution or a noncarbohydrate placebo immediately before exercise (5 ml/kg body mass, approximately 25 grams of carbohydrate) and every 15 minutes during the trial (2 ml/kg body mass for a total of about 45 grams of carbohydrate during the trial). Subjects reported to the trial after following a two day standardized diet and upon a ten hour fast. Muscle biopsies were taken before and after the 90 minute trial to assess muscle glycogen (Nicholas, Tsintzas, Boobis, & Clyde, 1999). Blood samples were taken at baseline and every 30 minutes to assess blood glucose and insulin, plasma glycerol and free fatty acids, and blood lactate. Sprint time was measured for 15 meter sprints throughout the trial.

Blood glucose concentrations were similar in each trial with no significant differences, although values tended to be higher in the carbohydrate-electrolyte group. Sprint times also remained similar between trials (Nicholas, Tsintzas, Boobis, & Clyde, 1999). The main findings of this study showed that muscle glycogen utilization was reduced by 22% when a carbohydrate-electrolyte solution was ingested prior to and during high-intensity intermittent exercise (Nicholas, Tsintzas, Boobis, & Clyde, 1999). Reducing muscle glycogen utilization may offer an improvement in endurance capacity during similar events, including soccer matches.

Present and Future Research on Carbohydrate Supplementation in Athletes

Based on previous research we know that blood glucose response to carbohydrates is important for athletes, especially those who participate in high-intensity, intermittent sports. Typical carbohydrates that are often used by athletes for pre-game supplementation include glucose and maltodextrin. Popular sports supplements that are

used by athletes include waxy maize and Vitargo®. There is a great deal of research regarding the effects of glucose and maltodextrin on blood glucose response; however, research is lacking in relation to the blood glucose response to waxy maize and Vitargo®. This study will look to test these two popular supplements against the two more widely used carbohydrates in an athletic population.

Conclusion

It is widely accepted that slow digesting carbohydrates or low glycemic foods show a blunted response in blood glucose levels after ingestion of food. Such foods would be an ideal fuel for endurance athletes who need sustained energy release during prolonged bouts of exercise. Some prior investigations have demonstrated that the ingestion of a pre-exercise carbohydrate solution can benefit performance of high-intensity intermittent exercise, such as soccer, as it is related to blood glucose concentrations, muscle glycogen levels, and improved performance. The purpose of this study is to examine the affects of different carbohydrates on blood glucose response in collegiate soccer athletes at rest. Observations of trends in blood glucose response at rest may have implications on which carbohydrates can keep blood glucose elevated during a bout of exercise.

Chapter 3: Methods

Study Design

This study utilized a crossover design with the five levels of the independent variable.

Participants

Ten females were recruited from the University of South Florida's women's varsity soccer team in Tampa, Florida ($n = 10$, age $20.10 \pm .99$ years, height 65.55 ± 2.77 inches, weight 64.12 ± 8.36 kilograms). Soccer players were selected due to the fact that they typically ingest carbohydrate supplements in conjunction with competitive matches to keep blood glucose levels elevated. Participants varied in age, height, and weight. Prior to the investigation, each participant was fully informed of the potential benefits and risks associated with participating in the trial and signed an informed consent in accordance with the Institutional Review Board (IRB). Four participants reported to the laboratory on five separate occasions and six participants reported to the laboratory on four separate occasions (refer to 'Procedures' for an explanation in the differences in number of visits below). Persons with diagnosed diabetes were excluded from this study. In addition, if a potential subject has a fasting blood glucose level of greater than 126 mg/dL, they were not allowed to participate in the study and were encouraged to make an appointment with their primary care physician. The determination of the fasting blood glucose level occurred during each visit to the laboratory after an overnight fast.

Instrumentation and Equipment

Body weight was obtained using the Tanita Digital BWB-800 A Class III scale and height was obtained using the “Health-O-Meter” Professional® height and weight scale. Blood glucose measurements were assessed using the Hemocue® Glucose 201 Analyzer (Cypress, CA). Blood glucose was measured through a finger stick with a single-use lancet device and lancets.

Procedures

Each subject reported to the laboratory on four separate occasions and followed the same procedures at each visit. Four of the subjects reported to the laboratory for an additional visit to provide blood glucose responses following the ingestion of a water control. All subjects reported to the Exercise and Performance Nutrition Laboratory after an eight-hour overnight fast. Each subject was instructed to avoid strenuous exercise the day before testing. Upon entering the laboratory, the subject’s height and weight was recorded and a baseline blood was taken via finger stick using a lancet and lancet device typically used for the assessment of blood glucose. Next, the subject consumed one of the four carbohydrate supplements (1 gram of carbohydrate per kilogram body weight) or the control supplement (refer to Table 2). The glucose and maltodextrin carbohydrate supplements were purchased from Natural Foods, Inc. (3040 Hill Avenue, Toledo, OH 43607-2983). The concentration of all carbohydrate beverages was 1 gram of carbohydrate per kilogram of body mass dissolved in a 7% solution. To attain a 7% solution the carbohydrate supplements were dissolved in approximately 24 to 30 ounces of water. Each participant was instructed to ingest the beverage within 10 minutes.

(Average ingestion time was 5.54 ± 3.36 minutes). Order of carbohydrate and control supplements was randomly assigned for each participant. After the subject ingested one of the test beverages, blood glucose measurements were taken at the 30, 45, 60, 90, 120, and 180 minute time points post- ingestion (a total of three hours). Refer to figure 1 below which describes an overview of each testing session.

Treatment	Description	Rate of Digestion
Waxy Maize	A starched derived from corn that has naturally high levels of amylopectin	Slow
Glucose	Most common monosaccharide	Moderate
Maltodextrin	Rapidly absorbed polysaccharide	Fast
Vitargo	Vitargo® is a patented carbohydrate with unique properties, specially formulated for athletes to give an effective loading of easily accessible muscle energy (glycogen) in the body.	Fast
Water	Control	Control

Table 2. Treatments

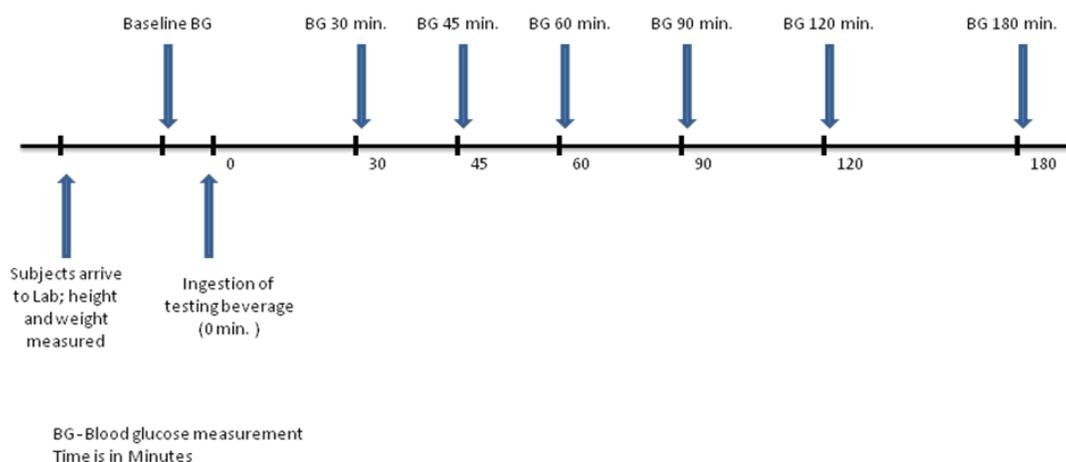


Figure 1. Overview of testing session

Statistical Analysis

An a priori power analysis was conducted to estimate the sample size needed to test the hypotheses of group differences. An effect size in another similar study investigating similar outcomes was relatively large. Sands et al. (2009) realized an effect size of 2.9 for differences in the peak blood glucose response between waxy maize carbohydrate and maltodextrin. Using this calculated effect size, an alpha level of .05, and a power of 0.8, a sample size of approximately 5-10 participants per group will be needed to detect a significant difference if one exists.

A one-way analysis of variance (ANOVA) was performed using IBM® SPSS® Statistics (version 19) at each of the seven time points to determine differences in the blood glucose response at each time point between the carbohydrate supplements. When a significant difference was detected by the repeated measures ANOVA, a pairwise comparison (with a Bonferonni adjustment for multiple comparisons) was conducted at each time point to determine where the significant difference was within the carbohydrate treatments. Effect size was also calculated on all significant findings using Cohen's d and these values are reported in the results section.

Chapter 4: Results

Ten subjects completed all aspects of testing. Due to ethical reasons and availability of resources, only four subjects completed the ingestion of the placebo control. To justify this decision, a repeated measures ANOVA was conducted to compare blood glucose response at each time point to baseline measures. There was no significant difference ($p = 0.581$) at any time point for the control group when compared to baseline. All other treatments realized a significant difference within the first thirty minutes.

Baseline Blood Glucose

H_{01} stated there would be no difference in blood glucose levels at baseline. Mean values at baseline were: placebo = 97.50 ± 1.20 , dextrose = 95.20 ± 6.22 , maltodextrin = 96.20 ± 5.73 , waxy maize = 95.20 ± 10.25 , Vitargo® = 91.40 ± 6.50 . The one-way ANOVA identified no significant difference ($p = 0.205$) in blood glucose levels at baseline. Therefore, based on these significant findings, we fail to reject the null hypothesis (H_{01}). Refer to figure 2 and table 3, which summarizes the time course changes for each treatment.

Blood Glucose at 30 Minutes

H_{02} stated there would be no difference between the five treatments in relation to blood glucose 30 minutes after ingestion. Mean values at 30 minutes were: placebo = 96.25 ± 1.52 , dextrose = 162.20 ± 23.16 , maltodextrin = 166.40 ± 22.89 , waxy maize = 120.30 ± 27.33 , Vitargo® = 164.90 ± 14.61 . The one-way ANOVA identified a

significant difference of $p < 0.001$. A pairwise comparisons (Bonferroni adjusted for multiple comparisons) revealed that there was a significant difference between the Placebo and all other treatments except waxy maize (dextrose; $p < 0.001$ [effect size = 1.9], maltodextrin; $p < 0.001$ [effect size = 5.8], and Vitargo®; $p < 0.001$ [effect size = 8.5]). There was also a significant difference between dextrose and waxy maize ($p = 0.008$ [effect size = 1.7]); maltodextrin and waxy maize ($p = 0.012$ [effect size = 1.8]); and Vitargo® and waxy maize ($p < 0.001$ [effect size = 2.1]). Therefore, based on these significant findings, we reject the null hypothesis (H_{02}). Refer to figure 2 and table 3, which summarizes the time course changes for each treatment.

Blood Glucose at 45 Minutes

H_{03} stated there would be no difference between the five treatments in relation to blood glucose 45 minutes after ingestion. Mean values at 45 minutes were: placebo = 95.00 ± 3.09 , dextrose = 134.50 ± 28.52 , maltodextrin = 132.70 ± 25.95 , waxy maize = 122.30 ± 31.034 , Vitargo® = 131.80 ± 22.67 . The one-way ANOVA identified a significant difference of $p < 0.001$. A pairwise comparisons (Bonferroni adjusted for multiple comparisons) revealed that there was a significant difference between Placebo and all other treatments except waxy maize (dextrose; $p = 0.010$ [effect size = 2.5], maltodextrin; $p = 0.009$ [effect size = 2.6], and Vitargo®; $p = 0.005$ [effect size = 2.9]). Therefore, based on these significant findings, we reject the null hypothesis (H_{03}). Refer to figure 2 and table 3, which summarizes the time course changes for each treatment.

Blood Glucose at 60 Minutes

H_{04} stated there would be no difference between the five treatments in relation to blood glucose 60 minutes after ingestion. Mean values at 60 minutes were: placebo =

91.75 ± 12.43, dextrose = 126.10 ± 24.34, maltodextrin = 114.70 ± 20.87, waxy maize = 116.60 ± 28.49, Vitargo® = 121.10 ± 16.77. The one-way ANOVA identified a significant difference of $p < 0.001$. A pairwise comparisons (Bonferroni adjusted for multiple comparisons) revealed that there was a significant difference between placebo and all other treatments except waxy maize (dextrose; $p = 0.008$ [effect size = 1.9], maltodextrin; $p = 0.022$ [effect size = 1.4], and Vitargo®; $p = 0.002$ [effect size = 2.0]). Therefore, based on these significant findings, we reject the null hypothesis (H_{04}). Refer to figure 2 and table 3, which summarizes the time course changes for each treatment.

Blood Glucose at 90 Minutes

H_{05} stated there would be no difference between the five treatments in relation to blood glucose 90 minutes after ingestion. Mean values at 90 minutes were: placebo = 87.75 ± 9.88, dextrose = 112.00 ± 16.05, maltodextrin = 111.50 ± 15.62, waxy maize = 115.50 ± 27.99, Vitargo® = 121.80 ± 13.79. The one-way ANOVA identified a significant difference of $p = 0.001$. A pairwise comparisons (Bonferroni adjusted for multiple comparisons) revealed that there was a significant difference between placebo and dextrose ($p = 0.003$ [effect size = 1.9]) and placebo and Vitargo® ($p = 0.005$ [effect size = 2.8]). Therefore, based on these significant findings, we reject the null hypothesis (H_{05}). Refer to figure 2 and table 3, which summarizes the time course changes for each treatment.

Blood Glucose at 120 Minutes

H_{06} stated there would be no difference between the five treatments in relation to blood glucose 120 minutes after ingestion. Mean values at 120 minutes were: placebo = 90.50 ± 5.26, dextrose = 86.10 ± 14.00, maltodextrin = 108.80 ± 16.99, waxy maize =

115.20 ± 25.35 , Vitargo® = 106.50 ± 11.16 . The one-way ANOVA identified a significant difference of $p=0.001$. A pairwise comparisons (Bonferroni adjusted for multiple comparisons) revealed that there was a significant difference between placebo and Vitargo® ($p= 0.027$ [effect size = 1.9]). Therefore, based on these significant findings, we reject the null hypothesis (H_{06}). Refer to figure 2 and table 3, which summarizes the time course changes for each treatment.

Blood Glucose at 180 Minutes

H_{07} stated there would be no difference between the five treatments in relation to blood glucose 180 minutes after ingestion. Mean values at 180 minutes were: placebo = 85.25 ± 11.73 , dextrose = 86.60 ± 10.20 , maltodextrin = 83.80 ± 7.49 , waxy maize = 105.00 ± 9.59 , Vitargo® = 82.70 ± 9.15 . The one-way ANOVA identified a significant difference of $p<0.001$. A pairwise comparisons (Bonferroni adjusted for multiple comparisons) revealed that there was a significant difference between waxy maize and all other treatments (placebo; $p=0.010$ [effect size = 1.9], dextrose; $p=0.003$ [effect size = 1.8], maltodextrin; $p= 0.001$ [effect size = 2.4], and Vitargo®; $p= 0.002$ [effect size = 2.3]). Therefore, based on these significant findings, we reject the null hypothesis (H_{07}). Refer to figure 2 and table 3, which summarizes the time course changes for each treatment.

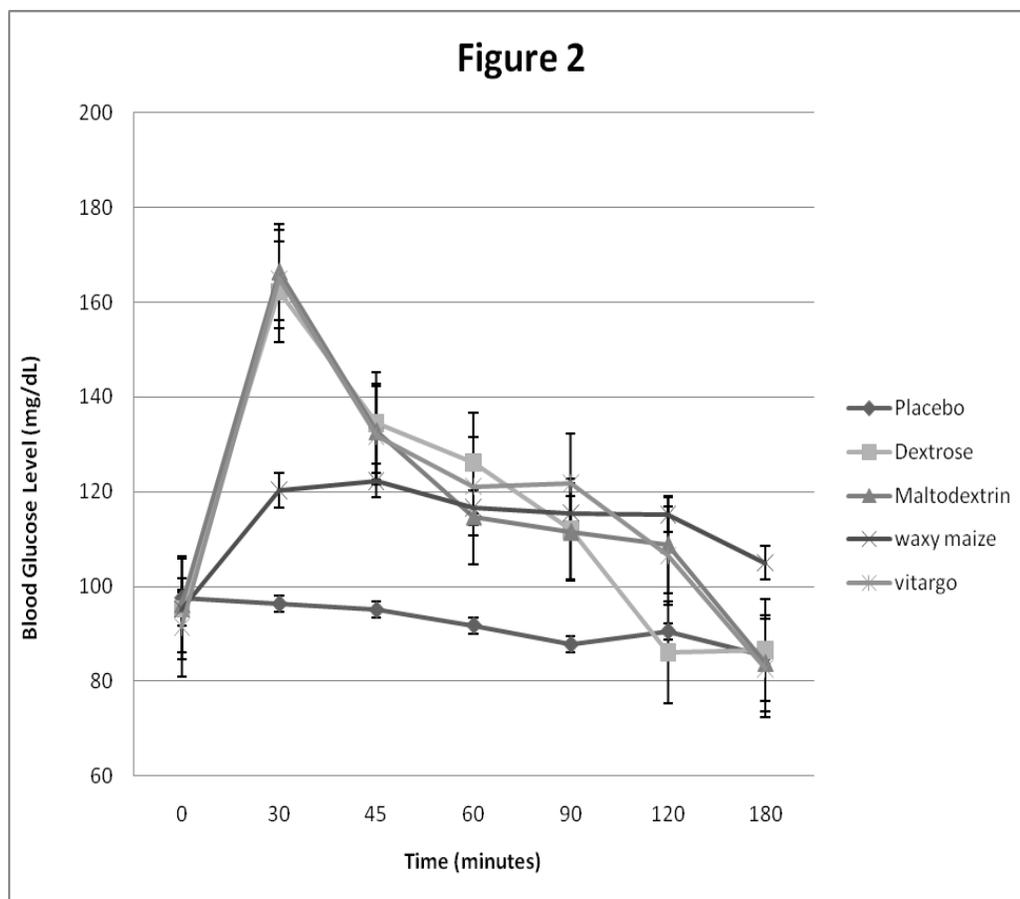


Figure 2. Time course changes for each treatment.

Treatment	Time						
	0	30	45	60	90	120	180
Placebo	97.5 ± 1.2	96.2 ± 1.5	95.0 ± 3.0	91.7 ± 12.4	87.7 ± 9.8	90.5 ± 5.2	85.2 ± 11.7
Dextrose	95.2 ± 6.2	162.2 ± 23.1	134.5 ± 28.5	126.1 ± 24.3	112.0 ± 16.0	86.1 ± 14.0	86.6 ± 10.2
Maltodextrin	96.2 ± 5.7	166.4 ± 22.8	132.7 ± 25.9	114.7 ± 20.8	111.5 ± 15.6	108.8 ± 16.9	83.8 ± 7.4
Waxy maize	95.2 ± 10.2	120.3 ± 27.3	122.3 ± 31.0	116.6 ± 28.4	115.5 ± 27.9	115.2 ± 25.3	105.0 ± 9.5
Vitargo®	91.4 ± 6.5	164.9 ± 14.6	131.8 ± 22.6	121.1 ± 16.7	121.8 ± 13.7	106.5 ± 11.1	82.7 ± 9.1

Table 3. Average blood glucose concentrations for each treatment at each time point throughout the trial (Results given as mean ± the standard deviation) are given in the table..

Chapter 5: Discussion

Maintenance of normal blood glucose concentrations is important in sustaining performance and preserving energy in high intensity-intermittent activities, such as soccer (Ostojic & Mazic, 2002). It has been reported that the ingestion of a carbohydrate supplement prior to a soccer match results in the maintenance of blood glucose levels and improves soccer performance. The purpose of this study was to examine the effects of different carbohydrates on resting blood glucose response in collegiate soccer athletes. The data generated from this investigation may help to determine the effectiveness of a carbohydrate supplement in providing sustained energy (measured via the blood glucose response following carbohydrate ingestion), which may result in improved soccer performance.

There were four carbohydrate supplements ingested in the present investigation:

- Dextrose
- Maltodextrin
- Waxy maize
- Barley starch/amylopectin (marketed as Vitargo®)

Each participant ingested one gram of carbohydrate per kilogram of body mass dissolved in a 7% solution. Thirty minutes following ingestion, three of the four carbohydrates (dextrose, maltodextrin, and Vitargo®) reached their peak glucose concentrations. Waxy maize was unique at the 30-minute post-ingestion time point as it elicited blood glucose

concentrations that were significantly lower than the other three carbohydrate sources. Interestingly, there was no significant difference in blood glucose levels at thirty minutes between waxy maize and the flavored water control. For the rest of the intervention period (from forty-five minutes post-ingestion to three-hours post-ingestion), blood glucose concentrations of dextrose, maltodextrin, and Vitargo® each declined steadily until they reached near-baseline levels at three hours post-ingestion. In contrast, the blood glucose concentration following waxy maize ingestion did not steadily decline over the three-hour post-ingestion period. In fact, at three hours post-ingestion of waxy maize, blood glucose concentration was still slightly elevated above baseline blood glucose levels. Although the blood glucose response of waxy maize ingestion was only slightly elevated at the three-hour post-ingestion time point, it was significantly higher in comparison to each of the other treatments (dextrose, maltodextrin, Vitargo®, and the water control). Based on these data, the main finding of this study was that a sharp increase in the blood glucose response was not observed following the ingestion of waxy maize; however, maintenance of an elevated blood glucose concentration over an extended period of time (i.e., three hours) was observed.

Contrary to the findings of the present investigation, waxy maize is commonly marketed as a fast absorbing and digesting carbohydrate supplement by its vendors. Dymatize's FLUD (Dymatize, 2011, para. 4) claims that it "passes through the stomach very, very rapidly." 1Fast400, (1Fast400, 2002-2011, para. 1) states that waxy maize "passes through the stomach much faster than any other carbohydrate source." While marketed as a fast absorbing supplement, previous exercise and clinical research supports the findings of the present investigation and have reported that waxy maize is, in fact, a

slow digesting and absorbing carbohydrate supplement. In a study performed at rest, researchers found the blood glucose response of waxy maize suggests that it may be a more suitable carbohydrate if a slower and more prolonged release of energy is desired, when compared to maltodextrin and a white bread control (Sands et al., 2009). A slower release of energy could be integral in eliminating hypoglycemia in athletes, leading to higher blood glucose concentrations throughout exercise and improved performance. Limitations of studies at rest include a decreased generalizability to performance during exercise as the results in resting conditions may not transfer accurately to results during activity.

In a study utilizing a rest period and an exercise period (Goodpastor et al., 1996), researchers found a significant rise ($p < 0.05$) in serum glucose during the thirty minutes of rest following the ingestion of a waxy starch carbohydrate (specific values were not listed). Goodpastor and colleagues (1996) also examined the effect of a resistant starch, glucose, and a placebo (dosages of one gram per kilogram of bodyweight) and discovered the same response with glucose attaining the highest serum glucose level. With the onset of exercise, serum glucose values dropped significantly in all treatments. This research conflicts with the present investigation in which a significant rise in blood glucose was not observed thirty minutes after ingesting waxy maize starch.

Similarly, Roberts and colleagues (2010) used nine trained, male cyclists to examine the effects of a waxy maize starch and maltodextrin on metabolic responses during prolonged exercise. Carbohydrates were ingested thirty minutes prior to the exercise session. The exercise session included a prolonged (150 minutes) cycling session (70% VO_2 peak) followed by cycling to exhaustion at 100% of peak oxygen consumption

(Roberts et al., 2010). Results of Roberts et al. (2010) study found a blunted initial increase in serum glucose after the ingestion of a waxy starch and stable serum glucose levels over time (155 minutes). The stable serum glucose levels over time during exercise could be ideal to sustain energy and performance. Due to the presence of an exercise protocol in the Roberts investigation (Roberts et al., 2010) that was not included in the present investigation, comparisons are limited.

While waxy maize revealed a slow rise and sustained blood glucose response over time in the present study, there were measurements for waxy maize that were not significantly different than the measurements for the water control (refer to figure 2 in chapter four which summarizes the time course changes for each treatment). Specifically, blood glucose measurements for waxy maize were not significantly different than measurements for the water control at 30, 45, 60, 90, and 120 minutes following ingestion of the treatment. Observing that waxy maize was not significantly different than water at multiple time points could question whether waxy maize is an applicable carbohydrate.

Another finding of this study was the blood glucose response of Vitargo®. It was found that Vitargo® peaked at thirty minutes with a fast initial rise in blood glucose levels. Similar to the present investigation, Stephens et al. (2008) showed a comparable blood glucose response for Vitargo®. When compared to a water control and a low molecular weight carbohydrate solution, Vitargo® (a high molecular weight solution) was found to have a two-fold greater rate of increase in the first thirty minutes of digestion than the other treatments. Differences between Stephens et al. and the present study may account for variability when comparing results. Specific differences include

the different populations being investigated. The present study examined division one collegiate female soccer players while Stephens et al. (2008) used a recreationally active male population. Another difference is the amount of carbohydrate ingested by the participants. Stephens et al. (2008) gave an absolute dosage of 100 grams of carbohydrate to each participant. The present study gave a relative dose of one gram of carbohydrate per kilogram of body weight for each participant; as a basis of comparison the average carbohydrate in the present study was 64 grams. Lastly, the present study assessed blood glucose response to the ingestion of carbohydrates at rest. Stephens and colleagues assessed blood glucose response to the ingestion of carbohydrates following an exhaustive bout of exercise.

Stephens and colleagues (2008) and Massicotte et al. (1986) are two previous studies that also used a water control to compare other carbohydrates to. The present study found no significant difference over time for blood glucose response to water. As to be expected, Stephens et al. (2008) also found no significant difference in blood glucose levels over a two hour time period, following the ingestion of a sugar-free flavored water. Massicotte and colleagues (1986) found a significant decrease in plasma glucose concentrations over time with the ingestion of water during a 180-minute bout of cycling. The exercise component of Massicotte et al. (1986) is likely responsible for the difference in results relative to the blood glucose response following water ingestion.

Results of the present study are also comparable to the results found in Sands et al. (2009) regarding the carbohydrate maltodextrin. The present study found an increase in rate of blood glucose response in the first thirty minutes of monitoring. Sands and colleagues also reported a fast rise in blood glucose when compared to waxy maize and a

white bread control. In their study, maltodextrin peaked around forty-five minutes compared to thirty-minutes in the present study. Maltodextrin also had a higher blood glucose response when compared to waxy maize in both studies. Although results of the Sands et al. investigation (2009) are similar to the findings in the present study, differences in the study designs could be responsible for the slight variation. The main difference between the studies is the form of carbohydrate that was ingested. The present study ingested beverage forms of carbohydrate powders dissolved into water, Sands et al. utilized gel and solids forms of carbohydrates. Roberts et al. (2010) also found a similar blood glucose response for maltodextrin. Following ingestion, maltodextrin quickly rose and peaked at thirty minutes. While this study involved an exercise component, the rise in blood glucose following the ingestion of maltodextrin occurred in the thirty minutes prior to the exercise bout.

The present study found a similar blood glucose response following the ingestion of dextrose to that of maltodextrin and Vitargo®. Masicotte and colleagues (1986) found that plasma glucose concentrations remained stable throughout their study (180 minutes) following ingestion prior to exercise. This study, however, utilized an exercise component (180 minutes of cycling at 50% of VO_{2max}) which could be responsible for the variation in findings. Sands et al. (2009) compared the blood glucose response of white bread to waxy maize and maltodextrin. The white bread control showed a gradual rise in plasma glucose reaching a peak concentration at sixty minutes, followed by a gradual lowering over a four-hour period. The response of the white bread control in this study may show variations in blood glucose response to dextrose due to the different form of the carbohydrate; solids versus liquids. Goodpaster and colleagues (1996) examined the

effects of pre-exercise starch ingestion on endurance performance. In relation to blood glucose response and glucose ingestion, they found serum glucose levels to rise significantly during the first thirty minutes of rest also attaining the highest value compared to the other treatments (waxy starch, resistant starch, and the placebo). At the onset of exercise, blood glucose values dropped but rebounded at the fifteen-minute time point and remained steady through the completion of the exercise. Results for the resting portion of the Goodpaster et al. study (2006), in relation to glucose, are similar to the blood glucose response of dextrose in the present study.

In light of these findings, further research is needed to examine and substantiate the effects of waxy maize and other carbohydrates on blood glucose response in female soccer players. Future studies should aim their focus on blood glucose response during exercise. Specifically, soccer specific exercises should be utilized to evaluate blood glucose response to different carbohydrates ingested prior to a practice or a match. Future studies should aim to emulate the study of Otojic and Mazic (2002) using various carbohydrates. The experimental design involved three phases; a soccer match, soccer - specific tests, and a relaxation-recovery phase. The soccer match consisted of two 45-minute halves with a 15 minute break in between. The second phase was completed immediately after the soccer match and consisted of four soccer- specific skills tests; dribble test, precision test, coordination test, and power test. The third and final phase was the relaxation and recovery phase. The recovery phase lasted for an hour and involved the changing of clothes, rest, and massage (Ostojic & Mazic, 2002). The participants were randomly assigned to one of two teams. One team was the control and ingested the placebo (water) beverage and the other team ingested the carbohydrate

treatment. Both teams consumed the fluid immediately before the trial and every 15 minutes during the 90-minute soccer match.

In addition, it would be beneficial to evaluate performance with and without the ingestion of carbohydrates prior to soccer specific evaluations (i.e., Yo-Yo Intermittent recovery Test). To ensure carry-over to a soccer match and ecological validity, it would be valuable to utilize a treadmill protocol that would imitate the demands of a soccer game as closely as possible. Such a protocol would involve the varying speeds (demands) of the soccer game; walking, jogging, running, sprint, and involve two periods of “work” with a small break in between.

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