Effect of a carbohydrate beverage on exercise performance in youth 7-17 years old

Lauren Jording

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Effect of a Carbohydrate Beverage on Exercise Performance in Youth 7-17 years old

by

Lauren Jording

Thesis

Submitted to the Department of Health Promotion and Health Performance

Eastern Michigan University

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MASTER OF SCIENCE

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Thesis Committee:

Rebecca W. Moore, Ph.D, Chair

Anthony Moreno, Ph.D.

Olivia Ford, Ph.D.

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Abstract

Sports enhancement products go through trends as new products are introduced and as old products are redesigned and re-introduced to the market. Gatorade® is a sports beverage that is often used by youth during sports. However, the effects of sports beverages on youth performance are unknown. One aim of this study was to determine if youth experience the same performance benefit from carbohydrate beverages as adults. A second aim of this study was to determine differences in metabolic measures (VO₂, VE, & RER) between the carbohydrate and water performance trials in youth and adults. A third aim was to examine changes in metabolic measures (VO₂, VE, & RER) throughout a 60-minute cycle ride in youth. It was hypothesized that youth, like adults, would experience a performance benefit from carbohydrate beverages. It was also hypothesized that there would be a difference in metabolic measures (VO₂, VE, & RER) between the carbohydrate beverage and water trials in youth and adults. The third hypothesis was that there would be a difference in metabolic measures (VO₂, VE, & RER) for youth throughout a 60-minute cycle ride. Nineteen subjects (8 youth aged 7-17 and 11 adults aged 18-30) were recruited to come to the Applied Exercise Physiology Laboratory on three separate occasions. During the participant’s first visit to the laboratory, they completed a VO₂peak test on a cycle ergometer (McMaster protocol). The second and third visits to the laboratory were identical, consisting of two 30-minute cycle rides, and one two-mile performance trial on a cycle ergometer. Metabolic measures (VO₂, VE, & RER), heart rate, blood pressure, and rating of perceived exertion (RPE) will all be measured during testing. Drink order was single-blind, randomized, and counterbalanced. Paired sample t-tests were used to determine differences in water and carbohydrate performance time trials in youth and adults. No statistical significance was found for adults or youth. Paired sample t-tests were used to determine differences in
metabolic performance data. No statistical significance was found for adults or youth. Paired sample t tests were used to determine differences in metabolic data for the 60-minute ride for youth. RER was significant between Time Point 1 (time during the trial) and Time Point 4 (time during the trial) for the water and carbohydrate trials. VO₂ was significant for the carbohydrate trial from Time Point 1 to Time Point 4. Differences were considered significant at an alpha level of p < .05. Limitations of the study included the adults using the same protocol as youth, small sample size, and not being able to disguise the taste between water and the carbohydrate beverage. It is imperative to do continued research specifically with youth and carbohydrate beverage consumption during exercise to get a deeper understanding of the benefits or lack thereof.
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Chapter 1

Introduction

A variety of sports supplements are currently available. Among these sports supplements, carbohydrate beverages are a common choice for both adults and children. Carbohydrate beverages, such as Gatorade®, contain added calories and sugar compared to water. A 12 oz serving of Gatorade® has 80 calories, and includes 160 mg sodium, 45 g potassium, 21 g carbohydrate, and 21 g of sugar (Gatorade®, 2013). Limited information is available on exercise performance when youth consume these carbohydrate beverages (Riddell, Bar-Or, Wilk, Parolin, & Heigenhauser, 2001). In an adult population, it has been well documented that consuming a carbohydrate beverage during exercise enhances performance and delays fatigue compared to water (Coyle, Hagberg, Hurley, Martin, Ehsani, & Holloszy, 1983, E.F. Coyle, Coggan, Hemmert, & Ivy, 1986). However, it is not known if a carbohydrate beverage positively influences performance in youth as it does in adults.

Consuming a carbohydrate beverage during exercise is a potential hazard, especially to children and adolescents, as 17% of youth 2-19 years old are obese (Ogden, Carroll, Fryar, & Flegal, 2015). During exercise calories are expended. However it is not clear if the number of calories expended will outweigh the number of calories consumed when children drink a carbohydrate beverage during exercise. Sports drinks contain electrolytes, carbohydrates, sugar, and sodium. These ingredients are included to increase endurance performance in adults, but their has been little research done on the performance benefits of sports drinks in youth (Jeukendrup, 2010).

Carbohydrates are included in sports drinks to delay the onset of fatigue, which will increase the performance of the athlete (Baker & Jeukendrup, 2014). It is known that
carbohydrate feeding during prolonged exercise can delay fatigue in adults (Coyle, Coggan, Hemmert, & Ivy, 1986). In their research, Coyle et al. (1986) found that when riding a cycle at 70% of VO$_{2\text{max}}$, highly trained endurance athletes were able to ride 33% longer when given carbohydrate than a placebo. Adults utilize carbohydrates differently than children (Timmons, Bar-Or, Riddell, 2003). Many studies have shown that youth utilize more fat than carbohydrate during exercise compared to adults at the same relative intensities (Mahon, 1997; Martinez, 1992; Timmons, Bar-Or, & Riddell, 2003). Studies show that during exercise, substrate utilization occurs differently for children compared to adults (Timmons, Bar-Or, & Riddell, 2007).

There is also inadequate research on how carbohydrate beverages affect youth’s performance during exercise. It is known that youth utilize substrates in a different way than that of adults (Baker & Jeukendrup, 2014). Youth rely less on endogenous carbohydrate and more so on endogenous fat in comparison to adults (Timmons et al., 2007). During prolonged exercise, exogenous carbohydrate is utilized faster in youth than adults (Timmons et al., 2007). In boys 10-14 years old, Riddell et al. (2001) (found that carbohydrate beverages (specifically made for the study) enhanced performance when participants rode at 90% of their peak power to fatigue (Riddell et al., 2001). It is unknown if the same effects will be seen in other age groups. Many studies have shown that at the same relative intensities during exercise, youth utilize more fat than carbohydrate compared to adults (Mahon, 1997; Martinez, 1992; Timmons et al., Riddell, 2003). Both boys and girls have higher fat oxidation, a two fold increase compared to adults, during exercise without the ingestion of a carbohydrate beverage (Timmons et al., Bar-Or et al., 2003; Timmons et al., 2007).
Significance

In the United States the number of those with obesity is increasing for both adults and youth. Consuming carbohydrate beverages, which contain many added calories, seems to be unnecessary without knowing that it is directly benefiting performance for youth (Riddell, 2001). The exogenous carbohydrate is utilized differently for youth than adults. However, there has been very little research performed to determine if there is a difference in performance for youth when a carbohydrate beverage is consumed. Currently, there is not any field research on children and carbohydrate beverages; all research has been completed in a lab setting. Field research would provide knowledge to coaches and parents about how carbohydrate beverages could enhance or hinder children’s exercise performance. This research project will fill the gap in literature on carbohydrate beverages and children’s exercise performance.

Purpose and Objectives of the Study

One aim of this study was to determine if youth experience the same performance benefit from carbohydrate beverages compared to adults.

A second aim of this study was to determine differences in metabolic measures (VO₂, Vₑ, & RER) between the carbohydrate and water performance trials in youth and adults.

A third aim was to examine changes in metabolic measures (VO₂, Vₑ, & RER) throughout a 60-minute ride in youth.

Hypotheses

It was hypothesized that youth, like adults, would experience a performance benefit from carbohydrate beverages.

It was also hypothesized that there would be a difference in metabolic measures (VO₂, Vₑ, & RER) between the carbohydrate beverage and water trials in youth and adults.
The third hypothesis was that there would be a difference in metabolic measures (VO2, VE, & RER) for youth throughout a 60-minute ride.

Null Hypothesis

There will be no difference in performance benefit for youth when consuming a carbohydrate beverage.

There will be no difference in metabolic measures (VO2, VE, & RER) between the carbohydrate beverage and water trials in youth and adults.

There will be no difference in metabolic measures (VO2, VE, & RER) for youth throughout a 60-minute ride.

Definitions

- **Carbohydrate beverage**: Performance enhancing beverage used during exercise that contains 6% carbohydrate.
- **Exogenous Carbohydrate**: An external source of carbohydrate.
- **Endogenous Carbohydrate**: An internal source of carbohydrate.
- **VO2max**: The maximal amount of oxygen an individual’s body is able to take up at the level of the lungs to be used as energy for the body during exercise.
Chapter 2

Review of Literature

The human body is similar to that of a car: without proper fueling the amount of work performed will be hindered. A vehicle without gasoline will not be able to accelerate; similarly, a body without proper nutrients will not be able to produce work. If diesel fuel is placed into a gas vehicle, the car will not perform how it should, as the vehicle requires a certain type of fuel. Just like the vehicle that requires certain types of fuel to operate properly, the human body requires certain foods to fuel an ultimate performance.

Exercise should be a high priority across the lifespan. Currently, with the rise in the obesity epidemic (Hancox, 2004; Ogden, 2015; Schwimmer, 2003; Stensel, 2008), it is even more important, for youth especially, to be properly educated on nutrition as well as exercise. Being educated in these topics allows the child to better understand what a healthy lifestyle is in order to place these new habits into their everyday life. It is recommended that youth participate daily in at least 60 minutes of moderate to vigorous physical activity (Janssen, 2010). The American College of Sports Medicine recommends aerobic and resistance training and/or bone loading activities. Examples of aerobic activity include brisk walking or running (ACSM, 2014). Youth should participate in aerobic activity daily (ACSM, 2014). Resistance and/or bone loading activities should occur two to three times per week and can include push-ups, jumping rope, and lifting weights (ACSM, 2014). Educating youth about physical activity recommendations may influence a behavior change now that will be sustained throughout the lifespan.

There currently are many types of performance enhancement products on the market. Though these products are aimed mostly for an adult population, there is merchandise targeted specifically for youth. The greatest market for youth’s performance enhancement products are
sports drinks (Committee on Nutrition and the Council on Sports Medicine and Fitness, 2011). A vast number of companies manufacture sports drinks of many flavors. The ingredients most commonly found in sports drinks are sodium and sugar. These ingredients are included to increase endurance performance and to enhance overall endurance performance in adults (Jeukendrup, 2010). However, youth consume these beverages in excess, and there is very little research showing their effects on youth’s endurance performance (Seifert, Schaechter, Hershorin & Lipshultz, 2011).

**Youth Participation in Sport**

In the United States, 75% of families have one or more children who participate in an organized sport (Adirim, 2003). There are 45 million youth 6-18 years old in the United States that participate in organized sports (DiFiori, Benjamin, Brenner, Gregory, Jayanthi, Landry & Luke, 2014). Being physically active in a sport increases a child’s quality of life (Bean, Fortier, Post, & Chima, 2014). Fraser-Thomas and Cote found fifth grade students who participated in youth sports ranked 45% of their day as being lots of fun compared to students that do not participate in youth sport, who ranked only 8% of their day as being lots of fun (Fraser-Thomas & Cote, 2004).

In order for youth to have a positive experience in sports, the following should be incorporated into programming: physical and psychological safety; structure; supportive relationships; a sense of belonging; positive social norms; a support system; skill building; and building of the family, school, and community efforts (Eccles & Gootman, 2002). A positive experience in youth sports is not a guarantee; however, with the proper design and implementation of the program, a positive experience is more likely to occur (Fraser-Thomas, Cote, & Deakin, 2005). By increasing the likelihood of a positive sport experience at a young
age, adherence to specific sports can occur while also better developing youths skills and later benefiting overall performance.

It was shown that there can be a vast decline in physical activity during adolescence (Lotan, 2005). With this decline, physical activity is not made a priority, which can lead to many health concerns throughout the lifespan (Bensimhon, 2006; Penedo, 2005; Services, 1996; Warburton, 2006). Some of the possible health concerns that can occur without regular participation in physical activity are obesity, dyslipidemia, and insulin resistance (Riddell, 2008).

The above statistics show that three fourths of families in the United States have at least one child if not more active in a sport (Adirim, 2003). This is a large number of youth within the population that are active. As youth grow, habits become instilled within them especially that of exercise habits, these habits become a lifestyle and remain with them into adulthood (Adams, Schoenborn, Moss, Warren, & Kann, 1995; Duke, Huhman, & Heitzler, 2003). A well-balanced diet is imperative for young athletes in order for proper growth and for the optimization of performance (Purcell, 2013). Regular participation of children in physical activity reduces the possibility for obesity, dyslipidemia, and insulin resistance (Riddell, 2008). Getting youth involved in a sport at a young age will aid in the development of skills for their specific sport.

**Nutritional Practices**

The majority of food consumed by youth is provided by the parents (Thomas, 2012). Typically, food given to children that participate in youth sports is simply something that is quick and easy for the parent, for example fast-food, packaged food items, and sugar-sweetened beverages (Bauer, 2008; Cavadini, 2000; French, 2001). The belief that it is acceptable for youth to consume unhealthy food stems from the parent thinking the child is active and will expend the extra calories (Thomas, 2012). Another reason children consume poor-quality food choices is
due to the parents resistance to deviate from their own unhealthy routines (Thomas, 2012). This indicates that parents, as well as youth athletes, must be better educated on the consumption of a healthy diet both while in and out of season (Thomas, 2012).

According to the *Gale Encyclopedia of Nursing and Allied Health*, the current youth dietary intake recommendations for those 4-13 years of age are as follows: 130 g/d of carbohydrates, 11-30 g/d of protein, and 25-35 g/d of fat (Kaczkowski, 2013). By eating a balanced diet, youth are able to reduce fatigue and risk of disease and injury while also getting the most out of training (Hoch, 2008). Finding a balanced diet that is proper for each child in comparison to their energy expenditure is imperative to a balanced energy requirement. Therefore, there are no energy deficits or excesses, both of which can lead to consequences such as delayed puberty, loss of muscle mass, injury, and obesity (Purcell, 2013). Determining the activity level (light, moderate, vigorous) of the child participating in sports is important so that caloric values can be calculated (Smith, 2015). Pre-, during, and post-exercise nutrition are imperative to how a child may perform. The child’s body must be properly nourished in order to see the most benefit in performance.

Before beginning exercise, pre-workout meals vary based upon the individual and what their stomach and gastrointestinal tract can handle (Holway, 2011). For example, some young athletes need something small, like a protein shake, while some cannot tolerate anything at all (Williams, 2006). The guidelines for food consumption before exercise encourage an easy to digest carbohydrate source 2 to 4 hours prior to exercise (Williams, 2006) and fluids should be consumed leading up to exercise (Burke, 2007).

On a normal training day, calorie consumption should be much lower than that of a competition day (Burke, Loucks, & Broad, 2006). However, due to the high amount of stress that
may be experienced on game day, a youth’s caloric consumption on game day tends to be much lower (Holway, 2011). It is recommended that youth consume 30-60 g/hour of carbohydrate for exercise that lasts longer than an hour (Smith, 2015). During exercise, fluid consumption should be based upon sweat rate and from there a plan should be made per individual (Smith, 2015). Smith et al. (2015) recommended also having sodium within the fluid being consumed to assist with what is lost via sweat. Proper nutrition and hydration are important both during training and while competing to maximize performance.

How many times per week the team has a game or a match will determine the type of recovery needed for each individual. If, for example, a team has only one match per week, the body will have time to nutritionally recover throughout that week. However, if a team plays three matches on back-to-back days, both carbohydrates and fluids need to be replenished quickly so the athlete doesn’t suffer any loses in performance (Burke, 1995). After exercise, it is recommended that 20 g of high-quality protein and 1.0-1.5 g/kg of body mass be consumed as well as 450 mL/0.5 kg of fluids (Smith, 2015). Nutrition and exercise performance has been studied in adults in great depth, whereas with youth, this topic has only skimmed the very surface (Phillips, 2012). The rest of the review of literature will focus on fluid consumption for both adults and children during exercise.

**Dehydration**

Limited research is available on how dehydration affects children’s exercise performance. It is known that, like adults, hydration status during sport affects performance of youth (Purcell, 2013; Smith, 2015). One study that has looked at this pressing issue determined a dehydration level of 1% affected the performance of 10-to-12 year-old boys (Wilk, Yuxiu, & Bar-Or, 2002).
Maintaining proper hydration is important for overall functioning of the body, especially when stressing the body with exercise (Baker & Jeukendrup, 2014). Without proper hydration, the body can experience unfavorable effects such as overheating and dehydration. When exercising, the amount of fluid lost is dependent upon the type of activity the individual is engaging in as well as the environmental conditions (Baker & Jeukendrup, 2014). Dehydration has many negative consequences to the human body that can lead to various conditions and diseases.

Some of the most common medical conditions reported to be associated with dehydration are urinary tract infections, blood clots, asthma, kidney stones, gallstones, constipation, headaches, cardiovascular disease, diabetic hyperglycemia, and bladder and colon cancers (Baker & Jeukendrup, 2014; Institute of Medicine and Food and Nutrition Board, 2004; Manz, 2005; Popkin, 2010). In the most severe cases, dehydration can result in death due to hypohydration (Baker & Jeukendrup, 2014). When dehydration occurs, both cardiovascular and thermoregulatory function can be impaired. With both cardiovascular and thermoregulatory function not operating at maximal capacity, an individual can feel as though they are working much harder than they actually are, and therefore, their overall performance is diminished (Institute of Medicine and Food and Nutrition Board, 2004; Appel, 2005; Sawka et al., 2007; Shirreffs, 2011).

It is argued that in adult athletes, the need to remind them to drink fluid’s is not necessary as they consume enough fluid due to their own thirst to keep them from dehydrating and seeing a decline in performance (Noakes, 2007). Rowland (2011) has proposed that a similar trend to Noakes (2007) adult theory will be seen in adolescents as well. An example of Rowland’s proposal is as follows: A 40.8 kg (90 lb) child would need 18 oz of water per hour during
exercise to keep hydrated (Rowland, 2011). This same child would need an estimated 6 oz per hour of fluid after exercise (Rowland, 2011). The rate at which an adult and child dehydrate is linked to the amount of fluid intake as well as their sweat rate (Rowland, 2008). Contrary to Noakes and Rowland’s theories, other researchers Bar-Or (1980), Wilk and Bar-Or (1996) and Wilk, Rivera-Brown, and Bar-Or (2007) state that both children and adults do not consume enough fluid during exercise to stay hydrated while exercising in hot environments. Children 9-12 years old that are given water to drink during exercise have a dehydration rate of 0.2-0.3% body wt/h (Wilk & Bar-Or, 1996).

**Fluid During Exercise**

Very little research is available on how dehydration affects children’s exercise performance. It is known that like adults, hydration status during sport affects performance of youth (Purcell, 2013; Smith, 2015). One study that has looked at this pressing issue, performed by Wilk et al. (2002) found both body weight changes as well as a limited total work output when 10-to-12 year-old boys were dehydrated. Through the previous study, it was determined a dehydration level of 1% affected the performance of youth boys (Wilk et al., 2002). During exercise, the recommendation of fluid consumption is based upon each individual’s sweat rate (Smith, 2015).

Water is stored in the body in either an intracellular compartment or an extracellular compartment (Baker & Jeukendrup, 2014). In the human body, 73% of the body’s lean mass is made up of water (Sawka & Coyle, 1999). When adults experience a fluid loss (hypohydration), a decrease in both plasma volume and stroke volume are seen, and an increase in heart rate is observed (Gonzalez-Alfonso, 1995; Montain & Coyle, 1992; Saltin, 1964). With fluid loss, the ability of each body system can be compromised (Casa, Armstrong, Montain, Rich, & Stone,
2000). However, if an individual is dehydrated, the body’s water compartments are being used to offset the dehydration, and therefore the body isn’t able to respond via sweating, resulting in an increase in core temperature (Nose, 1988; M. N. Sawka & Coyle, 1999). An increase in core temperature greatly hinders the athlete’s performance by decreasing the amount of time to exhaustion (Sawka et al., 1992).

Aside from just looking at how performance is affected by dehydration, there are many other markers within a study that can be analyzed. In 1980, Bar-Or researched voluntary hypohydration in boys 10 to 12 years old. There were two separate conditions to the research; during one data collection day the boys were made to drink a certain amount, and on the other day, the boys drank only when thirsty. The boy’s sweat rate was maintained in both the voluntary drinking and the forced drinking (Bar-Or, 1980). Heart rate was lower, 154bpm ± 12 bpm at the start of exercise and 169 bpm ± 15 bpm at the end of exercise, during the voluntary drinking trials than that of the forced drinking trials, 151 bpm ± 8 bpm at the start of exercise and 171 bpm ± 15 bpm at the end of exercise (Bar-Or, 1980). The Rate of Perceived Exertion (RPE), measured on the Borg scale, was reported around 9.5 for the start of each trial and around 10 for the end of each trial (Bar-Or, 1980). Similar to the RPE, the hematocrit, blood hemoglobin, and proteins were all relatively similar when comparing each trial (Bar-Or, 1980).

In 1996, Wilk and Rivera-Brown did a study on boy’s hydration while exercising in the heat and based the research on effect of drink flavor and NaCl on voluntary drinking. Heart rate was found to remain very similar between all trials, 84-88 bpm at baseline, 143-150 bpm during the exercise trial, and 88-94 bpm during rest (Wilk & Bar-Or, 1996). Temperatures of the forearm, subscapula, and thigh were taken and remained similar between all trials (Wilk & Bar-Or, 1996). Another study done by Wilk and Rivera-Brown in 2007 researched voluntary drinking
and hydration in non-acclimatized girls exercising in the heat. The sweat rates between all trials were similar. Heart rate increased while exercising from that of baseline to the first rest period by 15-18 bpm and then maintained for the second, third, and fourth resting periods when the heart rate was measured (Wilk, Rivera-Brown, & Bar-Or, 2007). Rectal temperature was measured as well as skin temperature that was measured at the subscapula, forearm, and thigh (Wilk, Rivera-Brown, & Bar-Or, 2007). There were only slight increases of the rectal temperature, 0.6 °C increase in one trial and an increase of 0.1 °C in the other two trials of the rectal temperature, the skin temperature remained at 33.0-33.5 °C during exercise and 33.4-33.9 °C at rest (Wilk, Rivera-Brown, & Bar-Or, 2007).

**Carbohydrate During Exercise in Adults**

While exercising, the use of carbohydrate beverages aid in replacing water that has been lost via sweat (Baker & Jeukendrup, 2014). The reason for including carbohydrate in a fluid replacement beverage is due to the impact that carbohydrate has on water absorption rates (Baker & Jeukendrup, 2014). In order to have optimal water absorption rates, it is recommended to have at least 0.9% glucose concentrations (Gisolfi, 1994). Both the amount and type of carbohydrate used within a beverage effect things such as how the carbohydrate is utilized by the body, the transportation mechanism type, and the sweetness of the beverage (Baker & Jeukendrup, 2014).

The types of carbohydrate being glucose, fructose, and sucrose (Baker & Jeukendrup, 2014). Carbohydrate is a common ingredient found in most sports drinks and is included to delay the onset of fatigue and therefore increase the performance of the athlete (Baker & Jeukendrup, 2014). However, performance can be hindered if there is too much carbohydrate contained in a sports beverage. A sports drink should not contain more than 8% carbohydrate concentration, as this will impact gastric emptying and discomfort (Murray, 1999; Shi, 2004).
When looking at carbohydrate ingestion, carbohydrates can be divided into two different groups, fast (60 g/h) and slow (40 g/h) oxidation (Baker & Jeukendrup, 2014). Examples of carbohydrates that are ingested at a faster rate include glucose, sucrose, maltose, maltodextrins, and amylopectin starches (Jeukendrup, 2010). Carbohydrates that are ingested at a slower rate are fructose, galactose, isomaltulose, trehalose, and insoluble starches (Jeukendrup, 2010). Each type of carbohydrate has a specific transport mechanism. Examples of carbohydrate transporters are SGLT, SGLT1, and GLUT5 (Jeukendrup, 2008; Jeukendrup, 2010). It has been found that carbohydrates transported via SGLT1 and GLUT5 have a much higher oxidation rate (Jeukendrup, 2008; Jeukendrup, 2010). Researchers have determined that when using carbohydrates in a sports drink, the best combination to utilize is a fast carbohydrate (such as glucose) as well as fructose in a sports drink (Jeukendrup, 2008; Jeukendrup, 2010). More specifically, a 2:1 glucose to fructose ratio should be used (Jeukendrup, 2013). Many studies have been conducted on how carbohydrate affects exercise performance.

Nine trained cyclists participated in four trials, a practice, control, glucose polymer (Polycose), and a caffeine trial (Ivy, Costill, Fink, & Lower, 1979). Prior to the caffeine trial the cyclist took in 250 mg of caffeine, during the trial the subject ingested an additional 250 mg of caffeine divided between the trial at 15 minute intervals (Ivy et al., 1979). The control trial beverage was lemonade with artificial sweeteners, and the caffeine and glucose polymer drink also were disguised with a lemonade flavor (Ivy et al., 1979). It was shown that ingestion of caffeine increases the amount of work output during prolonged strenuous exercise (Ivy et al., 1979). The glucose polymer was effective in keeping the blood glucose levels elevated (Ivy et al., 1979). Vast amounts of research have looked at carbohydrate ingestion and performance in adults.
Experienced adult cyclists rode on a cycle ergometer at 70-79% of the individuals VO₂max and rode at this intensity for as long as possible (Coyle et al., 1983). Participants were stopped from testing once the VO₂max intensity dropped below 50% or after 180 minutes depending on which criteria the cyclist reached first (Coyle et al., 1983). The cycle ergometer test was performed on three separate occasions separated by one week (Coyle et al., 1983). Cyclists completed the first visit to become familiar with the protocol, For the second and third visits, the same protocol was used; however, for one visit the cyclist was given a glucose polymer solution and the other visit was given a placebo solution (Coyle et al., 1983). The results of the study showed that when exercising at 70-80% VO₂max, while utilizing carbohydrate feeding, fatigue of the adult cyclist can be delayed (Coyle et al., 1983).

Ivy et al. (1983) researched glucose polymer and endurance. Ten males exercised on a treadmill at 45% VO₂max (Ivy et al., 1983). The treadmill speed was 3.0-4.4mph and the grade was 2.0-4.0% (Ivy et al., 1983). Three different protocols were used for testing: practice, control, and glucose polymer, with each trial being separated by one week (Ivy et al., 1983). During the practice protocol, water was provided to the men every 30 minutes beginning at 60 minutes (Ivy et al., 1983). The control protocol matched that of the glucose polymer protocol, but subjects ingested the polymer lemonade (Ivy et al., 1983). For the glucose polymer protocol, polycose was used and subjects ingested at 60, 90, 120, and 150 minutes (Ivy et al., 1983). Ivy et al. found that carbohydrates ingested during the second hour of exercise significantly increased endurance performance by 11.5%.

Previous research by Coyle et al. (1986) found that highly trained endurance athletes were able to cycle to fatigue, riding at 70% of their VO₂max, 33% longer when given carbohydrate than when given a placebo. When endurance athletes exercised, there was a
decrease in carbohydrate oxidation with no carbohydrate feeding; however, with carbohydrate feeding, carbohydrate oxidation was maintained (Coyle et al., 1986). RER remained stable, 0.86-0.84, with placebo for the first two hours of exercise and in the third hour declined to 0.80 (Coyle et al., 1986). However during the carbohydrate feeding trial, the RER remained at 0.80 for the entire four hour trial (Coyle et al., 1986). While exercising it was also found that within these endurance athletes, their blood glucose decreased with placebo, but maintained during the carbohydrate feeding trial (Coyle et al., 1986). The lowered blood glucose levels can be caused by a decreased uptake of glucose from the leg muscles, causing fatigue to occur earlier (Coyle et al., 1986). Highly trained endurance athletes are able to oxidize carbohydrate sources aside from muscle glycogen, such as blood glucose, at higher rates with prolonged strenuous exercise (Coyle et al., 1986). If adequate blood glucose supplementation is given during exercise there is less reliance on muscle glycogen with prolonged exercise (Coyle et al., 1986). This research shows that utilization of carbohydrate during exercise aids in adult’s ability to improve their exercise endurance.

Seven male triathletes and competitive cyclists completed three experimental trials over the course of three weeks. The seven subjects received the following treatment, one per trial, an intravenous infusion of 20% dextrose, ingestion of a carbohydrate beverage, and a placebo (Coggan & Coyle, 1988). Two bouts of exercise were completed for each of the three visits. The first bout of exercise the subject exercised to fatigue on a cycle ergometer while exercising at 65-73% VO₂max (Coggan & Coyle, 1988). A 20 minute rest period was then given. Following the rest period exercise bout two began. The protocol for exercise bout two was the exact same as exercise bout one (Coggan & Coyle, 1988). Hypoglycemia was related to the decline in carbohydrate oxidation, concluding that a decline in plasma glucose contributes to fatigue by
decreasing the availability of an introduced carbohydrate source with depleted muscle glycogen (Coggan & Coyle, 1988).

Twelve trained cyclists exercised at 48.8% VO$_2$max on three separate visits for two hours (Yaspelkis & Ivy, 1991). The three protocols used were 3 mL/kg of body weight, 2.0% glucose polymer solution, and a 8.5% glucose polymer solution (Yaspelkis & Ivy, 1991). The water or glucose solution was given every 15 minutes (Yaspelkis & Ivy, 1991). Muscle biopsies were performed from the vastus lateralis before and after the water and 8.5% glucose polymer trials (Yaspelkis & Ivy, 1991). The reduction in muscle glycogen was significantly less during the high glucose polymer trial than during the water trial (Yaspelkis & Ivy, 1991). Carbohydrate oxidation was also greater during the high glucose polymer trial than during the water trial during minutes 60-120 (Yaspelkis & Ivy, 1991).

A group of cyclists rode at 71% VO$_2$max for 105 minutes with and without carbohydrate ingestion (Coggan & Coyle, 1991). A sample from the vastus lateralis was taken and measured for muscle glycogen before and after exercise (Coggan & Coyle, 1991). There were no differences found in the muscle glycogen samples (Coggan & Coyle, 1991). The next group of cyclists tested rode at 71% VO$_2$max and had muscle biopsies taken at rest, after 120 minutes of exercise, and at fatigue from both the carbohydrate ingestion trial and the placebo trial (Coggan & Coyle, 1991). Coggan and Coyle (1991) found that after 181 minutes ± 11 minutes of exercise fatigue was reached with the placebo group; however, when fed carbohydrates throughout exercise, fatigue was delayed to 241 minutes ± 20 minutes.

Jeukendrup, Brouns, Wagenmakers, & Saris (1997) researched endurance performance over a one-hour period with carbohydrate feeding. Participants worked at 75% VO$_2$max for each of the two trial’s (Jeukendrup et al., 1997). Nineteen trained cyclist’s ingested a 7.6%
carbohydrate-electrolyte solution or a colored water placebo, totaling 14 ml/kg during the trials (A. Jeukendrup et al., 1997). When cyclists drank the 7.6% carbohydrate-electrolyte solution, performance was increased by 2.3% (Jeukendrup et al., 1997).

Six highly trained cyclists participated in a VO$_2$max followed by six exercise trials (Jeukendrup et al., 1999). The VO$_2$max test was used to determine the subjects’ workload for the following six exercise trials (Jeukendrup et al., 1999). Each of the six trials included 120 minutes of cycling at 50% VO$_2$max (Jeukendrup et al., 1999). The cyclists consumed no glucose, a 4.4% glucose solution, or a 22% glucose solution (Jeukendrup et al., 1999). Each of these trials were repeated once with isotope infusion and once without infusion (Jeukendrup et al., 1999). Glycogen oxidation was similar to the fasted condition, even when given the high glucose solution (Jeukendrup et al., 1999). With a large dose of ingested glucose, not all glucose appears in the plasma (Jeukendrup et al., 1999).

Ivy, Res, Sprague, & Widzer (2003) researched nine trained male cyclists that exercised on four different occasions. The first visit included baseline data and a VO$_2$max test. The second, third, and fourth visits were all randomized and included exercising at intensities from 45 to 75% VO$_2$max for three hours and at 85% VO$_2$max until fatigue (Ivy et al., 2003). During exercise a placebo, 7.75% carbohydrate solution, and a 7.75% carbohydrate/1.94% protein solution were given every 20 minutes (Ivy et al., 2003). Carbohydrate in comparison with the placebo showed an increase of 55% before fatigue occurred. The carbohydrate-protein solution delayed onset of fatigue 36% more so than that of the carbohydrate solution alone (Ivy et al., 2003). An improvement of endurance performance was found with the carbohydrate solution as well as the carbohydrate and protein solution (Ivy et al., 2003). The research that has been conducted on adults shows that carbohydrate ingestion during exercise does increase endurance performance.
Differences in Substrate Utilization Between Youth and Adults

In 1938, the first literature was published about physiological responses to treadmill running and walking specific to children. It was found that children had a lower RER during exercise than their adult counterpart (Robinson, 1938). Further research has shown that youth utilize substrates in a different way than that of adults (Baker & Jeukendrup, 2014). In a study that compared boys to men while cycling at 70% VO_{2peak}, researchers found that exogenous carbohydrate was oxidized faster in boys than in men (Timmons et al., 2003). It was also found that boys had a greater contribution via exogenous carbohydrate to total energy than that of men (Timmons et al., 2003).

A similar study focused on the relationship between pre-adolescent girls (12 years old) and adolescent girls (14 years old) while cycling at 70% VO_{2peak} (Timmons et al., 2007). It was found that unlike the boys and men, the pre-adolescent and adolescent girls had no age related differences in carbohydrate oxidation (Timmons et al., 2007). Timmons et al. (2007) also found that the contribution of exogenous carbohydrate to the total energy expenditure was not different between the pre-adolescent girls compared to the adolescent girls; this was also different than what was discovered in the comparison of boys to men (Timmons et al., 2003; Timmons et al., 2007). A similarity that was found in both studies showed that both boys and girls have higher fat oxidation, a two-fold increase compared to adults, during exercise without the ingestion of a carbohydrate beverage (Timmons et al., 2003; Timmons et al., 2007).

Many studies have shown that youth utilize more fat than carbohydrate during exercise than adults at the same relative intensities (Mahon, 1997; Martinez, 1992; Timmons et al., 2003). However, when given exogenous carbohydrate, the fat oxidation rate of boys compared to men, relative to body mass, was approximately 37% higher in children (Timmons et al., 2003). A
possible reason for youth utilizing more fat than carbohydrate could be due to a glycolytic system that isn’t fully developed; therefore, they are compensating by increasing their reliance on extramuscular sources such as exogenous carbohydrate (Timmons et al., 2003; B. W. Timmons et al., 2007). Another reason for a reduced capacity to utilize glycogen in boys and girls is due to a lower level of muscle glycogen initially (Timmons et al., 2007). Both of the studies by Timmons et al. (2003, 2007) show that during exercise there are differences in substrate utilization between children, just like with adults.

**Carbohydrate Beverages During Exercise in Youth**

It is known that ingestion of carbohydrate can improve both endurance and performance in adults. However, the optimal dose has not been determined (A Jeukendrup, 2008). Extensive research has been conducted on how exogenous carbohydrate consumption affects adults when exercising (Baker & Jeukendrup, 2014; Coggan & Coyle, 1988, 1991; Coyle et al.,1986; E. F. Coyle et al., 1983; Ivy et al., 1979; Ivy et al., 1983; Ivy et al., 2003; A Jeukendrup, 2008; AE Jeukendrup, 2010; A. Jeukendrup, 2013; A. Jeukendrup et al., 1997; A. E. Jeukendrup et al., 1999; Yaspelkis & Ivy, 1991). However, very little research is currently available on how exogenous carbohydrate consumption affects youth during exercise. In children, exercise performance has been shown to increase with carbohydrate ingestion during exercise (Dougherty, Chow, & Kenney, 2006; Phillips SM, 2010; Riddell MC, 2001).

Fifteen male basketball players, age 12-15 years old, participated in a research study analyzing and comparing dehydration and the ingestion of a 6% carbohydrate beverage (Dougherty et al., 2006). The participants came in on three separate occasions, using the same protocol each time aside from the beverage consumed (Dougherty et al., 2006). The three conditions tested were 2% dehydration, a 6% carbohydrate beverage, and a flavored water
EFFECT OF A CARBOHYDRATE

placebo (Dougherty et al., 2006). Participants entered an environmental chamber and exercised on both cycle ergometers as well as treadmills for 2 hours and 15 minutes at 50% VO_{2}\text{max} for the dehydration and euhydration portion of the protocol (Dougherty et al., 2006). After completing this portion of the protocol in the environmental chamber, participants were given an hour recovery period before completing 48 minutes of basketball drills with a 10-minute rest after 24 minutes (Dougherty et al., 2006). Dougherty et al. (2006) found that basketball skills diminished when the participants were dehydrated. However, during euhydration with a 6% carbohydrate beverage improvements were seen in both shooting skills as well as on-court sprinting (Dougherty et al., 2006).

Participants completed a two-visit research study analyzing a 6% carbohydrate-electrolyte solution in comparison to a placebo on endurance capacity (Phillips, 2010). The beverage (carbohydrate or placebo) was consumed 5 minutes prior to exercise (Phillips, 2010). Exercising protocol consisted of the following, 3x20 m at walking pace, 1x20 m sprint, 3x20 m running speed (55% \(V_{\text{peak}}\)), and 3x20 m running speed (95% \(V_{\text{peak}}\)) with a 3 minute recovery period between each segment (Phillips, 2010). The second portion of the protocol consisted of single 20m shuttles at 55% or 95% \(V_{\text{peak}}\); this part of the protocol was dictated by pre-programmed beeps on an audio CD (Phillips, 2010). When consuming the carbohydrate beverage in comparison to the placebo, time to exhaustion was delayed by 24.4% (Phillips, 2010).

Twelve 11-14 year old boys exercised on a cycle ergometer while consuming water, 6% glucose, or 3% glucose plus 3% fructose, all beverages were grape flavored (Riddell, Bar-Or, Wilk, Parolin, & Heigenhauser 2001). Participants exercised on three separate occasions, receiving each of the three fluids over the course of the study (Riddell et al., 2001). Exercise on the cycle ergometer occurred at 55% of the participants VO_{2\text{peak}} for three 30-minute exercise
bouts separated by 5 minute rest periods (Riddell et al., 2001). The last 30-minute exercise bout was followed by a 10-minute rest break prior to a performance trial at 90% of the participants predetermined peak power until exhaustion (Riddell et al., 2001). Beverages were given to participants at 30 minutes and 15 minutes before exercise began and at 0,15, and 30 minutes during each bout of exercise (Riddell et al., 2001). Participants had 30 seconds to drink the beverage (Riddell et al., 2001). It was found that both glucose and fructose are oxidized at similar rates during moderate-intensity exercise over and extended period of time (Riddell et al., 2001). Glucose and fructose contribute to ~16% total energy needs in boys 11-14 years old (Riddell et al., 2001). Compared to water, fructose delays exhaustion at 90% peak power output by ~40% after 90 minutes of moderate intensity exercise (Riddell et al., 2001).

Timmons et al. (2003) took a group of adult men and a group of pre- and early pubertal boys, both at the same exercise intensities and consuming the same amount of exogenous carbohydrate. It was found that healthy young boys oxidize more exogenous carbohydrate during 60 minutes of exercise than that of healthy young men (Timmons et al., 2003). Also found in this study was that the boys used more exogenous carbohydrate (50% higher than in males) for their total energy expenditure, showing that the exogenous fuel may show improved performance and sparing of an endogenous substrate that contributes to growth and development (Timmons et al., 2003). In a study done by Riddell et al. (2001), when looking at boys doing an all out sprint for cycling performance after completing 90 minutes of intermittent cycling, performance can be improved by 20 to 40 percent with a 6% glucose and fructose beverage compared to just a 6% glucose placebo beverage.

Pubertal status may also play a role in the reliance of exogenous carbohydrate in boys (Riddell, 2008). The highest oxidation rates of exogenous carbohydrate have been found in pre-
and early pubertal boys (Riddell, 2008). However, in girls, the rate of oxidation of exogenous carbohydrate is not different compared between 12-14-year-old girls (Timmons, et al., 2007). These findings show differences between boys and girls with substrate utilization during exercise (Timmons, et al., 2007). Most research that has been done looking at children and carbohydrate beverages during exercise has only been done on boys. Very few studies exist looking at girls and carbohydrate beverages during exercise.

**Summary**

When young adults exercise, they sweat and become dehydrated. Dehydration occurs because as they’re exercising, young adults do not realize the amount of fluid that needs to be consumed to offset the fluid that is being lost via sweat while competing. It has been shown in adults that carbohydrates not only improve performance, but also aid in keeping adults hydrated. Currently, there is very little research present on how carbohydrates affect young adults during exercise. The limited research that is available has shown that carbohydrate beverages do benefit young adults during exercise. There is a need for future research on performance, carbohydrate beverages, and young adults.
Chapter 3

Methodology and Procedures

Subjects

A total of 19 participants, youth ages 7-17 and adults ages 18-30, were recruited for this study from the Ypsilanti/Ann Arbor area. Participants came to the Applied Exercise Physiology Laboratory on an individual basis (with their parents if applicable) on three occasions. An outline of the protocol can be found in Figure 1. Each visit was separated by 3 to 4 days and no more than 2 weeks. Participants were tested around the same time of day. Participants were asked to refrain from eating 3 hours prior to each testing session and asked to refrain from vigorous physical activity the day of and the day before testing.

Data Collection

Prior to any exercise testing, all participants completed an informed assent (along with parental informed consent; see Appendix A) or an informed consent (see Appendix B), a Physical Activity Readiness Questionnaire (PAR-Q; see Appendices C and D), and a health history. This is standard pre-exercise screening according to the American College of Sports Medicine (ACSM). All participants then completed a pre-exercise evaluation. Anthropometric measures include height, seated height, weight, and body composition through skinfolds.

Height, seated height, and weight were taken in triplicate with a stadiometer and scale, respectively. The participant’s height was taken by having the participant take off their shoes and stand with their back against the stadiometer. Prior to taking the height of the participant the researcher ensured that the participant’s heels, buttocks, shoulders, and head were all against the stadiometer (Lohman, 1988). The researcher instructed the participant to take a slight breath in and moved the head plate to rest on top of the participant’s head, with enough pressure to press
the participants hair down (Lohman, 1988). The measurement was then recorded to the nearest 0.1 cm (Lohman, 1988). Seated height was taken by having the participant sit on a stool placed in front of the stadiometer. The participant had their back up against the stadiometer, making sure their lower back, shoulders, and head were all resting against the stadiometer. The hands of the participant rested on their knees (Lohman, 1988). The researcher then instructed the participant to take a slight breath in and move the head plate to rest on top of the participants’ head (Lohman, 1988). The measurement was recorded to the nearest 0.1 cm (Lohman, 1988).

Weight was measured for the participants using a Tanita scale. Prior to the participant stepping onto the scale, their shoes were removed. The participant stood on the scale with both feet, with their weight evenly distributed (Lohman, 1988). The researcher then recorded the weight of the participant.

Skinfolds were taken in triplicate at the calf and triceps to measure the youth participant’s body composition. All measures were made using a Lange skinfold caliper on the right side of the body and each site measurement was within 1-2 mm of one another (ACSM, 2014). The researcher pinched the participant’s skin using the thumb and index finger. The caliper was then placed directly onto the participant’s skin 1 cm from the researchers pinch (ACSM, 2014). The measurement was read while the researcher held the pinch on the participant, leaving the calipers on the location for 1-2 seconds prior to reading the measurement (ACSM, 2014).

The triceps skinfold is a vertical fold. The location of the measurement is half way between the acromion and olecranon processes on the posterior midline of the upper arm (ACSM, 2014). The researcher marked this exact location with a marker to ensure each measurement was taken in the same location. While this measurement was being taken, the
participant stood with their arms hanging to their sides in a relaxed fashion (ACSM, 2014). The second location was the medial calf. Like the triceps, this too is a vertical skinfold (ACSM, 2014). The calf skinfold measure was taken at the largest circumference of the calf on the midline of its medial border (ACSM, 2014). To ensure accuracy, the researcher marked this exact location with a marker so each measurement was taken in the same location. The average values were taken for each skinfold and were then placed into the skinfold equation. The equation used to calculate body composition for the males was $0.735(\text{triceps} + \text{calf}) + 1.0$ and for females the equation used was $0.610(\text{triceps} + \text{calf}) + 5.1$ (Slaughter, 1988).

Skinfolds were taken in triplicate at seven different locations to calculate the adults body composition. The seven skinfold locations were the triceps, chest, mid-axillary, subscapular, supra iliac, abdominal, and thigh. All measures were made using a Lange skinfold caliper on the right side of the body and each site measurement was within 1-2 mm of one another (ACSM, 2014). The researcher pinched the participant’s skin using the thumb and index finger. The caliper was then placed directly onto the participant’s skin 1 cm from the researchers pinch (ACSM, 2014). The measurement was read while the researcher held the pinch on the participant, leaving the calipers on the location for 1-2 seconds prior to reading the measurement (ACSM, 2014).

The triceps skinfold is a vertical fold. The location of the measurement is half way between the acromion and olecranon processes on the posterior midline of the upper arm (ACSM, 2014). The researcher marked this exact location with a marker to ensure each measurement was taken in the same location. While this measurement was being taken, the participant stood with their arms hanging to their sides in a relaxed fashion (ACSM, 2014). The second location is the chest, a diagonal fold. The skinfold is to be done along the natural line of
the skin, between the anterior axillary line and the nipple one-half for men and one-third for women (ACSM, 2014). The researcher marked this exact location with a marker to ensure each measurement was taken in the same location. The third location is the midaxillary, a vertical fold. This skinfold is located on the midaxillary line at the xiphoid process (ACSM, 2014). The researcher marked this exact location with a marker to ensure each measurement was taken in the same location. The fourth location is the subscapular, a diagonal fold at a 45° angle. The researcher measured 2 cm below the scapula at the interior angle (ACSM, 2014). The researcher marked this exact location with a marker to ensure each measurement was taken in the same location. The supra iliac, the fifth location, is a diagonal fold along the natural angle of the iliac crest (ACSM, 2014). The researcher is measured just above the iliac crest along the anterior axillary line (ACSM, 2014). The researcher marked this exact location with a marker to ensure each measurement was taken in the same location. The abdomen, the sixth location, is a vertical fold. The researcher measured 2 cm to the right of the umbilicus (ACSM, 2014). This measurement must be level with the umbilicus (ACSM, 2014). The researcher marked this exact location with a marker to ensure each measurement was taken in the same location. The thigh, the seventh location, is a vertical fold. The researcher first ensured the leg was relaxed (ACSM, 2014). Once the leg was relaxed the researcher measured from the top of the patella to the inguinal crease and placed a mark half way between (ACSM, 2014). The average values were taken for each skinfold and were then placed into the skinfold equation. The equation used to calculate body composition for the adult males was $1.112 - 0.00043499 \text{(sum of seven skinfolds)} + 0.00000055 \text{(sum of skinfolds)}^2 - 0.00028826 \text{(age)}$ (ACSM, 2014). The value (body density) from the above equation was then placed into the following equation to calculate percent body fat. The equation used for men was $(457/\text{Body Density}) - 414.2$ (ACSM, 2014). The equation
used to calculated body composition for the adult females was 1.097 – 0.00046971 (sum of the seven skinfolds) + 0.00000056 (sum of seven skinfolds)² – 0.00012828 (age); (ACSM, 2014).

The value (body density) from the equation above was then placed into the following equation to calculate percent body fat. The equation used for women was (495/ Body Density) – 450 (ACSM, 2014).

Resting heart rate and resting blood pressure were taken in triplicate prior to exercise. To take the resting heart rate measurement, the participant was seated. The researcher took a radial heart rate, using their pointer and middle fingers and placing their fingers over the participant’s radial artery (ACSM, 2014). The researcher then counted the number of beats felt over a fifteen second period and multiplied this number by four to get the participants resting heart rate (ACSM, 2014). The participants resting blood pressure was taken while the participant was seated. A blood pressure cuff was placed tightly over the participant’s biceps. The researcher then placed the stethoscope over the subject’s brachial artery. Once the stethoscope was secured over the participants’ brachial artery, the researcher inflated the blood pressure cuff, following a gradual deflation of the cuff in order to get the participants blood pressure (ACSM, 2014).

![Figure 1. Protocol Overview.](image)
Testing Protocols

**Experimental Session #1.** After completing pre-exercise measures, participants that were deemed healthy by ACSM guidelines completed a VO$_{2peak}$ test on a pediatric or adult cycle ergometer (Lode, Groningen, Netherlands). A VO$_{2peak}$ test is a widely used test in the field of exercise science to determine cardiovascular fitness (Carrel et al., 2008). The VO$_{2peak}$ test consisted of exercising for approximately 9-12 minutes.

Prior to exercise beginning, the Parvo metabolic system (Sandy, Utah) was calibrated. Ambient conditions, gas flow, and syringe calibration were run prior to the participants’ information being entered into the system. The participant’s age, gender, height (in cm) and weight (in kilograms) were entered into the Parvo metabolic system. Prior to the mouthpiece and mask being placed onto the participant, the nature of the test was described to them. The specific protocol utilized was the McMaster cycle ergometer protocol (see Table 1: McMaster Cycle Ergometer Protocol), designed specifically for children. This protocol is based upon the participant’s height in cm and gave the participant their initial work rate. During the test, participants maintained 50 rpms. Each stage lasted for 2 minutes, and heart rate, collected using the polar monitor, as well as the rating of perceived exertion were monitored throughout each stage. Rating of perceived exertion was measured using the Omni scale. The Children’s Omni scale of perceived exertion is a scale ranging from 0 to 10, with both the numbers and the pictures present for the participant to determine how hard they’re working (Utter, 2002). The participant continued to ride on the cycle ergometer until volitional fatigue (they were no longer able to continue). For the adult participants the workload began at 25 watts and increased every 2 minutes by 50 watts for males and 25 watts for females.
Table 1
*McMaster Cycle Ergometer Protocol*

<table>
<thead>
<tr>
<th>Height (cm)</th>
<th>Initial work rate (watts)</th>
<th>Increments (watts)</th>
<th>Duration (mins)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;120</td>
<td>12.5</td>
<td>12.5</td>
<td>2</td>
</tr>
<tr>
<td>120-139.9</td>
<td>12.5</td>
<td>25</td>
<td>2</td>
</tr>
<tr>
<td>140-159.9</td>
<td>25</td>
<td>25</td>
<td>2</td>
</tr>
<tr>
<td>≥160</td>
<td>25</td>
<td>50 for boys, 25 for girls</td>
<td>2</td>
</tr>
</tbody>
</table>

Following the explanation of what was expected of the participant, the Parvo metabolic system mouthpiece was placed into the participants mouth as well as a nose clip being placed over the participants nose. Once the mouthpiece and nose clip were secured on the participant, it was asked that the participant not speak and instead use hand signals to the researchers if they needed to communicate throughout the test. The hand signals were reviewed with the participants to ensure they felt comfortable and safe using them. Hand signals included how to ask for the fan and how to stop the test once the participant had reached volitional fatigue.

Throughout the test, metabolic measures were collected using the Parvo metabolic system. This involved the participant using a mouthpiece with a flow meter attached to collect expired gases. The mouthpiece did not interfere with the participant’s ability to exercise as they would normally. While the participant was riding on the cycle ergometer for the VO\textsubscript{2peak} test, RER, VO\textsubscript{2}, VCO\textsubscript{2}, and V\textsubscript{E} were all collected. The data collected from the VO\textsubscript{2peak} test was used for sessions 2 and 3 to determine the participant’s workloads.

**Experimental Sessions #2 and #3.** Prior to sessions 2 and 3, individuals were asked to keep a 24-hour food and physical activity log. The logs assisted in keeping both food consumption and activity consistent prior to each test. Participants were advised to refrain from any vigorous physical activity the day prior to as well as the day of testing. For session 2, participants completed an exercise session on the cycle ergometer. The exercise session was
approximately 75 minutes in duration, consisting of two 30-minute rides followed by a 2-mile performance trial. Participants rode at 55% of their VO$_{2\text{peak}}$ determined from the VO$_{2\text{peak}}$ test completed during session 1. Resting heart rate, RPE, and metabolic measures (RER, VO$_2$, VCO$_2$, and $V_E$) from the Parvo metabolic cart were also taken prior to exercise. Resting metabolic measures (RER, VO$_2$, VCO$_2$, and $V_E$) were collected for one minute prior to exercise beginning.

During the trial, participants consumed either water (placebo) or a 6% carbohydrate beverage (Gatorade©). The participant consumed the drink (either the placebo or the carbohydrate beverage) at 10 minutes, 20 minutes, and 30 minutes for both sessions 2 and 3. During the time that the drink was administered the participant was not wearing the mouthpiece or metabolic mask, the participant continued to ride the Lode while consuming the beverage. The carbohydrate beverage was given during session 2 or 3, and the placebo was administered at the opposite session. The total amount of fluid consumed during the experimental session was equal 16 ml/kg of body weight (Timmons et al., 2003). Drink order was single-blind, randomized, and counterbalanced.

During the first 30 minutes of the trail, metabolic measures (RER, VO$_2$, VCO$_2$, and $V_E$) were taken from minutes 12-17 and 25-30 minutes. For the remainder of the ride the participant was not wearing the mouthpiece or the metabolic mask. Heart rate and RPE were taken every 5 minutes. There was a 5-minute rest period following the 30-minute ride. Participants then rode for another 30-minutes and metabolic measures, heart rate, and RPE were all collected in the same manner as the first 30-minute ride. Following the second 30-minute ride, there was a 10-minute rest period.
Each participant then performed a 2 mile time trial on the cycle ergometer. Participants were asked to ride as hard as they could for 2 miles for time. Heart rate, RPE, and metabolic measures were collected throughout the 2 mile time trial. Metabolic measures were taken during the entire 2-mile time trial, heart rate, and RPE were taken every minute. Individuals performance was measured based upon the time it took each subject to complete the two miles. For the third session, participants complete the identical protocol as in session 2, but consumed whichever beverage wasn’t previously given.

**Measures**

**Metabolic measures.** VO$_2$, VCO$_2$, and V$_{E}$ were analyzed throughout the test.

Metabolic measurements were compiled using the Parvo metabolic system. Measurements were taken during Ride 1, Ride 2, and during the performance trials. For Ride 1 and 2 subject’s metabolic measurements were taken from 12-17 minutes as well as 25-30 minutes.

**Heart rate.** Heart rate was measured for each subject using a Polar heart rate monitor. Children wore a chest strap during the entire test. Heart rate was recorded every 5 minutes during Ride 1 and Ride 2. For the performance trial heart rate was recorded every minute.

**Skinfolds.** At the participant’s initial visit skinfolds were taken to determine their body composition. The skinfold site’s that were measured are the calf and triceps for youth. The measurements were then placed into the Slaughter-Lohman formula. The skinfold sites that were measured for adults were the triceps, chest, mid-axillary, subscapular, supra iliac, abdominal, and thigh. The measurements were then placed into the ACSM body density and percent body fat formulas.
Rate of perceived exertion. Rating of perceived exertion (RPE) was determined by showing children the Children’s Omni RPE scale. The Omni RPE scale is a 0-10 scale that children can point or verbally tell test administrators how hard they were working. The Omni scale has both numerical values as well as pictures. RPE was recorded every 5 minutes during Ride 1 and Ride 2. For the performance trial, RPE was recorded every minute.

Statistical Analysis

Data analysis was configured using Statistical Package for the Social Sciences (SPSS) Version 25. Each purpose statement, hypothesis, and statistical analysis is outlined below:

1) One aim of this study was to determine if youth experience the same performance benefit from carbohydrate beverages compared to adults. It was hypothesized that youth, like adults, would experience a performance benefit from carbohydrate beverages.

   A paired samples t-test was used to determine differences in youth’s performance time trials (carbohydrate beverage vs. water). A paired samples t-test was also used to determine differences in the adult performance time trials (carbohydrate beverage vs. water). Differences were considered significant at an alpha level of $p<.05$.

2) A second aim of this study was to determine differences if metabolic measures ($VO_2$, $V_E$, & RER) between the carbohydrate and water performance trials in youth and adults. It was also hypothesized that there would be a difference in metabolic measures ($VO_2$, $V_E$, & RER) between the carbohydrate beverage and water trials in youth and adults.
A paired samples $t$-test was used to determine differences in metabolic measures
(VO$_2$, VE, & RER) in youth. Differences were considered significant at an alpha
level of $p<.05$.

3) A third aim was to examine changes in metabolic measures (VO$_2$, VE, & RER)
throughout a 60-minute ride in youth. The third hypothesis was that there would be a
difference in metabolic measures (VO$_2$, VE, & RER) for youth throughout a 60-minute
ride.

A paired samples $t$-test was used to determine differences in metabolic measures
(VO$_2$, VE, & RER) between the water and carbohydrate trials in youth.

Differences were considered significant at an alpha level of $p<.05$. 
Chapter 4

Results

There were a total of 19 participants (12 males and 7 females) who completed this study. Twenty participants began the study; however, one participant dropped out of the study after only completing the first visit for unknown reasons. Participants were divided into two groups, youth (7-17 years old) and adults (18-30 years old). Descriptive statistics for both youth and adults can be found in Table 2.

Table 2
Descriptive Statistics of Participants

<table>
<thead>
<tr>
<th></th>
<th>Youth (n = 8)</th>
<th>Adults (n = 11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>12.25 ± 3.41</td>
<td>23 ± 3.82</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>157.662 ± 19.96</td>
<td>172.645 ± 9.58</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>53.975 ± 18.70</td>
<td>72.136 ± 12.82</td>
</tr>
<tr>
<td>% Body Fat</td>
<td>22.514 ± 9.12</td>
<td>14.174 ± 7.22</td>
</tr>
<tr>
<td>Initial VO\textsubscript{2max} (ml/kg/min)</td>
<td>37.313 ± 5.25</td>
<td>38.291 ± 6.37</td>
</tr>
</tbody>
</table>

Note. Descriptive statistics are reported as mean ± standard deviation

One aim of this study was to determine if youth experience the same performance benefit from carbohydrate beverages compared to adults. A secondary aim of this study was to determine differences if metabolic measures (VO\textsubscript{2}, V\textsubscript{E}, & RER) between the carbohydrate and water performance trials in youth and adults. A third aim was to examine changes in metabolic measures (VO\textsubscript{2}, V\textsubscript{E}, & RER) throughout a 60-minute ride in youth. It was hypothesized that youth, like adults, would experience a performance benefit from carbohydrate beverages. It was also hypothesized that there would be a difference in metabolic measures (VO\textsubscript{2}, V\textsubscript{E}, & RER) between the carbohydrate beverage and water trials in youth and adults. The third hypothesis was that there would be a difference in metabolic measures (VO\textsubscript{2}, V\textsubscript{E}, & RER) for youth throughout a 60-minute ride.
Paired $t$-tests were run to determine if there was a statistical difference in performance times when consuming water compared to a carbohydrate beverage for both youth and adults. Differences were considered significant at an alpha level of $p<.05$. It was found that there was no significance between performance time trials when comparing the carbohydrate beverage and water in youth. There was also no statistical significance between performance time trials (carbohydrate beverage vs. water) for adults. Youth had a faster performance trial when consuming a carbohydrate beverage. Adults had a faster performance trial when consuming water. Below in Tables 3-4b, Pair 1 refers to youth (C) and Pair 2 refers to adults (A). Refer to Tables 3-4b.

Table 3
*Descriptive Statistics of Performance Times*

<table>
<thead>
<tr>
<th>Pair 1</th>
<th>TimeCHOC</th>
<th>N</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>TimeWaterC</td>
<td>10:53</td>
<td>8</td>
<td>04:55</td>
<td>01:44</td>
</tr>
<tr>
<td>Pair 2</td>
<td>TimeCHOA</td>
<td>11</td>
<td>02:30</td>
<td>00:45</td>
</tr>
<tr>
<td>TimeWaterA</td>
<td>07:47</td>
<td>11</td>
<td>02:30</td>
<td>00:45</td>
</tr>
</tbody>
</table>

Table 4a
*Paired Samples Test for the Performance Trials*

<table>
<thead>
<tr>
<th>Pair 1</th>
<th>TimeCHOC - TimeWaterC</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>95% Confidence Lower</th>
</tr>
</thead>
<tbody>
<tr>
<td>TimeCHOA</td>
<td>TimeWaterA</td>
<td>*****</td>
<td>01:32</td>
<td>00:32</td>
<td>*****</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pair 2</th>
<th>TimeCHOA - TimeWaterA</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>95% Confidence Lower</th>
</tr>
</thead>
<tbody>
<tr>
<td>TimeCHOA</td>
<td>TimeWaterA</td>
<td>00:10</td>
<td>00:30</td>
<td>00:09</td>
<td>*****</td>
</tr>
</tbody>
</table>
Paired t-tests were conducted to determine if there was a statistical difference in metabolic measures between the carbohydrate and water performance time trials for youth. Differences were considered significant at an alpha level of $p<.05$. It was found that there was no significance within the metabolic measures between the carbohydrate and water performance time trials for youth. Pairs 1, 2, and 3 display the values for VO$_2$, V$_E$, and RER for the carbohydrate and water performance trials. VO$_2$, V$_E$, and RER were all higher during the carbohydrate trial compared to the water trial. Refer to Tables 5-6b.

Paired t-tests were conducted to determine if there was a statistical difference in metabolic measures between the carbohydrate and water performance time trials for adults. Differences were considered significant at an alpha level of $p<.05$. It was found that there was no significance within the metabolic measures between the carbohydrate and water performance time trials for youth. Pairs 1, 2, and 3 display the values for VO$_2$, V$_E$, and RER for the carbohydrate and water performance trials. VO$_2$, V$_E$, and RER were all higher during the carbohydrate trial compared to the water trial. Refer to Tables 7-8b.
Table 5
*Descriptive Statistics for Metabolic Performance Data for Youth*

<table>
<thead>
<tr>
<th>Pair</th>
<th>VO2_CHO_Performance</th>
<th>N</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1</td>
<td>34.2214</td>
<td>8</td>
<td>6.67071</td>
<td>2.35845</td>
</tr>
<tr>
<td></td>
<td>VO2_W_Performance</td>
<td>8</td>
<td>8.36943</td>
<td>2.96859</td>
</tr>
<tr>
<td>Pair 2</td>
<td>53.0833</td>
<td>8</td>
<td>19.29555</td>
<td>6.82201</td>
</tr>
<tr>
<td></td>
<td>VE_CHO_Performance</td>
<td>8</td>
<td>20.63772</td>
<td>7.29654</td>
</tr>
<tr>
<td></td>
<td>VE_W_Performance</td>
<td>8</td>
<td>20.63772</td>
<td>7.29654</td>
</tr>
<tr>
<td>Pair 3</td>
<td>RER_CHO_Performance</td>
<td>8</td>
<td>0.14099</td>
<td>0.04985</td>
</tr>
<tr>
<td></td>
<td>RER_W_Performance</td>
<td>8</td>
<td>0.03092</td>
<td>0.01093</td>
</tr>
</tbody>
</table>

Table 6a
*Paired Samples Test for Metabolic Performance Data in Youth*

<table>
<thead>
<tr>
<th>Paired Differences</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>95% Confidence Lower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1 VO2_CHO_Performance - VO2_W_Performance</td>
<td>1.61025</td>
<td>6.35873</td>
<td>2.24815</td>
<td>-3.70578</td>
</tr>
<tr>
<td>Pair 2 VE_CHO_Performance - VE_W_Performance</td>
<td>2.30900</td>
<td>10.09096</td>
<td>3.56769</td>
<td>-6.12725</td>
</tr>
<tr>
<td>Pair 3 RER_CHO_Performance - RER_W_Performance</td>
<td>0.04300</td>
<td>0.11438</td>
<td>0.04044</td>
<td>-0.05262</td>
</tr>
</tbody>
</table>

Table 6b
*Paired Samples Test for Metabolic Performance Data in Youths*

<table>
<thead>
<tr>
<th>Paired Differences</th>
<th>Upper</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1 VO2_CHO_Performance - VO2_W_Performance</td>
<td>6.92628</td>
<td>.716</td>
<td>7</td>
<td>.497</td>
</tr>
<tr>
<td>Pair 2 VE_CHO_Performance - VE_W_Performance</td>
<td>10.74525</td>
<td>.647</td>
<td>7</td>
<td>.538</td>
</tr>
<tr>
<td>Pair 3 RER_CHO_Performance - RER_W_Performance</td>
<td>0.13862</td>
<td>1.063</td>
<td>7</td>
<td>.323</td>
</tr>
</tbody>
</table>
Table 7
*Descriptive Statistics for Metabolic Performance Data for Adults*

![Paired Samples Statistics Table]

Table 8a
*Paired Samples Test for Metabolic Performance Data in Adults*

![Paired Samples Test Table 1]

Table 8b
*Paired Samples Test for Metabolic Performance Data in Adults*

![Paired Samples Test Table 2]
Paired *t*-tests were also conducted to determine if there was a statistical difference among the metabolic measures (VO$_2$, V$_E$, & RER) between the carbohydrate trial and water trial for youth during the 60-minute ride. Differences were considered significant at an alpha level of *p*<.05. RER was significant for the water and carbohydrate trials. VO$_2$ was significant for the carbohydrate trial. Metabolic measures were measured at Time Point 1 and Time Point 4 of the 60-minute ride. Time Point 1 was an average of minutes 12-17 of the 60-minute ride. Time Point 4 was an average of minutes 55-60 of the 60-minute ride. Pair 1 shows the VO$_2$ data for Time Points 1 and 4, Pair 2 shows the V$_E$ data for Time Points 1 and 4, and Pair 3 show the RER data for Time Points 1 and 4. Tables 7-8b show metabolic data from the water trial of the 60-minute ride. Tables 9-10b show metabolic data from the carbohydrate beverage trial of the 60-minute ride. VO$_2$ remained the same during the water trial and had a slight increase during the carbohydrate trial. V$_E$ decreased during the water trial and increased during the carbohydrate trial. RER decreased during the water trial and decreased during the carbohydrate trial. Refer to Tables 6-9b.

**Table 9**  
*Descriptive Statistics for Metabolic Ride Data for Water in Youth*
Table 10a
*Paired Samples Test for Metabolic Ride Data for Water in Youth*

![Paired Samples Test for Water in Youth](image)

Table 10b
*Paired Samples Test for Metabolic Ride Data for Water in Youth*

![Paired Samples Test for Water in Youth](image)

Table 11
*Descriptive Statistics for Metabolic Ride Data for Carbohydrate in Youth*

![Paired Samples Statistics](image)
Table 12a
*Paired Samples Test for Metabolic Ride Data for Carbohydrate in Youth*

<table>
<thead>
<tr>
<th>Paired Differences</th>
<th>Paired Samples Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>Pair 1 VO₂ CHO₁ - VO₂ CHO₄</td>
<td>-2.89737</td>
</tr>
<tr>
<td>Pair 2 VE CHO₁ - VE CHO₄</td>
<td>-1.99037</td>
</tr>
<tr>
<td>Pair 3 RER CHO₁ - RER CHO₄</td>
<td>.04125</td>
</tr>
</tbody>
</table>

Table 12b
*Paired Samples Test for Metabolic Ride Data for Carbohydrate in Youth*

<table>
<thead>
<tr>
<th>Paired Samples Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Pair 1 VO₂ CHO₁ - VO₂ CHO₄</td>
</tr>
<tr>
<td>Pair 2 VE CHO₁ - VE CHO₄</td>
</tr>
<tr>
<td>Pair 3 RER CHO₁ - RER CHO₄</td>
</tr>
</tbody>
</table>
Chapter 5

Summary

Research has shown that youth utilize substrates differently than adults (Baker & Jeukendrup, 2014). Youth are able to make use of exogenous carbohydrate faster than adults when exercising for prolonged periods of time (Timmons, 2007). It has been well documented within the adult population that consumption of a carbohydrate beverage during exercise both enhances performance and decreases the onset time of fatigue in comparison to water (Coyle et al., 1986; Coyle et al., 1983). However, there are a very limited number of studies that have been conducted on youth’s exercise performance and carbohydrate beverages. Considering the increase in the prevalence of childhood obesity (Hancox, 2004; Ogden, 2015; Schwimmer, 2003; Stensel, 2008), it is important to educate youth on what they should and should not consume. Although it is simple to grab a carbohydrate beverage, such as Gatorade®, they contain added calories and sugar compared to water. Carbohydrate beverages contain many ingredients said to increase performance; however, little research has been done on sports drinks and youth performance (Jeukendrup, 2010).

The purpose of this study was to determine the effect of a carbohydrate beverage on cycling time trial performance compared to water in youth in a controlled laboratory setting. Participants came into the Running Science Laboratory on three separate occasions, one performance trial was done while the participant consumed water and the second performance trial was completed while the participant drank a carbohydrate beverage. An aim of this study was to determine if youth elicit the same response when consuming a carbohydrate beverage in performance compared to adults. Both adults and youth completed the exact same performance protocol while riding a Lode cycle ergometer. Youth completed the carbohydrate performance
EFFECT OF A CARBOHYDRATE

trial faster than that of the water performance trial. Adults completed the water performance trial faster than the carbohydrate performance trial. It was found that there was no significance within the metabolic measures between the carbohydrate and water performance time trials for youth. During the 60-minute ride, RER was significant during the water and carbohydrate trials and VO₂ was significant for the carbohydrate trial for youth.

Obesity and Youth

Obesity remains a concern in the United States for both adults and youth. From the years 2011-2014, 36% of adults and 17% of youth were classified as obese (Ogden et al., 2015). Among adults, women have a higher rate of obesity compared to men, but in youth no differences were seen between sexes (Ogden et al., 2015). In order to lower these statistics, youth must participate in physical activity. There are 45 million youth 6-18 years old in the United States that participate in organized sports (DiFiori, 2014). During exercise, youth consume carbohydrate beverages. Sports drinks contain many added calories that youth often do not burn off during exercise. Youth consume carbohydrate beverages in excess, and there is very little research showing their effects on youth’s endurance performance (Seifert et al., 2011).

Performance

Performance has been improved through the consumption of a carbohydrate beverage during exercise for adults. Coyle et al. (1983) performed a study that used a cycling protocol for adult cyclists. The adults cycled on three separate occasions, using the same protocol each time (Coyle et al., 1983). For the first visit, the cyclist got familiar with the protocol. On the second and third visits, the cyclist received a placebo solution, and the other visit they received a glucose polymer solution (Coyle et al., 1983). Coyle et al. (1983) found that when the adult cyclists were exercising at 70-80% VO₂max while drinking the glucose polymer solution, fatigue of the
cyclist was delayed. Following Coyle’s research many began investigating carbohydrate beverages and adults exercise performance.

In 1983, Ivy et al. found that ingesting a carbohydrate during prolonged exercise could increase endurance performance by 11.5%. Coyle et al. (1986) found that adult cyclists were able to cycle to fatigue riding at 70% of their VO2max, 33% longer when given a carbohydrate beverage compared to a placebo, therefore showing that utilization of a carbohydrate beverage during exercise promotes the ability to improve their exercise endurance. In a study done in 2003, Ivy et al. found a 55% increase in performance before fatigue occurred in comparison to the placebo when cyclists exercising at varied intensities. The more recent studies that have been performed on adults and carbohydrate beverages tell the same stories as the research that has been done in the past. Carbohydrate ingestion while exercising does aid in the improvement of endurance performance.

With the research available on adults and carbohydrate beverages, it would be expected that youth would have a similar improvement in exercise performance as adults. However, this was not the case in this study. It is believed that youth did not see an improvement in exercise performance due to the short duration of the performance trial and the differences that exist between substrate utilization between adults and youth. It is known that children and adults utilize substrates differently. In the studies that have been completed on youth and exercise performance without a carbohydrate beverage, it has been found that youth have a higher fat oxidation, two fold, that of adults (Timmons et al., 2003; Timmons et al., 2007). Research has also shown an increased fat oxidation in youth when given exogenous carbohydrate (Timmons et al., 2003). A possible explanation for children utilizing more fat than carbohydrate could be due to a glycolytic system that is still under developed (Timmons et al., 2003; Timmons et al., 2007).
Another reason for a reduced capacity to utilize glycogen in youth is due to a lower level of muscle glycogen initially (Timmons et al., 2007).

Timmons et al. (2003) found a difference when comparing boys to men during exercise with a carbohydrate beverage. The study found that during exercise endogenous carbohydrate utilization was lower compared to exogenous carbohydrate utilization in boys compared to men (Timmons et al., 2003). Timmons et al. (2003) believed that this could be due to boys preserving the endogenous fuels and could relate to pubertal status. The current study did not find any differences between adults and youth. This could be due to the smaller sample size and also due to not breaking down the age groups of youth into pre-puberty and puberty. The present study also had men, women, boys, and girls and not just men and women.

**Metabolic Factors**

**\( \text{VO}_2 \).** The average \( \text{VO}_2 \) for adults during the performance water trial was 35.32 mL/kg/min ± 8.02 mL/kg/min and for the performance carbohydrate trial 33.96 mL/kg/min ± 6.93 mL/kg/min. This shows an increase in \( \text{VO}_2 \) when consuming water compared to that of the \( \text{VO}_2 \) while consuming a carbohydrate beverage. The average \( \text{VO}_2 \) for youth during the performance water trial was 32.61 mL/kg/min ± 8.40 mL/kg/min and for the performance carbohydrate trial 34.22 mL/kg/min ± 6.67 mL/kg/min. For youth this shows an increase in \( \text{VO}_2 \) when consuming the carbohydrate beverage compared to the water trial \( \text{VO}_2 \).

It was expected that there would be a difference in \( \text{VO}_2 \) between the carbohydrate and water performance trials for both adults and youth. The data shows a difference in \( \text{VO}_2 \) between the carbohydrate and water trials, listed above. When consuming a carbohydrate beverage during exercise, it is known to enhance performance and delay the onset of fatigue, allowing
participants to exercise for a longer duration (Coyle et al., 1986; Coyle et al., 1983). An O\textsubscript{2} drift was expected among the participants, due to the duration of exercise.

Timmons et al. (2003) found that VO\textsubscript{2} remained the same between boys and males during the carbohydrate and placebo trials. During the carbohydrate trial, the average VO\textsubscript{2} for boys was 31.4 mL/kg/min and 31.2 mL/kg/min for the placebo trial (Timmons et al., 2003). For the adult male group, VO\textsubscript{2} was 31.9 mL/kg/min for the carbohydrate trial and 32.1 mL/kg/min for the placebo trial (Timmons et al., 2003). In comparison to the present study, it appears that both groups (adult and youth) were working about as hard as the participants in Timmons et al. (2003) study. The present study shows a slight difference between the carbohydrate and water trials when comparing youth to adults.

V\textsubscript{E}. The average V\textsubscript{E} for adults during the performance water trial was 79.15 L/min ± 32.28 L/min and 74.96 ± 27.95 L/min for the performance carbohydrate trial. The average V\textsubscript{E} for youth during the performance water trial was 50.77 ± 20.64 L/min and for the performance carbohydrate trial was 53.08 L/min ± 19.30 L/min. It was expected that V\textsubscript{E} would be about the same for both trials. During both performance trials, participants should have been pushing themselves to reach the 2-mile distance as quickly as possible.

During the water trial, adults were breathing more rapidly compared to that of the carbohydrate trial. For youth, it appears they were breathing more rapidly during the carbohydrate trial compared to that of the water trial. The overall average for both adults and youth for V\textsubscript{E} were within 3-4 L/min, therefore showing that during both trials, the participants were breathing at almost the same rate.

Timmons et al. (2003) found that V\textsubscript{E} for boys and men remained almost identical between the carbohydrate and placebo trials. Boys had an average V\textsubscript{E} of 30.8 L/min for the
carbohydrate trial and 30.2 L/min during the placebo trial (Timmons et al., 2003). Men had an average $V_E$ of 65.4 L/min for the carbohydrate trial and the placebo trial (Timmons et al., 2003). When comparing the data to the present study, both groups (youth and adult) were working harder compared to the findings of Timmons et al. (2003).

**RER.** The average RER during the performance water trial for adults was 0.98 ± 0.09 and 0.99 ± 0.08 for the performance carbohydrate trial. The average RER for youth during the performance water trial was 0.90 ± 0.03 and 0.95 ± 0.14 during the performance carbohydrate trial. It was expected that RER would be higher during the carbohydrate trial compared to that of the water trial due to the participant consuming a carbohydrate beverage.

For adults, RER was higher during the carbohydrate trial compared than the water trial. During the carbohydrate trial, RER was higher for youth than the water trial. RER was higher during the carbohydrate trial compared to that of the water trial for both adults and youth because when the body is burning fat, RER is lower and when the body is burning carbohydrate as a fuel source, RER is higher.

In a study similar to the present research, it was found that RER remained the same for both boys (0.84 ± 0.01) and men (0.84 ± 0.03) when ingesting a carbohydrate beverage or the placebo (Timmons et al., 2003). In comparison, youth RER averaged to 0.93 ± 0.09 and adults RER averaged to 0.99 ± 0.09 between both trials. It appears that in the present study RER was slightly higher for both youth and adults, but there were also girls and females included in this data set compared to an all boy or male data set.

**Strengths of the Study**

Strengths of the study included a wide age range of youth being tested, researching an area that has not been very thoroughly examined, and being able to compare adult and youth data.
due to using the same protocol. Most studies that have been conducted in this area of research have been done on youth ages 12-17. This particular study investigated youth aged 8-16, allowing further insight into youth that are younger. Currently, the amount of research available in this area is very limited, and due to the lack of research, most carbohydrate recommendations for youth are based upon what is found in the adult population. This study has provided additional information on carbohydrate beverages and hopefully will allow further questioning and research in youth performance and carbohydrate beverages. Although utilizing the same protocol can also be considered a limitation, for the purpose of this study, it allowed researchers to compare both the adult and youth data on an even playing field.

**Limitations of the Study**

Limitations of this study included putting adults through the same protocol (McMaster cycle ergometer protocol) as youth, allowing for less of a response from adults; having a small sample size; and not being able to disguise the taste between the water and the carbohydrate beverage. Due to the adults using the same protocol, it did allow for an across-the-board comparison between the adults and youth. However, this protocol may not have been challenging enough for the adults. Another limitation of the study was the small sample size. If the sample size were larger, perhaps there would have been a different story to be told. A third limitation to the study was the inability to disguise the taste of the carbohydrate beverage compared to that of the water. Participants could more than likely very easily distinguish between the two beverages, therefore giving them more incentive to push themselves harder for one trial compared to another.
Conclusion

In conclusion, the results indicate no statistical significance between performance trial times among the adults and youth. However, youth completed the carbohydrate performance trial, faster than the water performance trial. In contrast, the adult group finished the water performance trial faster than the carbohydrate performance trial. There were no metabolic differences found among metabolic measures in the carbohydrate and water trials for youth. RER (carbohydrate and water trial) and VO$_2$ (carbohydrate trial) did show significance during the 60-minute ride. It is imperative to do continued research specifically with youth and carbohydrate beverage consumption during exercise to get a deeper understanding of the benefits or lack thereof.

Recommendations for Future Research

Future research should utilize a different protocol(s) to elicit a response for performance time trials for youth and adults, to see if indeed adults and youth would respond differently than what occurred in the present study. Another area of study that could be focused on would be clarification on the need to supplement a workout with a carbohydrate beverage compared to that of a supplementation with fat during a workout to enhance performance. Studies on youth should also be completed outside of a lab environment. For example, youth that play soccer should have a study developed specifically around a soccer protocol. This will allow for coaches and parents to get more information about how youth utilize carbohydrate beverages during specific activities and sports.
References


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... performance, during intermittent, high intensity shuttle running in adolescent team games players aged 12-14 years. European Journal of Applied Physiology, 109, 811-821.


doi:10.1155/2015/734649


Appendix A: Informed Consent

Eastern Michigan University
Applied Physiology Laboratory
Informed Consent for Research Involving Human Subjects

Title of Project:
Effect of a carbohydrate beverage on exercise performance in youth 7-17

The person in charge of this study is Dr. Rebecca W. Moore. Throughout this form, this person will be referred to as the “investigator.”

Purpose of this study:

The purpose of this study is to determine the effect of a carbohydrate beverage on exercise performance in youth on a bicycle in a controlled laboratory setting and to compare adult-youth differences.

What will happen if my child participates in this study?

Participation in this study involves:

On three separate occasions you will be asked to come to The Applied Physiology Laboratory (Warner 248) on Eastern Michigan University’s campus. Each visit will be separated by at least 3 days and no more than 2 weeks. For the first visit, you will perform a bicycle test called a VO$_{2\text{max}}$ test. The VO$_{2\text{max}}$ test will consist of 9 to 12 minutes of exercise using a protocol called the McMaster Cycle Ergometer Protocol. The VO$_{2\text{max}}$ test begins at a low intensity and progresses by increasing watts (intensity) on the bicycle. The VO$_{2\text{max}}$ test will be used to determine exercise intensity for visits 2 and 3. You will wear a mask during the test to collect the air you breathe out. Heart rate will be collected using a heart rate monitor and a subjective rating of perceived exertion (RPE) will be obtained using the Omni scale. During the first visit, your anthropometric measurements (measure of body size) will also be obtained, including: weight, height, seated height, and body composition through skinfold measurement at the chest, triceps, and subscapular (upper back) for men and triceps, suprailiac (hip), and abdominal for women.

For visits 2 and 3, you will ride a bicycle for a total of approximately 75 minutes. Prior to the trial, you will complete a 24-hour physical activity recall and dietary log. The physical activity recall and dietary log will consist of you reporting what physical activities you participated in and foods you consumed, respectively, over the previous 24-hours. Prior to the exercise trial, your blood glucose and blood lactate measurements will be taken via fingerstick and anthropometrics measurements will be taken. Baseline metabolic measurements will be taken using the Parvo metabolic analyzer. You will then ride on the bicycle for 30 minutes at 55% VO$_{2\text{max}}$ (intensity is determined from the first visit), receiving the carbohydrate beverage or the placebo (drink with no carbohydrate) at 10, 20, and 30 minutes. The total amount of fluid consumed during the experimental session will equal 24 ml/kg of body weight (Timmons et al.,
This is sufficient enough fluid to maintain hydration. Metabolic measurements will be collected during the trial from minutes 12-17 and 25-30 of the ride. Heart rate and RPE will be taken every 5 minutes during the 30-minute ride. You will then have your blood glucose and blood lactate taken again via fingerstick immediately following exercise. Following the 30-minute exercise session, you will rest for 5 minutes. You will then complete a second 30-minute ride. The same measurements taken during the first ride will be repeated. Following the second ride, your blood glucose and blood lactate will be taken via fingerstick. You will then rest for 10 minutes. Following the rest period, you will perform a 2-mile time trial. You will be instructed to ride as hard as you can for the 2-miles. Upon completion of the time trial, your blood lactate and blood glucose will be taken again.

You will then be asked to return to the laboratory for Visit 3. You will be given the carbohydrate or water beverage, whichever you did not receive during Visit 2. Other than the beverage given, the exact same protocol from Visit 2 will be followed for Visit 3.

You will be asked to adhere to several restrictions prior to performing each of the laboratory training sessions. Your physical activity the day before testing should be light and easy. We ask that you refrain from eating or being physically active 3-4 hours prior to testing.

**Risks:**

The potential risks involved with this study are similar to those associated with exercise. You are at no greater risk than if you were participating in a physical education class or exercising on your own. You will be constantly monitored during the testing sessions, which will minimize risk. This study does involve vigorous physical activity. Therefore, if your VO$_{2\text{max}}$ is less than 31ml/kg/min for females or 38ml/kg/min for males, you will excluded from this study (Heyward, 1998). Participants will be excluded from this study if they identify any health risks associated with exercise on the PAR-Q and/or health history such as chest pain, dizziness, severe exercise induced asthma, or if the child’s doctor has advised them not to be physically active for any reason. Participants will be stopped during exercise if they are feeling nauseous, dizzy, or any other subjective indication that they are not feeling well. Participants will be stopped if they become hypoglycemic (low blood glucose <70mg/dl).

In the event an emergency is to occur during data collection, a medical emergency action plan will be followed. A first aid and CPR certified exercise physiologist will be present during testing. There will always be at least two individuals, including the exercise physiologist, present for data collection. If an emergency is to occur, 911 will be called first. In addition to calling 911, the Eastern Michigan University public safety will also be notified by calling (734) 487-1222 so they are aware of the emergency as well. If a subject is to go non-responsive, the exercise physiologist will administer CPR while the other individual goes to get the AED, located near Warner 107. If necessary, the exercise physiologist will use the AED. The subject will have care administered to them until EMS arrives.

**Benefits:**
There are no direct benefits for you by participating in this study. You will receive $10 for completing all three trails.

It is important for you to understand that at any time, you may withdraw from the study without prejudice or effect on your relationship with Eastern Michigan University.

**How will my information be kept confidential?**

All of the results from this study will be kept confidential. If publication occurs, only numbers, not names, will be used. Other groups may have access to your research information for quality control or safety purposes. These groups include the University Human Subjects Review Committee, the Office of Research Development, the sponsor of the research, or federal and state agencies that oversee the review of research. The University Human Subjects Review Committee is responsible for the safety and protection of people who participate in research studies. We may share your information with other researchers outside of Eastern Michigan University. If we share your information, we will remove any and all identifiable information so that you cannot reasonably be identified.

The results of this research may be published or used for teaching. Identifiable information will not be used for these purposes.

Throughout the study, some of the data obtained from you participation will be made available to you. At the conclusion of the study, any additional data obtained from your child’s participation will be made available to you. All participant information will remain confidential and kept in a secure file in the Department of Health Promotion and Human Performance.

**Storing study information for future use**

We would like to store your information from this study for future use related to the effects of carbohydrate use in youth. Your information will be labeled with a code and not your name. Your information will be stored in a password-protected or locked file. Your de-identified information may also be shared with researchers outside of Eastern Michigan University. Please initial below whether or not you allow us to store your information:

__________Yes  __________No

**Are there any costs to participation?**

Participation will not cost you anything.

**Will you be paid for participation?**

You will be given an incentive worth $10 for completing this study.

**What happens if I am injured while participating in the research?**

If you are injured as a result of participating in this study, we will assist you in getting necessary medical treatment. You or your insurance company will be responsible for the cost. Eastern Michigan University does not provide any form of compensation for injury.
Study contact information

If you have any questions about the research, you can contact the Principal Investigator, Dr. Rebecca W. Moore, at rmoore41@emich.edu.
For questions about your rights as a research subject, contact the Eastern Michigan University Human Subjects Review Committee at human.subjects@emich.edu or by phone at 734-487-3090.

Voluntary participation

Participation in this research study is your choice. You may refuse to participate at any time, even after signing this form, with no penalty or loss of benefits to which you are otherwise entitled. If you leave the study, the information you provided will be kept confidential. You may request, in writing, that your identifiable information be destroyed. However, we cannot destroy any information that has already been published.

Statement of Consent

I have read this form. I have had an opportunity to ask questions and am satisfied with the answers I received. I give my consent to participate in this research study.

Signatures

_______________________________________
Subject’s name

_______________________________________  _______________________
Subject’s signature  Date
I have explained the research to the subject and answered all his/her questions. I will give a copy of the signed consent form to the subject.

_______________________________________
Name of Person Obtaining Consent

_______________________________________  _______________________
Signature of Person Obtaining Consent  Date
Appendix B: Informed Assent

Eastern Michigan University
Applied Physiology Laboratory
Informed Assent for Research Involving Human Subjects

Title of Project:
Effect of a carbohydrate beverage on exercise performance in youth 7-17 years old

The reason (purpose) we are doing this research study is to determine the effect of a sugary beverage on your exercise performance while riding a bicycle in our laboratory.

You will visit the laboratory three times. The first time you visit the laboratory, you will ride the bike for 9 to 12 minutes. The first test will start easy and become harder. You will ride the bicycle until it becomes too hard to pedal. During the test we will collect the air you breath out by wearing a mask that covers both your nose and mouth connected to the equipment we are testing. This will measure your breathing during exercise. We will also measure your heart rate and ask you how hard you are exercising. We will also measure your height, weight, seated height, and body composition.

The second and third times you visit the laboratory, we will ask you to ride a bike twice for 30 minutes followed by a 2-mile ride. During the first 30 minutes, you will get a drink of either water or a flavored sugary beverage three times. During the 30-minute ride, will collect the air you breath out, heart rate, and ask you how hard you are exercising. You will then get a 5-minute rest period and we will take a small blood sample from your finger. You will then ride the bicycle for another 30 minutes. The same measurements during the first ride will be taken. You will then rest for 10-minutes and another small blood sample from your finger will be taken. After the second 30-minute ride, you will cycle for 2 miles as hard as you can while being timed. The third visit to the laboratory will be exactly the same as the second visit except you will drink either the water or flavored sugary beverage, whichever you didn’t receive during the second trial.

You will benefit from this study by learning valuable information about your fitness.

You should know, that during the test, you will be exercising and working hard. You may sweat, get tired, and you may be uncomfortable at the end. We will do all that we can to make you as comfortable as possible. You can stop the test at anytime. You do not have to be in this study if you do not want to and are free to quit at anytime. No one will be mad at you.

When we are finished with testing, we are going to make a report about what we learned from you. The report will not include your name and no one will know that you were apart of this study.

If you would like to participate in this study, please write and sign your name.

I, ________________________________, want to be in this research study.
Appendix C: Children’s PAR-Q/Health History Screening

Eastern Michigan University
Applied Physiology Laboratory
Research Involving Human Subjects
Children’s PAR-Q/Health History Screening Form

Title of Project:
Effect of a carbohydrate beverage on exercise performance in youth 7-17 years old

Child's name: ___________________________________

Parent/Guardian name: ___________________________________

Address: ____________________________________________

_________________________________________________________________

Postcode: _____________________________________________

Childs Date of Birth: __________________________ Current Age: __________________

Emergency Contact Details:

Home: ____________________________________________

Name and Relationship to Child: ________________________________

Work: ______________________________________________

Name and Relationship to Child: ________________________________

Health Questions:

Does your child have or has he or she ever experienced any of the following? Please Circle:

1. High or Low Blood Pressure Y / N
2. Elevated blood cholesterol Y / N Diabetes Y / N
3. Chest pains brought on by physical exertion Y / N
4. Childhood epilepsy Y / N
5. Dizziness or fainting Y / N
6. Any bone, joint, or muscular problems with arthritis Y / N
7. Asthma or respiratory Problems Y / N
8. Any sustained injuries or illness Y / N
9. Any allergies Y / N
10. Is your child taking any medication Y / N
11. Has your doctor ever advised your child to exercise Y / N
12. Is there any reason not mentioned above why any type of physical activity may not be suitable for your child Y / N

If you have answered ‘YES’ to any of the above questions please give full details here and seek medical clearance prior to the session.
Appendix D: Adult PAR-Q/Health History Screening

Eastern Michigan University
Applied Physiology Laboratory
Research Involving Human Subjects
Adult PAR-Q/Health History Screening Form

Title of Project:
Effect of a carbohydrate beverage on exercise performance in youth 7-17 years old

Participants name: ________________________________

Address: ________________________________

_________________________________________

Postcode: ________________________________

Date of Birth: ___________________________ Current Age: ___________________________

Emergency Contact Details:

Home: ________________________________

Name and Relationship to Participant: ________________________________

Work: ________________________________

Name and Relationship to Participant: ________________________________

Health Questions:
Do you have or have you ever experienced any of the following? Please Circle:
1. High or Low Blood Pressure Y / N
2. Elevated blood cholesterol Y / N Diabetes Y / N
3. Chest pains brought on by physical exertion Y / N
4. Epilepsy Y / N
5. Dizziness or fainting Y / N
6. Any bone, joint, or muscular problems with arthritis Y / N
7. Asthma or respiratory Problems Y / N
8. Any sustained injuries or illness Y / N
9. Any allergies Y / N
10. Are you taking any medication Y / N
11. Has your doctor ever advised you to exercise Y / N
12. Is there any reason not mentioned above why any type of physical activity may not be suitable Y / N

If you have answered ‘YES’ to any of the above questions please give full details here and seek medical clearance prior to the session.
Appendix E: IRB Approval

UHSRC Determination: EXPEDITED MODIFICATION APPROVAL

Date: September 22, 2017

To: Lauren Jording
Eastern Michigan University

Re: UHSRC: # J20170714-2 Category: Expedited

Approval Date: September 22, 2017 Expiration Date: July 19, 2018

Title: Effect of a Carbohydrate Beverage on Exercise Performance in Youth 7-17 years old

Your requested modifications have been approved in accordance with all applicable federal regulations. This approval includes the following: (1) The addition of Brandon Bastianelli to the research study team.

Renewals: This approval does not change the original expiration date. This study expires on July 19, 2018. If you plan to continue your study beyond July 19, 2018, you must submit a Continuing Review Form by June 19, 2018 to ensure the approval does not lapse.

Modifications: All additional changes must be approved prior to implementation. If you plan to make any minor changes, you must submit a Minor Modification Form. For any changes that alter study design or any study instruments, you must submit a Human Subjects Approval Request Form.

Problems: All major deviations from the reviewed protocol, unanticipated problems, adverse events, subject complaints, or other problems that may increase the risk to human subjects or change the category of review must be reported to the UHSRC via an Event Report form.

Follow-up: If your Expedited research project is not completed and closed after three years, the UHSRC office requires a new Human Subjects Approval Request Form prior to approving a continuation beyond three years.
Please use the UHSRC number listed above on any forms submitted that relate to this project, or on any correspondence with the UHSRC office.

Good luck in your research. If we can be of further assistance, please contact us at 734-487-3090 or via e-mail at human.subjects@emich.edu. Thank you for your cooperation.

Sincerely, University Human Subjects Review Committee

University Human Subjects Review Committee Eastern Michigan University 200 Boone Hall Ypsilanti, Michigan 48197 Phone: 734.487.3090 E-mail: human.subjects@emich.edu www.emich.edu/ord (see Research Compliance)

The EMU UHSRC complies with the Title 45 Code of Federal Regulations part 46 (45 CFR 46) under FWA00000050.