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The Effects of Water or Sports Drink Ingestion Prior to Exercise on the Performance of Middle Distance, Amateur Runners in a Thermoneutral Environment

Julie A. Barnes  
*Grand Valley State University*

Scott G. DeVries  
*Grand Valley State University*

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THE EFFECTS OF WATER OR SPORTS DRINK INGESTION PRIOR TO EXERCISE ON THE PERFORMANCE OF MIDDLE DISTANCE, AMATEUR RUNNERS IN A THERMONEUTRAL ENVIRONMENT

By

Julie A. Barnes
Scott G. DeVries

THESIS

Submitted to the Department of Physical Therapy at Grand Valley State University Allendale, Michigan in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN PHYSICAL THERAPY

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Julie A. Barnes and Scott G. DeVries
April 24, 1999
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ABSTRACT

Sports drinks have been shown to influence running performance, however, the best methods of hydration are still unclear. The purpose of this study was to determine the effects of water versus sports drink (6% carbohydrate/electrolyte) hydration prior to an exercise bout on the performance of middle distance, amateur runners. Ten subjects were randomly assigned to run two trials and began with either ingestion of water or sports drink. They then completed a maximal treadmill test to volitional exhaustion and returned two days later and drank the opposite drink. Maximal oxygen consumption (VO$_{2\text{max}}$), time of run, heart rate, respiratory exchange ratio, and expiratory volume were analyzed to measure performance. The Wilcoxon Signed Ranks Test showed $p = .036$ when comparing the VO$_{2\text{max}}$ of sports drink trials versus water trials, however, no other outcome measures reached a significant level. Therefore, drinking a sports drink prior to a middle distance run appears to improve VO$_{2\text{max}}$ when compared to water ingestion.
ACKNOWLEDGMENTS

We would like to thank the following people for their contributions of time and energy in order to complete this research: Daniel Vaughn, Paul Stephenson, Bill Dujmovic and the study participants. A special thanks to James Scott, committee chairman, for his patience, guidance, and expertise. Everyone's contributions have provided us with a valuable learning experience.
PREFACE

Hypothesis

Whether an individual ingests water or sports drink prior to a middle distance run protocol in a thermoneutral environment will have no significant effect on the means of various performance measures. The performance measures investigated in the present study were maximal oxygen consumption, time of run, heart rate, respiratory exchange ratio, and expiratory volume.

Operational Definition of Terms

1. Middle distance: Defined as five kilometers.

2. Trained athlete: Someone who has been running greater than an average of 25 miles per week for a period of two months or more.

3. Amateur athlete: Someone who has been running an average of between 10 to 25 miles per week for a period of at least two months.

4. Thermoneutral Environment: Temperature of surroundings between 68 and 75 degrees F.
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CHAPTER 1
INTRODUCTION

For years researchers and athletes have struggled to find new and more effective ways to improve performance. Proper fluid ingestion to prevent dehydration is one method for improving performance. Dehydration impairs performance by causing nausea, emotional instability, increased work effort, dizziness, muscle spasms, increased core temperature during exercise, and circulatory insufficiency (Bacharach, et al., 1994; Berning and Steen, 1991; Kies and Driskell, 1995; Sawka, 1992; Sawka, Young, Francesconi, Muza, and Pandolf, 1985; Wolinsky and Hickson, 1994). Ingesting fluid hydrates the body allowing it to maintain a steady body core temperature. This creates a homeostatic balance between water and electrolytes that become unbalanced with increased activity and sweat production (Costill as cited in Powers and Howley, 1997).

Controversy regarding the best way to provide hydration still exists. Some researchers state that electrolytes should be included in fluid replacements to replenish the electrolytes lost in sweat during exercise, and to replenish carbohydrates (CHOs) which provide additional fuel for energy. Carbohydrates also aid fluid absorption from the small intestine into the body (Coyle and Montain\textsuperscript{1}, 1992; Kies and Driskell, 1995; Maughan and Noakes, 1991). Others suggest that minimal amounts of electrolytes are lost in sweat, and therefore, do not need to be replaced (Colgan, 1993). Researchers also suggest CHO\textsubscript{s} hinder gastric emptying of water into the intestine promoting a longer period of fluid depletion (Gisolfi and Duchman, 1992).
The amount of electrolytes and/or CHO's required may be dependent on the environmental conditions and resultant rate of sweat production. As the environmental temperature increases, the body sweats more to assist in thermoregulation. The increased energy requirements during exercise results in sweating, thereby promoting water and electrolyte loss. The increased energy requirements also increase utilization of CHO's. Therefore, most clinical studies have focused on hydration in a high temperature, high humidity environment. Little research has been done regarding fluid replacement benefits on performance measures in a thermoneutral environment (Kies and Driskell, 1995).

Many studies also focus on exercise of long duration because of the effects of dehydration. Fluids are usually given to subjects during the training episode. Again, little research has been done involving hydration prior to a work bout of short duration and high intensity. Additionally, most of the current research has been done on cyclists for the convenience of being able to ingest fluid while performing. Traditionally, cyclist's and runner's performance has been measured by the speed, maximal oxygen consumption (VO$_{2\text{max}}$), respiratory exchange ratio (RER), heart rate (HR), cardiac output, time to completion, rate of perceived exertion (RPE), core body temperature, and many other performance outcomes (Bacharach, et al., 1994; Coyle and Montain$^2$, 1992; Wells, et al., 1985). Wells, et al. (1985) suggests, when comparing various drinks during running trials, that VO$_{2\text{max}}$ may be an indicator of improved running times. Little is known about the effects of pre-exercise hydration on amateur, middle distance runners.

Existing research regarding optimal pre-exercise hydration parameters for improved performance remains incomplete. What are the effects of hydrating prior to a
maximal test? How do middle distance runners respond to ingestion of sports drinks prior to running? The present research will specifically address whether water or sports drink has an effect on middle distance running.

The American College of Sports Medicine (ACSM) guidelines recommend that a person drink at least 16 ounces (oz.) of fluid before physical activity, five to 10 oz. of fluid every 15 to 20 minutes during activity, and 16 oz. of fluid for each pound of weight loss after the physical activity (American College of Sports Medicine [ACSM], 1996). These guidelines make no mention of hydration related to work bout intensity. Intensity may influence the amount of sweat production, preferred metabolic pathway, and substrate utilization.

The significant aspects of this study and data include: addition of information to scholarly research and current literature, improvement of physical therapy practice, and improvement of techniques for hydration prior to exercise. The information gathered from this study will add to scholarly research by improving knowledge regarding the most effective type of hydration to improve performance and application of proper hydration for amateur, middle distance runners. Research of this topic will improve physical therapists' knowledge of peak performance training techniques and knowledge of exercise physiology. This study may improve the effectiveness of hydration techniques on peak performance of amateur, middle distance runners.

**Purpose of Study**

The purpose of the present study is to determine the effects of water hydration or sports drink hydration (CHO/electrolyte replacement) on individuals prior to an exercise protocol on performance of middle distance, amateur runners. The null hypothesis is that
whether an individual ingests water or sports drink prior to a middle distance run protocol in a thermoneutral environment has no significant effect on the means of various performance measures. The performance measures investigated in the present study were VO$_{2\text{max}}$, time of run, HR, RER, and expiratory volume.
CHAPTER 2

REVIEW OF LITERATURE AND CONCEPTUAL FRAMEWORK

It is recognized throughout the exercise community that hydration is beneficial to performance. During physical activity, body water is lost through sweat as a thermoregulatory mechanism to cool the body causing impaired stroke volume and cardiac output, which results in increased body core temperature and heart rate (Coyle and Montain, 1992; Murray, 1992; Sawka, 1992). It has been reported that a loss of 2% body weight can negatively affect running performance (Armstong, Costill, and Fink as cited in Millard-Stafford, Starling, Rosskopf, and DiCarlo, 1992). The primary component lost in sweat is water. Electrolytes lost in sweat and CHO's utilized by the working muscles are also diminished during exercise. As sweat rate increases, the amount of sodium and chloride lost also increases (Gisolfi and Duchman, 1992; Kies and Driskell, 1995; Wolinsky and Hickson, 1994). Greater utilization of CHO's occurs as exercise intensity increases to provide a continuous energy supply to the working muscles (Coyle and Montain, 1992; Kies and Driskell, 1995). Various methods of CHO replenishment may impact VO_{2max} which is the measure of choice when predicting distance running success (Powers and Howley, 1997). Studies are ongoing regarding optimal replenishment of CHO's and electrolytes to enhance performance.

Environmental Factors

Specific factors play an important role in running performance such as the environment, duration of exercise, intensity of exercise, level of fitness, and hydration.
prior to exercise. Each of these factors contributes to sweat and electrolyte loss and CHO utilization. Environmental factors such as temperature and humidity must be taken into account. Reports have shown that greater changes occur in body fluids during exercise in a hot environment versus a cool one (Lamb and Brodowicz, 1986). When the environmental temperature exceeds skin temperature, the body gains heat. In attempt to maintain homeostasis, the body produces sweat as a cooling mechanism to compensate for the rise in body temperature (Powers and Howley, 1997). Increased sweating is alleged to produce increased electrolyte loss, therefore, most studies are done in high heat environments (Gisolfi and Duchman, 1992; Kies and Driskell, 1995; Wolinsky and Hickson, 1994). However, Houmard, et al. (as cited in Powers and Howley, 1997) states that electrolyte loss is not increased as a result of increased sweat production during exercise of moderate intensity and short duration in the heat. Little data exists regarding hydration in a neutral temperature environment (Kies and Driskell, 1995). Exercise duration and intensity are factors in determining the amount of fluid ingestion and replacement required during or prior to exercise.

Exercise Duration

The duration of exercise influences the amount of fluid ingestion needed because duration affects sweat production. However, little information is confirmed regarding proper fluid ingestion in middle distance runners. The ACSM recommends ingestion of 300-500 ml of 6-10% CHO drink prior to exercise and 500-1000 ml during the exercise for events of less than one hour (Gisolfi and Duchman, 1992; Kies and Driskell, 1995). The amount of fluid ingestion needed depends on the duration of the run.
More information is necessary regarding the differences between middle (defined by Brandon, 1995 as a distance of 800 to 3000m) and long (defined by Brandon, 1995 as a distance greater than 3000m) distance runners (Farrell, et al.; Costill and Thomason; Acevedo and Goldfarb; Houmard, et al. as cited in Brandon, 1995). Most studies have been done on long distance runners, triathletes, and cyclists. Middle distance running is unique because of its short duration and high intensity (Brandon and Boileau, 1987; Brandon, 1995; Morgan and Craib, 1992).

A cycling performance study regarding CHO replenishment reported that during a "sprint type performance ride" the time to reach 500 revolutions improved when ingesting a CHO drink during exercise when compared to a placebo group. Furthermore, the research suggests that a 10% CHO drink improves cycling performance greater than a 6.4% CHO drink (Bacharach, et al., 1994).

Estimation of performance for long duration activities, which are largely aerobic, are commonly measured by VO$_{2\text{max}}$. Maximum oxygen consumption refers to the body's ability to transport and utilize oxygen. Thus, cyclists and distance runners with a large VO$_{2\text{max}}$ may be able to perform for a longer duration than those with a small VO$_{2\text{max}}$ (Powers and Howley, 1997).

**Exercise Intensity**

Exercise intensity can influence whether aerobic or anaerobic pathways are utilized for energy production. During middle distance running, it has been shown, that both pathways are used simultaneously (Brandon, 1995). Other studies have stated that the ability to utilize an anaerobic pathway is a good indicator of performance in endurance running events when compared to aerobic pathway use (Brandon and Boileau,

The body’s use of fats or CHOs is determined by exercise intensity. During high intensity exercise, defined as greater than 70% of VO\textsubscript{2max}, CHOs are the dominant substrate utilized. As exercise intensity increases, there is a crossover from fat utilization to CHO utilization. This shift to CHO metabolism occurs because of increased recruitment of fast muscle fibers. Hence, CHOs are the predominant substrates metabolized during a high intensity activity (Powers and Howley, 1997). The ACSM guidelines for hydration are targeted to exercise intensities of 80 to 130% VO\textsubscript{2max} (Kies and Driskell, 1995).

In a study regarding CHO/electrolyte replenishment prior to and during a 40 kilometer run, running performance was timed during the last five kilometers. Results showed running performance in the last five kilometer to be significantly (p < .03) faster when compared to a placebo drink. The authors note that CHO/electrolyte replacement produces similar thermoregulatory and physiological responses compared to the placebo during a run, but improved run performance (Millard-Stafford, et al., 1992). The energy requirements of amateur versus trained athletes differ within similar intensities.

**Trained Versus Amateur Athletes**

Varying activity levels may require different levels of hydration. Trained athletes have a larger total body water content than amateur athletes because of large muscle mass (Sawka, 1992). Trained athletes generally have exercise bouts of high intensity and duration producing greater fluid loss. Amateur athletes do not train at this same intensity
or duration producing relatively less fluid loss. Therefore, increased water and CHO replenishment is necessary for trained athletes.

The information available on the differences between amateur and trained athletes focuses mostly on physiologic differences. Trained runners are able to supply their bodies with energy demands at a continuous rate and have a more economic physiology which influences factors such as heart rate (HR), ventilation, VO2max, and fatigue (Brandon and Boileau, 1987; Bulbulian, Wilcox, and Darabos; Lacour, et al.; DiPrampero as cited in Brandon, 1995). During exercise, HR in a trained athlete increases at a slower rate than in an amateur athlete because of improved stroke volume in the trained athlete. The chronic effect of aerobic exercise on the pulmonary system is a decrease in the rate and an increase in the depth of ventilation (Smith and Mitchell; Baladey and Weiner; Badenhop, et al. as cited in Brannon, Foley, Starr, and Saul, 1988). Pulmonary and cardiac changes allow for an increased VO2max. Due to the cardiopulmonary changes in the heart, trained athletes show less fatigue during exercise. Trained athletes are also able to tolerate longer periods of anaerobiasis and delay its onset due to decreased lactic acid concentrations in the blood (McArdle, Katch, and Katch as cited in Brannon, Foley, Starr, and Saul, 1988; Wasserman, 1994). This has been show to be an indicator of performance success in a close race (Brandon and Boileau, 1987; Bulbulian, Wilcox, and Darabos; Lacour, et al.; DiPrampero as cited in Brandon, 1995).

Fluid Characteristics

A variety of drink preparations can be utilized for hydration of a middle distance runner. Studies involving different types of fluid ingestion must control the variables of flavor, color, and temperature to ensure a valid design. Drinks are typically masked for
flavor and color using Nutrasweet™ and food coloring, respectively (Bacharach, et al., 1994; Davis, et al., 1988; Millard-Stafford, et al., 1990). According to Fox (1995), "...aspartame-sweetened products do not appreciably increase the osmolarity of the electrolyte solution" (p. 91). Therefore, Nutrasweet™ should have no effect on performance. Temperature of the drink is another factor that must be considered.

McArthur and Feldman's study has shown that gastric emptying rates for coffee given at 4°C, 37°C, and 58°C were not different. However, Sun's study showed that gastric emptying rates for orange juice given at 4°C were slower than for drinks given at body temperature (as cited in Maughan and Noakes, 1991).

**Hydration Prior to, During, and Post-Exercise**

Investigation of hydration prior to, during, and post-exercise is lacking regarding middle distance runners. Hyperhydration prior to exercise is one convenient and practical method of hydration for runners. This may be beneficial for middle distance runners who perform at high intensity and short duration where time is a more critical factor to performance (Berning and Steen, 1991). Thus, hyperhydration decreases the amount of water breaks needed in a middle distance run.

Most studies have examined hydration during exercise in relation to comfort level and convenience for the athlete. Studies show that there is a balance for runners between necessary intake of fluid for health reasons and the time it takes to consume fluid (Coyle and Montain, 1992). The comfort level for the runner must also be considered. First, fluid ingestion is imperative to prevent the adverse effects of dehydration. Kies and Driskell (1995) and Coyle and Montain (1992) report that dehydration level and perceived exertion are positively correlated. As a result of dehydration, performance
level decreases. The second factor to consider is gastrointestinal (GI) discomfort. Ingestion of fluids during exercise produces some degree of gastrointestinal discomfort and a reduced pace due to the time spent drinking (Coyle and Montain, 1992). Gastrointestinal discomfort during exercise is a result of slowed function due to increased sympathetic nervous system response and altered blood flow away from the digestive organs. In order to compensate for the decrease in digestion rate, greater amounts of fluid intake must occur to achieve required hydration. However, greater fluid intake during exercise often leads to nausea and vomiting (Maughan and Noakes, 1991). Because comfort level for runners is vital to performance, hydration prior to running is often more convenient and practical.

Wolinsky and Hickson (1994) support the idea of fluid hydration post-exercise especially related to nutrient beverages. The advantages associated with post-exercise consumption include quicker recovery rate particularly important to those who perform moderate to high intensity exercise daily. Recovery may be quicker due to increased plasma volume, electrolyte and/or fuel stores. Berning and Steen (1991) also report the necessity of fluid replenishment after exercise. It is recommended that runners replace each pound of body weight lost with 500 ml (16 oz) after exercise (American Dietetic Association study as cited in Berning and Steen, 1991). Fluid replacement post-exercise may be preferred by athletes compared to replacement during exercise for the purposes of practicality and comfort.

**Carbohydrate/Electrolyte Drink Versus Water**

There are several controversial theories regarding the necessity of CHO and electrolyte replenishment versus pure water in middle distance runners. Berning and
Steen (1991), Gisolfi and Duchman (1992), Kies and Driskell (1995), and Wolinsky and Hickson (1994) found little evidence to support the necessity of a sports drink prior to an event of less than one hour duration. Sweat loss rarely exceeds 2-3 l/h during exercise lasting less than one hour and therefore, the necessity of adding electrolytes to a sports drink is questionable. Electrolytes may, however, increase the palatability of the sports drink and facilitate fluid absorption (Gisolfi and Duchman, 1992; Kies and Driskell, 1995). Carbohydrates are more frequently recommended in a pre-event drink because of their direct effect on muscle performance and increased palatability of the drink (Berning and Steen, 1991; Kies and Driskell, 1995; Wolinsky and Hickson, 1994). However, CHO's may also contribute to the decreased gastric emptying rate, which limits the amount of fluid that can be absorbed (Kies and Driskell, 1995; Gisolfi and Duchman, 1992; Maughan and Noakes, 1991).

A study by Davis, et al. (1988) compared three cycling trials in which the subjects ingested a 6% CHO drink, 2.5% CHO drink, and a water placebo. They found no difference in heart rate, sweat rate, plasma volume, or rectal temperature. They suggest that ingestion of a 6% CHO drink can maintain blood glucose levels and improve prolonged cycling performance.

**Electrolytes**

The biochemical effect of CHO's/electrolytes is based on the function in the body. The primary electrolytes in the body include: calcium, phosphorus, magnesium, potassium, sodium, and chloride. Calcium is needed for proper muscle contractility, nerve transmission, and possible glycogen breakdown (Krause, et al.; Williams as cited in Berning and Steen, 1991). Phosphorus and magnesium have been linked to exercise
metabolism. Phosphorus plays a role in releasing oxygen in red blood cells. Magnesium plays a role in glucose metabolism, which affects muscle contraction characteristics (Williams as cited in Berning and Steen, 1991). Sodium and chloride are concerned with fluid balance maintenance and nerve impulse transmission for muscle contraction (Krause, et al. as cited in Berning and Steen, 1991). All of these studies stated that electrolytes were lost in sweat, the greatest loss shown in sodium and chloride (Wolinsky and Hickson, 1993). The literature states that the little amount of electrolytes lost in sweat during an event of less than one hour duration can be replenished through a well balanced diet (Berning and Steen, 1991; Wolinsky and Hickson, 1993). Electrolytes are lost in sweat, whereas CHOs are metabolized by the working muscles.

**Carbohydrates**

"The primary purpose of carbohydrate ingestion during continuous, strenuous exercise is to maintain blood glucose concentration and maintain carbohydrate oxidation during the latter stages of prolonged exercise" (Coggan and Coyle; Coyle, Coggan, Hemmert, and Ivy as cited in Coyle and Montain1, 1992, p. 672). Carbohydrates can be stored as skeletal muscle glycogen or in the liver for energy during aerobic and anaerobic exercise. During aerobic exercise, CHO's may become depleted resulting in decreased rate of glycolysis. This results in decreased levels of pyruvate available to drive the Krebs cycle eventually leading to decreased adenosine triphosphate (ATP) levels. This will negatively affect muscle performance and increase muscle fatigue (Powers and Howley, 1997). When muscle glycogen or blood-born glucose is utilized during anaerobic glycolysis, it facilitates lactic acid build up. In the general population, lactic
acid build up produces muscular fatigue leading to decreased performance of the athlete (Wolinsky and Hickson, 1993).

Carbohydrate utilization is related to the amount of oxygen consumed and the amount of carbon dioxide produced. Carbohydrates are a more efficient fuel than fat at high intensities because they require less oxygen for oxidation. Thus, if less oxygen is required for oxidation, more oxygen can be utilized by the muscles, contributing to a higher VO$_{2\max}$ (Powers and Howley, 1997). Biochemical functioning of CHOs and electrolytes can be affected by intensity of exercise and sweating.

**Sweat**

Sodium and chloride are the primary electrolytes lost in sweat at 40-60 mEq/l and 30-50 mEq/l, respectively. Potassium (3-4 mEq/l) and magnesium (1-5 mEq/l) are also lost, but show a less significant contribution to the osmolarity of sweat (Kies and Driskell, 1995). The numbers of ions lost depends on the environmental temperature and the rate of sweating (Allan and Wilson as cited in Gisolfi and Duchman, 1992). Sweat lost during events less than one hour usually will not exceed 2-3 l/hour and therefore, salt lost will not exceed 60-120 mEq/hour. Gisolfi and Duchman (1992) suggest that there is no need to replace the ions lost under these circumstances, but they may be added to enhance palatability and facilitate absorption. “There is no good evidence to support the addition of electrolytes other than sodium to drinks to be consumed during exercise” (Maughan and Noakes, 1991). Although ion replacement is not considered critical in events of less than one hour, CHO ingestion is often suggested.
Carbohydrate ingestion is recommended to aid in fluid absorption to provide adequate blood glucose concentrations (Coyle and Montain\(^2\), 1992; Maughan and Noakes, 1991; Powers and Howley, 1997). However, reports have shown that CHOs inhibit gastric emptying rates which affects the amount of CHO supplied to the working muscle. Excessive amounts can contribute to dehydration by promoting secretion of fluid into the intestine (Coyle and Montain\(^2\), 1992; Maughan and Noakes, 1991).

Recommendations exist regarding proper CHO supplementation. To resist premature fatigue in an event lasting less than one hour, Gisolfi and Duchman (1992), suggest that 30 to 50 grams of CHO be ingested. To achieve this optimal concentration, 300 to 500 ml of a 6 to 10% CHO solution can be ingested. A fine line exists between the ability of CHOs to facilitate absorption and the negative effect of inhibiting gastric emptying rate.

To prohibit a delay in gastric emptying rates, a low percentage of CHO is recommended. However, as the percentage of CHO in a beverage decreases, the amount of fluid ingested must increase to compensate for the decreased concentration. Hunt and Spurrell (as cited in Gisolfi and Duchman, 1992) examined gastric emptying to show that the majority of fluid is emptied from the stomach to the intestines within the first 15 minutes with a gradual tapering of the remaining fluid until 30 minutes. Therefore, the body can only absorb a limited amount of fluid in a given time. For example, to obtain 30 to 60 grams per hour of CHO, a 2% CHO solution needs to be ingested at an amount of 3,000 ml/h. The body cannot reasonably accomplish this and the appropriate CHO delivery is compromised (Coyle and Montain\(^1\), 1992; Gisolfi and Duchman, 1992). Therefore, many commercial beverages contain 6 to 8% CHO concentration to balance grams of CHO.
needed with the gastric emptying rate. Table 1 shows various beverages and their CHO content (Gatorade Thirst Quencher, 1995):

Table 1

Beverage Comparison

<table>
<thead>
<tr>
<th>Beverage</th>
<th>Carbohydrates (grams/8oz.)</th>
<th>Carbohydrate %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gatorade Thirst Quencher®</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>Powerade®</td>
<td>19</td>
<td>8</td>
</tr>
<tr>
<td>Allsport®</td>
<td>19</td>
<td>8</td>
</tr>
<tr>
<td>Orange Juice</td>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>Water</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Testing Guidelines

Testing procedures should follow the ACSM guidelines to maximize safety of subjects participating in studies. Because maximal performance testing is rigorous, certain criteria must be considered for participation of exercise testing and the termination of a maximal test (see Appendix C, D, and E). Other relative indications for exercise test termination must be evaluated and assessed by the researcher.

The ACSM gives specific guidelines for maximal test procedures. For younger and/or active individuals, protocols with large increments during testing are recommended. A ramp protocol may also be used which involves increasing workload at a constant and continuous rate. The total test time is suggested to be eight to ten minutes with a 1 to 3% increase in grade per minute for treadmill testing. The ACSM suggests
these testing protocols be individualized based on the target population (ACSM Guidelines, 1995). Protocols other than those recommended by the ACSM are also available and can be specific to the type of athlete. During any exercise test there are certain outcome variables used to measure performance.

**Outcome Measures**

Variables associated with performance include: heart rate (HR), maximal oxygen consumption ($VO_{2\text{max}}$), respiratory exchange ratio (RER), ventilatory exchange ($V_{E}$), speed, grade, time, and perceived exertion scales. HR is the amount of times the heart beats in any given amount of time. HR is a measure of intensity at which the body is performing. As the exercise intensity continues to rise, a point is reached where maximal heart rate will be achieved and anaerobic exercise will ensue (Brannon, Foley, Starr, and Saul, 1988).

Maximal oxygen consumption is defined as the greatest rate of oxygen uptake by the body during strenuous exercise. It is determined by maximal cardiac output and the maximal arteriovenous oxygen difference (Powers and Howley, 1997). The equation for maximal oxygen consumption is: $HR_{\text{max}} \times stroke\, volume\, max \times (arteriovenous\, oxygen\, difference)\, max$. (Powers and Howley, 1997). Maximal oxygen consumption is generally considered to be the variable that best describes the capacities of the cardiovascular and respiratory systems (Boileau, Mayhew, Riner et al. as cited in Brandon, 1995). The velocity at which $VO_{2\text{max}}$ is reached has "... been shown to serve as an indicator of performance in middle- and long-distance running events" (Hill and Rowell, 1996).

Predicted oxygen consumption ($VO_{2}$ measured in $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) at maximum effort can be calculated using speed and grade. Three components involved in estimating
VO₂ are resting (R), horizontal (H), and vertical (V) components. The general metabolic equation for energy expenditure is: VO₂ = R + H + V. For running, VO₂ = (3.5 ml·kg⁻¹·min⁻¹) + (m/min × 0.2) + (grade (frac) × m/min × 0.9). This formula is applied at the last level of exercise to calculate VO₂ (ACSM Guidelines, 1995).

Respiratory exchange ratio (RER) is defined as the ratio of carbon dioxide output (VCO₂) per volume of oxygen (VO₂) consumed. The RER estimates the percent fat and CHO utilized as fuel during exercise. As work intensity increases, a progressive decrease in fat utilization is demonstrated and carbohydrate utilization is increased. As the RER value approaches 1.0, carbohydrates are being utilized increasingly more (Powers and Howley, 1997).

Ventilatory exchange (Ve), or minute ventilation, is a measure of the movement of air between the lungs and the environment (Ve = (Tidal Volume × breathing frequency)/min). This exchange rapidly increases at the beginning of exercise. It then gradually rises to a steady state (Powers and Howley, 1997).

As speed increases, exercise intensity increases. A greater intensity requires a greater energy cost for the increased work. The velocity maintained during a run separates amateur and trained runners based on their ability to maintain the high energy demands, accounting for the differences in performance levels (Lacour, Magnacelaya, Barthelemy, et al.; DiPrampero, Atchou, Bruckner, et al. as cited in Brandon 1995). Grade is the angle of inclination at which the run is performed. The percent grade is another factor that can play a role in determining run intensity (Powers and Howley, 1997). During a maximal treadmill test, quantitative measures as well as qualitative measures can be monitored.
The most common way to measure subjective response is through a rate of perceived exertion (RPE) scale. The Borg Scale is the most commonly used RPE scale for evaluating patient responses during graded exercise tests. Intensity perceptions have been shown to be a predictor of \( \text{VO}_{2\text{max}} \) with less error than heart rate alone (Morgan and Borg as cited in Noble, 1982). A limitation of using the Borg scale is its inability to account for intrasubject comparison of perceived physical strain (Borg, 1982). Heart rate and \( \text{VO}_{2\text{max}} \) were shown to be correlated at \( r = .957 \) to \(.999\), and RPE and percent \( \text{VO}_{2\text{max}} \) were shown to be correlated at \( r = .893 \) to \(.988\) (Kurokawa and Ueda, 1992). Similar data suggest that RPE is useful as a frame of reference for regulation of high level exercise intensity in healthy men and women (Eston and Williams, 1988).

Various outcome measures are used to validate a \( \text{VO}_{2\text{max}} \) test (see Appendix G). Williams, et al. and MicMiken and Daniels suggest the RER be greater than or equal to 1.15, a HR of ± 10 beats per minute within the subject's predicted maximal HR during the last exercise stage, and a plateau in \( \text{VO}_2 \) as work rate increases. Two of these criteria must be met to ensure a valid \( \text{VO}_{2\text{max}} \) test or determine if a subject should discontinue a maximal treadmill test (as cited in Powers and Howley, 1997). An objective measurement tool, the Beckman Metabolic Measurement Cart (MMC), is reliable and valid for the measurement of ventilation gas analysis.

**Beckman Metabolic Measurement Cart**

The validity and reliability of the Beckman MMC have been shown in various studies. Measurement of variables such as minute ventilation, \( \text{O}_2 \) uptake, \( \text{CO}_2 \) production, and respiratory exchange ratio have been shown to be reproducible during maximal exercise (Kannagi, Chang, Bruce, and Hossack, n.d.). Compared with the
Parkinson-Cowan and semi-automated system, the Beckman MMC showed similar
cresults upon gas exchange analysis. The differences between the three systems were
always less than 5% and often less than 2%. This established that the Beckman MMC is
valid (Wilmore, Davis, and Norton, 1976). Two comparisons were made to establish
reliability of the Beckman MMC. The first comparison involved testing the same
individuals on four separate occasions for minute ventilation, O₂ uptake, CO₂ production
and respiratory exchange ratio. Correlations for each measurement were found to be r = .99, r = .99, r = .99, and r = .93 respectively. These same variables were tested against a
manual method showing correlations of r = .97, r = .98, r = .99, and r = .93 respectively
(Kannagi, Chang, Bruce, and Hossack, n.d.).
CHAPTER 3

METHODOLOGY

Design

The purpose of this study was to determine the effects of water hydration or sports drink hydration (CHO/electrolyte supplement) prior to an exercise bout on the performance of middle distance, amateur runners. The design was a one-group interrupted time group series design. The independent variables were water ingestion and sports drink ingestion. The dependent variables were performance as measured by: VO$_{2\text{max}}$, stop time, $V_e$, HR, RER at VO$_{2\text{max}}$, and RER at 75% of VO$_{2\text{max}}$, speed, grade, and RPE scale. One area of concern involved with this methodology was the willingness of subjects to perform a maximal treadmill test to volitional exhaustion. To circumvent this potential problem, the benefits of study participation were promoted during volunteer recruitment, such as a free evaluation of physiologic status including VO$_{2\text{max}}$.

Advantages of this method included randomization of the population, and the subjects acted as their own control group. Disadvantages of this design included subject learning effect, the possibility of an extraneous event occurring between trials, and training effects as a result of the first test (Portney and Watkins, 1993).

Study Site and Subjects

This study used a convenience population of 10 runners between the ages of 20 and 35 who ran an average of between 10 to 25 miles per week. The convenience sample was randomized via a coin toss method to assign subjects to begin with water or a sports
drink. An equal number was randomly assigned each group. For inclusion in this study the subjects: 1) were able to read and write English, 2) were between the ages of 20 and 35, 3) ran an average of between 10 to 25 miles per week for a period of at least two months, 4) were defined as “apparently healthy” by the ACSM guidelines (see Appendix C), 5) were free of contraindications for participation in an exercise test based on ACSM guidelines (see Appendix D). The subjects were asked to fill out a health screen questionnaire (Appendix B). Exclusion from the study was mandatory if the subjects answered yes to more than one of the health screening questions that affected their “apparently healthy” status. Subjects were then informed as to the nature of the study and the study’s associated risks and benefits. Participants were given the opportunity to ask any questions and then read and signed the informed consent form (see Appendix A). The testing was conducted at the Human Performance Laboratory in the Field House at Grand Valley State University via clearance through James Scott, B.S., M.A., P.E.S.

**Equipment and Instruments**

The Beckman MMC was developed by JH Wilmore, JA Davis, and AC Norton to improve the accuracy and reliability of physiological measurement gathering during rest and exercise. It is a data gathering system that measures $V_e$, respiratory rate, tidal volume, $VO_2$, $VCO_2$, ventilatory exchange of $O_2$ and $CO_2$, RER, and HR. The purpose of the Beckman MMC is to make respiratory and metabolic measurements on exercising subjects (Wilmore, Davis, and Norton, 1976). It contains sensors and analyzers for examining and measuring expired air. The gas collection system consists of a rebreathing apparatus, low resistance tubing, and a high velocity volume transducer. The gas is assessed as expired gas flows through a drying column into the Beckman OM-11 $O_2$
analyzer and a LB-2 CO\textsubscript{2} analyzer. The Beckman MMC has been shown to be both reliable and valid by Wilmore, Davis, and Norton (1976) and Kannagi, Chang, Bruce, and Hossack (n.d.). Other equipment required for data analysis and collection includes the Quinton 18-60 treadmill, Quinton Program Controller, Quinton ECG Recorder, and Quinton ECG Monitor.

The running protocol used was uniquely designed to target middle distance, amateur runners. The time frame was designed to reflect an approximation of how long it takes to complete a five kilometer run. The speed and grade relationships were chosen to produce respiratory fatigue before muscle fatigue, consistent with that produced in a similar run. The maximal speed used was selected because of its similarity to a five kilometer running speed without inducing a sprint. This is important because middle distance runners can be described as endurance athletes and not sprinters. After maximal speed was attained, grade increases were incrementally introduced to produce fatigue in the appropriate time frame. The protocols were developed using a compilation of various standard protocols. Both male and female protocols were developed to account for gender differences in race time completion. The protocol was piloted to determine the slope and deflection point consistency with maximum testing guidelines. The protocol that was developed is provided in Table 2.

The Borg scale for RPE was developed by Gunnar Borg for the purpose of understanding and quantifying subjective symptoms and relating them to objective findings. The Borg scale is the most widely used scale for measurement of subjective responses of subjects in graded exercise tests. Borg (1982) states that the Borg scale of RPE is correlated to both HR and percent VO\textsubscript{2max}.
Table 2

Graded Exercise Protocol for Female and Male Subjects to Achieve Volitional Exhaustion

<table>
<thead>
<tr>
<th>Minutes</th>
<th>Female Speed (mph)</th>
<th>Male Speed (mph)</th>
<th>% Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3.5</td>
<td>3.5</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>4.5</td>
<td>4.5</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>5.5</td>
<td>5.5</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>6.0</td>
<td>6.5</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>6.5</td>
<td>7.0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>6.5</td>
<td>7.0</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>6.5</td>
<td>7.0</td>
<td>2</td>
</tr>
<tr>
<td>14</td>
<td>6.5</td>
<td>7.0</td>
<td>4</td>
</tr>
<tr>
<td>16</td>
<td>6.5</td>
<td>7.0</td>
<td>6</td>
</tr>
<tr>
<td>18</td>
<td>6.5</td>
<td>7.0</td>
<td>8</td>
</tr>
<tr>
<td>20</td>
<td>6.5</td>
<td>7.0</td>
<td>10</td>
</tr>
<tr>
<td>22</td>
<td>6.5</td>
<td>7.0</td>
<td>12</td>
</tr>
<tr>
<td>24</td>
<td>6.5</td>
<td>7.0</td>
<td>14</td>
</tr>
<tr>
<td>26</td>
<td>6.5</td>
<td>7.0</td>
<td>16</td>
</tr>
</tbody>
</table>
A pilot study to ensure the researchers and equipment consistency was conducted on two subjects. The subjects ran the maximal treadmill test while attached to all the equipment involved in the actual test procedure. Intertester reliability was not a concern because only one investigator performed the set-up of the equipment. The validity was established by comparison of the investigator’s results with other normative data collected on the same equipment.

Procedures

The Grand Valley State University Human Subjects Review Board conducted a full review of this study prior to recruitment of participants. A study was conducted to determine the researcher’s and equipment consistency. Subjects were recruited from Grand Valley State University and the greater Grand Rapids area. Upon communication with potential subjects, the subjects received instructions regarding pretest activity and fluid ingestion (see Appendix F) and were given a date on which to arrive at the Human Performance Lab for testing. Upon arrival, subjects were told the purpose and procedures involved in the testing. First, the subjects were asked to fill out a self report health screen questionnaire. The questionnaire was reviewed to determine subject inclusion, safety factors, and data analysis information. After all questions were answered, the participants were then asked to read and sign the informed consent form. Participants were then monitored for HR and blood pressure (see Appendix B).

Subjects were encouraged to perform their typical pre-run stretching routine. After ample stretching, as determined by the subjects, ingestion of either water or a sports drink occurred based on randomization into two groups. Four hundred milliliters of either a 6% CHO solution of Gatorade Thirst Quencher® or water was prepared with two
grams of Nutrasweet™. A 6% CHO solution was chosen because it is the most readily available to consumers while also exhibiting properties necessary to facilitate adequate gastric emptying and fluid absorption. The subjects remained unaware of the fluid type through masking of flavor using Nutrasweet™ and nose plugging. The fluid was given at room temperature (~70°).

The Beckman MMC was calibrated prior to testing of each subject. Subjects were then connected to the Beckman MMC equipment and a five lead electrocardiogram (ECG). The running protocol began between 15 and 20 minutes after fluid ingestion.

The Borg Scale for perceived exertion was administered at the end of each workload. Data regarding VO_{2max}, V_{E}, RER, speed, and grade were collected every minute. The test was completed upon subject volitional exhaustion, or as determined by ACSM guidelines for test termination (Appendix E and G). Upon test completion, subjects performed a cool-down routine that consisted of walking for three minutes at three to three and a half miles per hour or until ECG readings returned to pre-run values, stretching as needed, and hydration as needed (ACSM, 1995). The subjects were instructed to run no more than three miles per day between trials. The subjects returned two days later and performed the identical procedure. However, the opposite drink was ingested prior to exercise.

Data Analysis

Descriptive statistics were computed to describe the data collected and to determine if the data met the assumption of normal distribution. Since the assumptions of a normal distribution were not met, a parametric test could not be used. The non-parametric statistical test used to analyze the data were a Wilcoxon Signed Ranks Test.
This statistical technique allowed determination of any positive or negative effects on performance between the two drinks ingested. Data were examined using the SAS computer program. The dependent variables were $\text{VO}_{2\text{max}}$, stop time, $V_E$, HR, RER at $\text{VO}_{2\text{max}}$, RER at 75% of $\text{VO}_{2\text{max}}$, speed, grade, and RPE. Independent variables were the type of drink ingested, either water or sports drink. A p-value $\leq .05$ was selected for the rejection of the null hypothesis.
CHAPTER 4
RESULTS/DATA ANALYSIS

Subjects

Ten subjects were recruited from Grand Valley State University and the greater Grand Rapids, Michigan area to participate in this study. The subjects consisted of eight females and two males that were between the ages of 20 and 35 and ran an average of 10 to 25 miles per week for at least two months prior to the testing. The mean age of the subjects was 25 ± 2.11 years (mean ± standard deviation). The mean height and weight were 168.64 ± 8.56 centimeters and 61.13 ± 10.70 kilograms, respectively. Table 3 is a summary of the age, height, and weight of the subjects tested.

Table 3
Summary of Subject Characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>25.00</td>
<td>2.11</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168.60</td>
<td>8.56</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>61.13</td>
<td>10.70</td>
</tr>
</tbody>
</table>

Data were collected and examined from all 10 subjects. Outcome measures were gathered every minute during testing until test completion.
Techniques of Data Analysis

Statistical analyses were performed using the SAS program. Maximal oxygen consumption and stop times were analyzed according to sports drink versus water and trial 1 versus trial 2. The data were analyzed according to sports drink versus water to determine whether either drink had an effect on performance outcome measures. The data were analyzed according to trial 1 versus trial 2 to determine if familiarity with the procedure and the protocol influenced the test outcomes. The descriptive statistics analyzed were the mean, standard deviation, and standard error mean. The descriptive analyses revealed a lack of normal distribution. The inferential statistical analysis included correlation and significance level.

A non-parametric statistical analysis was utilized because the assumptions for normal distribution were not met. The non-parametric statistical technique selected was the Wilcoxon Signed Ranks Test, which measures the direction of difference and the relative amount of difference (Portney and Watkins, 1993). Results of the Wilcoxon Signed Ranks Test showed a p value of .036 for VO$_{2\text{max}}$ when comparing water trials to sports drink trials. Table 4 shows the results for all variables measured by the Wilcoxon Signed Ranks Test. According to the selected p $\leq .05$, the VO$_{2\text{max}}$ during the water and sports drink trials indicated a significant difference. This indicates that there is sufficient evidence to conclude that the mean VO$_{2\text{max}}$ differs when an individual ingests water or a sports drink prior to a middle distance run research protocol.
Table 4

Summary for Non-parametric Statistics of the Wilcoxon Signed Ranks Test

<table>
<thead>
<tr>
<th>Variables (Cond. 1 vs. Cond. 2)</th>
<th>Mean ± SD (Cond. 1)</th>
<th>Mean ± SD (Cond. 2)</th>
<th>p=</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO_{2max} (ml/kg/min) of SpD vs. H_2O</td>
<td>44.64 ± 6.17</td>
<td>42.33 ± 6.78</td>
<td>.036*</td>
</tr>
<tr>
<td>VO_{2max} (ml/kg/min) of Trial 2 vs. Trial 1</td>
<td>43.83 ± 7.08</td>
<td>43.14 ± 6.05</td>
<td>.798</td>
</tr>
<tr>
<td>Stop Time (min) of SpD vs. H_2O</td>
<td>14.26 ± 1.53</td>
<td>14.02 ± 1.55</td>
<td>.262</td>
</tr>
<tr>
<td>Stop Time (min) of Trial 2 vs. Trial 1</td>
<td>14.17 ± 1.70</td>
<td>14.11 ± 1.37</td>
<td>.838</td>
</tr>
<tr>
<td>V_e (L/min) of SpD vs. H_2O</td>
<td>90.82 ± 13.70</td>
<td>87.84 ± 16.81</td>
<td>.646</td>
</tr>
<tr>
<td>V_e (L/min) of Trial 2 vs. Trial 1</td>
<td>88.64 ± 16.18</td>
<td>90.04 ± 14.58</td>
<td>.308</td>
</tr>
<tr>
<td>HR (beats/min) of SpD vs. H_2O</td>
<td>194.40 ± 9.62</td>
<td>193.10 ± 10.75</td>
<td>.284</td>
</tr>
<tr>
<td>HR (beats/min) of Trial 2 vs. Trial 1</td>
<td>194.10 ± 10.16</td>
<td>193.40 ± 10.28</td>
<td>.858</td>
</tr>
<tr>
<td>RER at VO_{2max} of SpD vs. H_2O</td>
<td>1.15 ± .05</td>
<td>1.13 ± .11</td>
<td>.838</td>
</tr>
<tr>
<td>RER at VO_{2max} of Trial 2 vs. Trial 1</td>
<td>1.11 ± .08</td>
<td>1.17 ± .07</td>
<td>.102</td>
</tr>
<tr>
<td>RER at 75% of VO_{2max} of SpD vs. H_2O</td>
<td>.93 ± .06</td>
<td>.92 ± .06</td>
<td>.40</td>
</tr>
<tr>
<td>RER at 75% of VO_{2max} of Trial 2 vs. Trial 1</td>
<td>.93 ± .06</td>
<td>.93 ± .06</td>
<td>.726</td>
</tr>
</tbody>
</table>

Note. SpD = Sports Drink; H_2O = Water.
* p ≤ .05.
Statistics

The mean and standard deviation were calculated for all outcome measures. Mean and standard deviation for VO_{2max} of water versus sports drink, VO_{2max} of trial 1 versus trial 2, and stop time of sports drink versus water were determined to be the primary foci of the analyses. Figure 1 represents the mean of water and sports drink for VO_{2max} in ml/kg/min. This shows that the VO_{2max} mean for sports drink levels are greater than the water levels. Recall the means were different with a significance of p = .036. The mean and standard deviation of VO_{2max} for water and sports drink was 42.33 ± 6.78 and 44.64 ± 6.17, respectively.

Figure 1. Mean Maximal Oxygen Consumption of Water vs. Sports Drink. a: significance < .05

Figure 2 represents the VO_{2max} measurements for each subject according to water and sports drink categories. The graph indicates that nine of the 10 subjects showed an increased VO_{2max} between water and sports drink trials.
Mean $VO_{2\text{max}}$ for trial 1 and trial 2 were 43.14 ± 6.05 and 43.83 ± 7.08, respectively.

Figure 3 represents the mean $VO_{2\text{max}}$ for trial 1 versus trial 2 indicating no significant difference between the trials with $p=.798$. 

Figure 2. Maximal Oxygen Consumption of Water vs. Sports Drink.

Figure 3. Mean of Maximal Oxygen Consumption of Trial 1 vs. Trial 2.
Figure 4 represents the individual VO\textsubscript{2max} values comparing trial 1 and trial 2. This indicates that six out of 10 subjects did not improve VO\textsubscript{2max} on the second trial suggesting no significant differences between trials with a p = .798.

![Figure 4. Maximal Oxygen Consumption of Trial 1 vs. Trial 2.](image)

Mean stop times, time to volitional exhaustion, for sports drink and water were 14.26 ±1.53 and 14.02 ± 1.55, respectively. Figure 5 shows the mean stop times for sports drink and water with p = .262, indicating no significant difference in stop times between sports drink and water trials.
Figure 5. Mean Stop Time of Water vs. Sports Drink.

Figure 6 represents the individual stop times comparing sports drink versus water. This graph indicates that seven out of 10 individuals increased their stop time with the sports drink, but shows no significant difference in stop times between sports drink and water trials with $p = .262$.

Figure 6. Stop Time of Water vs. Sports Drink.
CHAPTER 5
DISCUSSION AND IMPLICATIONS

Discussion of Findings

The findings of this study reject the null hypothesis that whether an individual ingests water or sports drink prior to a middle distance run protocol in a thermoneutral environment has no significant effect on the means of various performance measures.

There are three primary outcome measures to consider when comparing the present study to previous literature. First, the present study found that the mean VO\textsubscript{2max} was greater for those who ingested the sports drink versus water with p = .036 suggesting that the sports drink significantly improved VO\textsubscript{2max}. However, little research was found to support the use of CHO/electrolyte drinks to improve VO\textsubscript{2max}. Although electrolytes are included in sports drinks, previous studies made no attempt to separate the effects of the electrolytes from those of the CHOs. Electrolytes facilitate fluid absorption and are generally considered essential when focusing on fluid replacement following exercise.

Carbohydrates have a direct effect on muscle performance, therefore, the present study primarily focused on CHOs.

A literature review revealed a study suggesting no difference in physiological measures following ingestion of various fluids. Davis, et al. (1988) measured HR, sweat rate, plasma volume, and rectal temperature during separate cycling trials. It was suggested that no difference was found between these outcome measures when comparing sports drinks to a water placebo. The present results indicate that a difference
in VO$\textsubscript{2max}$ may exist when comparing sports drink to water. Davis, et al. (1988) did not measure VO$\textsubscript{2max}$, which may have been a significant outcome measure.

Similarly, Okano, et al. (1988) found that during cycling trials, there were no differences in oxygen uptake between pre-exercise fructose ingestion and various placebo drinks. Thus, a comparison of the literature to the present study was difficult because of differences in outcome measures, exercise type, duration, and intensity. The previously mentioned studies involved exercise bouts between 90 and 120 minutes while working at either 60 or 75% of VO$\textsubscript{2max}$. During high intensity, low duration exercise the body uses CHO$\textsubscript{s}$ to produce energy. Exercising at a low intensity, high duration causes the body to use fats primarily. Therefore, CHO$\textsubscript{s}$ were the primary substrate used in the present study, as demonstrated by RER values above one upon trial completion.

The body utilizes either fats or CHO$\textsubscript{s}$ as substrates during exercise, depending on the intensity of the work load (Powers and Howley, 1997). The sports drink used in the present study was a 6% CHO$\textsubscript{solution$. The water contained no CHO$\textsubscript{s}$. Therefore, ingestion of a sports drink prior to a run may increase the amount of CHO$\textsubscript{s}$ available to the body. Carbohydrates utilize oxygen more efficiently than fat, resulting in greater energy production for the body (Powers and Howley, 1997). The p value for VO$\textsubscript{2max}$ in the present study was significant when comparing sports drink to water. This suggests that ingestion of a CHO/electrolyte drink prior to a middle distance run improves VO$\textsubscript{2max}$ and may enhance the ability to run for a longer period of time (Powers and Howley, 1997).

The present study showed improved VO$\textsubscript{2max}$ in nine of 10 subjects who ingested sports drink prior to running. A possible reason why one subject did not show
improvement in VO$_{2\text{max}}$ after ingesting the sports drink was due to initiation of the menstrual cycle on that trial day. Blood loss may result in decreased hemoglobin levels resulting in decreased oxygen transport. Thus, it may negatively affect VO$_{2\text{max}}$ (Powers and Howley, 1997).

The mean VO$_{2\text{max}}$ of trial 1 versus trial 2 showed $p = .798$ which indicated no significant change in VO$_{2\text{max}}$ between trials. Further support for no difference between trials is a correlation of .778. This suggests that conditions for the trials were similar. It is unlikely that familiarity with the procedure and the protocol influenced the test outcomes.

The stop time for sports drink versus water ($p = .262$) was not significant. It may, however, suggest that the sports drink may have played a role in prolonging stop time, even though the $p$ level did not reach significance. Previous literature regarding running as it relates to CHO/electrolyte drinks is limited. McMurray, et al. (as cited in Lamb and Brodowicz, 1986) reported that performance times for runners who ingested water or sports drinks were similar. The test procedure, however, differed from the present study because the aforementioned subjects ran in excess of one hour at a submaximal level.

Conversely, Millard-Stafford, et al. (1992) suggested that running speed improves during the last five kilometers of a 40 kilometer run when ingesting a CHO/electrolyte drink versus water. In the present study, although speed increases were not directly measured because of a standardized protocol, run duration did show improvement. This suggests some type of improvement in performance secondary to sports drink ingestion.

A study by Bacharach, et al. (1994) suggests improved cycling performance after ingesting a CHO drink for time to complete 500 revolutions when compared to a placebo.
This study indicates an improved stop time after ingestion of a CHO drink. The present results may suggest an improved stop time with ingestion of a sports drink. However, the p value does not reach a significant value (p = .262).

When CHOs are depleted during exercise, muscular fatigue results. By ingesting CHOs prior to running, it increases the CHOs available to support muscular function increase (Powers and Howley, 1997). Therefore, an individual ingesting CHOs prior to a middle distance run may have a longer run duration when compared to an individual ingesting water with no CHO supplementation (Coyle and Montain, 1992).

Limitations

Several limitations existed in this study. First, the water and sports drink were given at room temperature, 20 minutes prior to the maximal treadmill run. This limited the study to a specific temperature and time of drink ingestion. Sports drinks come in a variety of carbohydrate and electrolyte concentrations. This study is limited to the specific concentration chosen and did not allow investigation of the independent effects of CHOs and electrolytes on performance. The specific volume of drink also limited the study. The present study used 400 milliliters, however, the ACSM (1995) recommends ingesting 300 to 500 milliliters of fluid prior to exercise of less than one hour duration. Also, the drinks were masked for color and flavor, however, four of the ten subjects stated they were able to distinguish which drink they ingested.

The controlled environment of the Human Performance Lab and the nature of a maximal treadmill test did not precisely match the conditions in which five kilometer runners naturally perform. The subjects were also connected to a mask for gas analysis, which could affect performance. The results gained from this study were specific for
healthy individuals aged 20 to 35 who run approximately 10 to 25 miles per week. The subjects each began their run between 15 and 20 minutes after drinking the fluid. However, the five minute variation in test starting time may have affected gastric emptying rates and performance. Other limitations included sampling method, small sample size, geographic restrictions, and the lack of cultural diversity.

Conclusion

In conclusion, ingestion of a sports drink prior to a five kilometer run may be more beneficial than ingesting water. Significant improvements were noted in VO$_{2\text{max}}$ in subjects who ingested sports drink as opposed to water. Any type of hydration prior to running may be beneficial, however, the present research was specific to comparing water and sports drink. Benefits of hydrating with a sports drink prior to a five kilometer run include an improved VO$_{2\text{max}}$ and a possible improvement in the duration of the run.

There was a lack of literature regarding hydration in middle distance, amateur runners. This is because more significant outcome measures can be seen in trained distance athletes. Because of this lack of relevant information, healthcare professionals may have a difficult time educating clients on proper hydration prior to middle distance running. The present study provides objective information regarding the amount and type of fluid that should be ingested prior to five kilometer run. The results of this study indicate a need for further research regarding whether ingestion of a sports drink improves the duration or speed of a run and whether a sports drink affects males and females differently. Future researchers would benefit by conducting a similar study using a larger sample size to strengthen the statistical significance of all the performance measures.
References


APPENDIX A

Informed Consent Form

Title of Study
The Effects of Water or Sports Drink Ingestion Prior to Exercise on the Performance of Middle Distance, Amateur Runner in a Thermoneutral Environment

Investigators
The study is being performed by Grand Valley State University Master of Physical Therapy students, Julie Barnes and Scott DeVries. This research will be completed under the supervision of James Scott, B.S., M.A., P.E.S. Dan Vaughn, P.T., M.O.M.T. and Paul Stephenson, Ph.D. will serve as advisors. The research will be conducted at Grand Valley State University’s Human Performance Lab in Allendale, Michigan. The study will include a total of 10 male and female subjects ages 20-35.

Purpose of Study
The purpose of this study is to determine the effects of water hydration or sports drink hydration (carbohydrate/electrolyte replacement) prior to an exercise bout on the performance of middle distance, amateur runners. The results of this study will provide further information regarding proper hydration methods prior to exercise for the running athlete.

Procedures
Upon arrival, I will be asked to fill out a health screening questionnaire and informed consent form. I will be allowed to ask any questions prior to the continuation of testing. I will be allowed ample stretching and preparation time. I will then be asked to drink 400 ml of water or sports drink. After 15 minutes, I will be connected an air collection device and heart monitor and will begin the testing protocol on the treadmill. I will continue to maximal exertion as determined by the researchers or myself. I understand that my oxygen consumption and heart rate will be monitored continuously, throughout and I will be connected to a mask for air collection and a heart monitor. At the completion of the exercise test I will walk for three minutes at 3 to 3.5 miles per hour as a cool down method. I will be provided with adequate fluids and time to stretch. I will return two days later to repeat the same procedure. I understand that I am one of ten subjects completing this testing procedure.

Risks and Precautions
I understand that this test will involve running at a high intensity for up to 26 minutes. and it will cause an increase in breathing rate, muscle activity, and heart rate. I understand that a certain level of discomfort is expected including muscle soreness and fatigue, but serious injury and harm are not anticipated. However, due to the nature of the testing, certain risks do exist. These risks will be made aware to me before I participate in the study and as they arise.
Risks Associated with Maximal Exercise Testing: (Based on ACSM Guidelines, 1995)

- Less than or equal to 0.01% chance of death during or immediately following a maximal exercise bout.
- Less than or equal to 0.04% chance of myocardial infarction during or immediately following a maximal exercise bout.
- Approximately a 0.1% chance of a complication requiring hospitalization during or immediately following a maximal exercise bout.

An emergency plan is established and will be implemented should the need arise. Personnel with cardiopulmonary resuscitation certification (CPR) will be present at all times during testing. If an emergency situation presents itself, the researchers will dial 9-911. A dispatcher will send appropriate personnel to the Human Performance Lab. The director of the Human Performance Lab has reviewed this system and finds it satisfactory.

Benefits
I understand that my participation in this test is not designed to improve my running ability. Results may provide me with information regarding optimal fluid intake prior to running. The test is also a valuable measure of my current physical condition.

Duration
Each of the two testing sessions is designed to take approximately one hour.

Confidentiality
The information gathered during this study will remain confidential. I will be assigned an identification number and will not be referred to by name throughout the course of the research. If the test results are published in a scientific journal, no names will be used.

Voluntary Participation
I understand that my participation in this study is voluntary, and I can withdraw at any time without consequence. It is my responsibility to let the researchers know if I am feeling unusual the day of testing.

Contacts/Questions
If I have any further questions about the research, I understand that I can ask them at any time. I can contact Julie Barnes, SPT at (616) 877-4587, Scott DeVries, SPT at (616) 538-3613, James Scott at (616) 895-3228, or Dan Vaughn at (616) 895-2678. A copy of the study results will be made available to me upon request.
Voluntary Participation and Withdrawal from Study

I understand that my participation in this study is voluntary, and I can withdraw at any time without consequence. The investigators may discontinue my test for various reasons, which will be explained to me at that time. Any refusal to participate will not jeopardize my relationship with any of the researchers, Grand Valley State University, or their Physical Therapy Department.

Informed Consent

I have read this informed consent form, and I feel that I can safely complete a maximal stress test. This study has been sufficiently explained to me, and all of my current questions have been adequately answered. My signature below indicates that I understand the information provided on this form and my willingness to participate as a subject. I acknowledge that I have received a copy of this consent form.

________________________________________       ___________________________
Investigator Signature                        Date

________________________________________       ___________________________
Participant Signature                        Date

________________________________________       ___________________________
Participant Name                            Date

________________________________________       ___________________________
Witness Signature                           Date
APPENDIX B

Health Screening Questionnaire

Date: ________________  Age: __________
Height: _____________  Weight: ________
Subject ID #: ________  Gender: Male or Female

Medical History: (Please circle Yes or No for each of the following questions)
**Please ask questions as they arise.

1. Have you seen your physician in the last six months for a running related injury?
   Yes  No

2. Do you have any heart or respiratory problems?
   Yes  No

3. Do you have any chest pains when you exercise?
   Yes  No

4. Do you have any muscle, bone, or joint problem that cause pain while running?
   Yes  No

5. Do you lose your balance because of dizziness or lose consciousness?
   Yes  No

6. Are you pregnant?
   Yes  No

7. Do you smoke?
   Yes  No

8. Do you have any adverse reactions to sports drinks (carbohydrate/electrolyte drinks)
   or Nutrasweet?
   Yes  No

9. Are you aware of any other reason why you should not participate in physical
   activity?
   Yes  No

10. Are you on any prescription medications for blood pressure or a heart condition?
    Yes  No
11. Do you have an immediate family history of heart attack or sudden death?  
   Yes  No

12. Do you have high blood pressure (140/90 mmHg)?  
   Yes  No

13. Do you have high cholesterol?  
   Yes  No

14. Do you have diabetes mellitus?  
   Yes  No

Activity Level: (Please fill in the blank)

1. Approximately how many miles do you run per week? ______________________

2. On average, how long does it take you to run 3.1 miles (5 kilometers)? _________

3. How long (weeks, months, years) have you been running at this mileage? _________

Pretest Physiologic Status: (To be completed by investigator)

Heart Rate:_____  Blood Pressure:_____

Posttest Physiologic Status:

Heart Rate:_____  Blood Pressure:_____
APPENDIX C

Apparently Healthy Characteristics

The apparently healthy subjects are asymptomatic individuals who have no more than one major coronary risk factor.

Risk Factors

1. Family history: Myocardial infarction or sudden death before 55 years of age in father or other male first-degree relative, or before 65 years in mother or other female first-degree relative.

2. Current cigarette smoking

3. Hypertension: Blood pressure \( \geq 140/90 \) mmHg, confirmed by measurements taken on at least two separate occasions, or on antihypertensive medication.

4. Hypercholesterolemia: Total serum cholesterol \( > 200 \) mg/dL or HDL \( < 35 \) mg/dL.

5. Diabetes mellitus: Persons with insulin dependent diabetes mellitus (IDDM) \( > 30 \) years old, or have had IDDM for \( > 15 \) years, and persons with noninsulin dependent diabetes who are \( > 35 \) years.

* Additional risk factors are given by the ACSM but have been excluded here based on the subject parameters of this study.

APPENDIX D

Contraindications to Exercise Testing

Absolute Contraindications

1. Recent significant change in ECG.
2. Unstable angina.
3. Uncontrolled ventricular or atrial arrhythmias that compromise cardiac function.
4. Third degree AV heart block without pacemaker.
5. Acute congestive heart failure.
6. Aortic stenosis.
7. Dissecting aneurysm.
8. Myocarditis or pericarditis.
9. Thrombophlebitis or intracardiac thrombi.
10. Recent systemic or pulmonary embolus.
11. Acute infections.
12. Significant emotional distress.

Relative Contraindications

1. Resting diastolic blood pressure > 115 mmHg or resting systolic blood pressure > 200 mmHg.
2. Moderate valvular heart disease.
3. Known electrolyte abnormalities.
4. Fixed-rate pacemaker.
5. Frequent or complex ventricular ectopy.
7. Uncontrolled metabolic disease.
8. Chronic infectious disease.

9. Neuromuscular, musculoskeletal, or rheumatoid disorders that are exacerbated during exercise.

10. Advanced or complicated pregnancy.

APPENDIX E

ACSM Indications for Discontinuation of Exercise Testing

Absolute Indications

1. Suspicion of myocardial infarction (MI) or actual MI.

2. Severe or moderate angina (3+ on a 1+ to 4+ scale).

3. Drop in systolic blood pressure with increased exercise accompanied by signs or symptoms or a drop below standing resting pressure.

4. Serious arrhythmias.

5. Signs of poor perfusion including pallor, cyanosis, cold or clammy skin.

6. Unusual or severe shortness of breath.

7. Central nervous system problems including ataxia, vertigo, visual problems, gait deviations, or confusion.

8. Technical inability to monitor electrocardiogram (ECG).

9. Upon patients request.

Relative Indications

1. Pronounce ECG changes from baseline.

2. Any progressive chest pain.

3. Physical or verbal communication of severe fatigue or shortness of breath.

4. Wheezing.

5. Intermittent claudication or leg cramps.

6. Systolic blood pressure > 260 mmHg; diastolic blood pressure > 115 mmHg.
7. Less serious arrhythmias.

8. Exercise induced bundle branch block.

APPENDIX F

Subject Instructions

1. Subjects should avoid food, alcohol, caffeine, or using tobacco products within three hours of testing.

2. Subjects should avoid significant exercise on the day of assessment (i.e. any running, biking, swimming, or other physical exertion).

3. Clothing should be worn that allows freedom of movement during exercise. Running shoes should also be worn.

4. Subjects may wish to have someone accompany them to the testing to drive them home afterward.

5. Subjects will continue their regular medication and diet schedule.

6. Subjects will bring a list of all current medications.

7. Subjects will run no more than three miles per day in between assessments.

8. Subjects will drink no fluids other than water beginning at five hours before exercise. Two hours before testing subjects should drink 16 ounces of water and intake no fluid after that.

9. Subjects will familiarize themselves with running on a treadmill at least two days prior to exercise testing.

APPENDIX G

Indications of a Valid VO\textsubscript{2max} Test

The following indications have been proposed as validators of a VO\textsubscript{2max} test when two of the criteria are met (Williams, et al. and MicMiken and Daniels as cited in Powers and Howley, 1997).

1. An RER of $\geq 1.15$.

2. A HR that is $\pm 10$ beats/min within the subject’s predicted max HR during the last exercise stage.

3. A plateau in VO\textsubscript{2} as work rate increases.