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The effectiveness of a coconut beverage on exercise performance

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ABSTRACT

THE EFFECTIVENESS OF A COCONUT BEVERAGE
ON EXERCISE PERFORMANCE

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Background: Coconut water (CW) is a new sports drink on the market appealing to consumers who are seeking a more natural alternative to the traditional carbohydrate-containing sports beverage. CW contains five essential electrolytes as compared to the standard sports drinks which typically contains only two or three. Very little research has been completed in testing the effect of CW in exercise performance; however, carbohydrate-based sports drinks have been confirmed to replete glycogen reserves and thus act as an effective ergogenic aid.

Objective: The purpose of this study was to examine the effects of CW on recovery and exercise performance in comparison to plain water and another common sports drink.

Methods: Twelve physically active males aged 18-45 with excellent VO_{2max} scores (as defined by the American College of Sports Medicine guidelines) completed the study which consisted of three experimental trials in a repeated-measures crossover design. At each trial, subjects consumed 12 ounces of one of three beverages: water, CW, or a leading carbohydrate electrolyte (CE) beverage every 15 minutes during a 90-minute run at 60-70% VO_{2max}. The beverages were randomized and blind to both subjects and researchers. At the end of each 90-minute run, participants completed a treadmill anaerobic test (TAT) until volitional fatigue. Distance traveled and TAT time were used to assess performance.

Results: There were no significant differences between CW, CE, or water in TAT performance time (p=0.146) or distance traveled (p=0.225) during the 90-minute run when a repeated-measures ANOVA was completed.

Conclusions: Participants performed similarly during the CW, water, and CE beverage trials in terms of distance traveled during the 90-minute run and TAT time. Additional research is needed to continue to examine the effectiveness of CW as a sports performance aid.

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THE EFFECTIVENESS OF A COCONUT BEVERAGE ON EXERCISE PERFORMANCE

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CHAPTER I

INTRODUCTION

Background

Sports nutrition, or the study of nutrients an athlete ingests to optimize athletic performance, is increasing in popularity. While there are many aspects of performance that are not within an athlete's control (age, genetics, and weather), athletes can control their nutrient, fluid, and supplement intake as well as their training regimen. Many collegiate athletic and professional teams hire and consult with registered dietitian nutritionists (RDNs) and certified specialists in sports dietetics (CSSD) as they see the impact of proper nutrition on game-day outcomes, energy levels, performance, and effort.[1]

One of the most important nutritional considerations in the sports nutrition field is related to dehydration. During prolonged aerobic exercise, fluid loss from sweat can cause weight loss, loss of minerals through the skin, early fatigue, stress, and impaired athletic performance.[2,3] Water loss of a mere 1% of body mass can cause decreased performance, which often is undetected until it is too late.[4,5] Typical exercise recommendations include staying well hydrated before, during, and after exercise in order to reduce these complications. The American College of Sports Medicine (ACSM) recommends athletes consume 3-8 fluid ounces of water every 15-20 minutes if they are exercising for less than 60 minutes; the recommendation changes to 3-8 fluid ounces of a sports beverage (defined as 5-8% carbohydrate (CHO) with electrolytes) if exercising for over 60 minutes to achieve optimal performance.[3,5]

The ACSM guidelines for consumers state that “carbohydrate consumption helps to sustain and improve exercise performance during high intensity exercise longer than one hour [as well as lower intensity for longer periods]” in addition to helping replenish glucose/glycogen stores and accelerate rehydration.[3] Glycogen stores, the stored form of glucose, and CHO typically make up the primary fuel source for the body during aerobic exercise.[6] After glucose from the bloodstream is used, the body relies on liver glycogen stores and muscle glycogen reserves.[6,7] Glycogen depletion and low blood glucose (hypoglycemia) can limit performance and be a source of fatigue in exercise lasting 60-90 minutes.[6] Repeated exercise without replacing the body’s glycogen stores can lead to fatigue and decreased performance over time.[4,8,9]

With an increasingly health-conscious population, many people are looking to eliminate or reduce the intake of sports drinks which contain additives and often large amounts of sugar. Alternatives include more natural, less processed drinks and ingredients, one of which is coconut water (CW). According to Mintel Market Research, the number of CW products launched globally in the past five years grew 540%.[10,11] In the United States, the number of CW products released between 2012 and 2013 increased by 92%.[11] CW contains electrolytes and minerals, both which are vital to exercise recovery.[12] Typically, CW contains fewer additives and no high fructose corn syrup compared to some standard sports drinks which may contain more processed or unrecognizable ingredients.[12] Many of the claims regarding the efficacy of CW are however based on testimonials and there is a scarcity of evidenced-based research, which leaves experts reticent to make recommendations without the scientific evidence to back it up.

There is a dearth of research connecting the consumption of CW with improved exercise performance or recovery. However, people in more humid climates such as the Middle East, South America, and Southeast Asia have been drinking different varieties of CW for years.[13] There have been some studies in relation to CW as a rehydrating solution in dehydrated patients or those with gastrointestinal distress.[2,14] In terms of the effect of CW on exercise performance in the U.S. very few peer-reviewed research studies have been completed.[14] This makes it difficult for RDNs, sports nutritionists, exercise physiologists, and coaches to make evidence-based recommendations.

Most of the calories contained in a CW or other electrolyte beverages are from CHO, with only minimal amounts of protein and fat. CW does contain sugar (CHO), which provides energy. There is a large amount of research about CHO supplementation, rehydration, and exercise recovery.[2,15-18] Many authors have shown some benefit in performance with a CHO beverage supplement in their studies.[15,17] These authors measured performance in a controlled environment where participants were asked to either run or cycle for a prolonged period such as 1-2 hours and given a supplement, beverage, or placebo at set intervals. The prolonged exercise period resulted in depleted glycogen energy stores, or at least significantly lowered.[2,17,18] Then the participants were asked to complete a run or cycle at maximum effort until volitional fatigue. Measurements such as performance or power output and time sustained can be taken and analyzed depending on the ingested CHO supplement (if any). A number of authors have tested various beverages this way and studies could be easily modified to include CW.[15,17-19]

CW companies use the electrolyte content as a selling point for their product. CW contains all five essential electrolytes --sodium, potassium, chloride, calcium, and magnesium-- and some authors call it a “natural nutritious beverage” because of the similar electrolyte content to human blood and potential “medicinal” benefits.[2,12,14,20-22] One such CW company claims the right proportion of all five electrolytes allows for optimal recovery and rehydration in addition to proper muscle contraction, mental focus, nervous system function, lubrication of joints and muscles, and formation of protective linings as compared to other sports drinks.[12] In contrast, most common carbohydrate electrolyte (CE) beverages such as Gatorade contain sodium, potassium, and chloride but not normally calcium or magnesium. Sports drinks typically add some electrolytes, namely sodium, potassium, and possibly chloride, to help maintain fluid electrolyte balance.[23] However, it is hard to delineate specific roles that electrolytes have in improving performance and physiological state, especially because they are typically seen in combinations in the drinks.[23] Higgins, James, and Price[24] showed that ingesting sodium improved high-intensity cycling performance and Schubert and Astorino[25] found improvement in treadmill performance. However other authors, such as Cosgove and Black[26] saw no effect of sodium supplementation on three-hour cycling trials. Sodium bicarbonate and sodium citrate have both been tested, with sodium bicarbonate ($NaHCO_3$) appearing to have better buffering capacity yet increased GI discomfort.[26] According to the National Institute of Health (NIH), chloride is known as essential for fluid balance in the body; sodium and potassium are needed for muscles and nerves to work properly; and calcium helps muscles and blood vessels contract and expand.[27]

Athletes need to perform their best, so they are seeking products which may help them achieve their goal(s). Consumers have a right to know what products are more beneficial than others in the multi-billion dollar sports drink industry.[23] Research would help validate or confirm claims about CW and allow consumers to make more educated decisions on what products are appropriate for them.

Statement of Research Problem

The purpose of this repeated-measure crossover design study was to examine the effects of CW on recovery and performance during exercise. Three beverages (water, CW, and a CE beverage) were provided to the participants while monitoring performance time. Since each participant completed each of the three beverage trials, they served as their own control. The order of the beverage assignment was randomized. The water served as a baseline and the CW and CE beverages served as the experimental trials. These beverages contained slightly different electrolytes and percentages of CHO. With CW beverages being fairly new on the market, and not yet well studied, research gaps exist in regard to effectiveness of these beverages in the context of exercise. While some evidence of CW as a rehydrating solution and usefulness for its electrolyte content exists, use in running tests instead of water or CHO drinks has not thoroughly been studied.[2,13,14] While there is extensive research on CHO drinks, many people are looking for healthier alternatives to these beverages.[15,16,19,23,25]

Research Question

1. Will the consumption of CW alter performance times on the treadmill anaerobic test (TAT) in comparison to water and a CE beverage?

2. Will the consumption of CW alter distance traveled during the 90-minute run in comparison to water and a CE beverage?

Independent Variables

The independent variable was the beverages given to participants during exercise (CW, CE beverage, or water).

The CW trial included 12 oz of CW (Coco5, Chicago, IL) which consisted of filtered water, natural young CW concentrate, pure cane sugar, natural lemon lime extract, citric acid, natural sea salt, and natural rebiana, consumed every 15 minutes during the 90-minute running period. Twelve ounces of CW contains 60 calories, 12 grams CHO, 90 mg sodium, and 120 mg potassium.[12]

The CE beverage trial included Gatorade (Chicago, IL) which was diluted with water (8 oz Gatorade, 4 oz filtered tap water) and consisted of water, sugar, dextrose, citric acid, natural flavor, salt, sodium citrate, monopotassium phosphate, gum arabic, glycerol ester of rosin, and yellow 5, consumed every 15 minutes during the 90-minute running period. This 12 oz solution contains ~53 calories, 14 grams CHO, ~107 mg sodium, and 30 mg potassium, according to Gatorade's website.[28] The water trial included 12 oz of filtered tap water consumed at 15-minute intervals during the 90-minute running period, which provides 0 calories and 0 g CHO.

Dependent Variables

At the end of 90 minutes of running at the participants' 60-70% VO_{2max} and 0% incline, participants completed the TAT, where the treadmill was set at a 20% grade and the speed increased to 8 mph. The two measures of performance, or dependent variables, were the time the participant ran on the treadmill for the TAT and the distance traveled during the 90-minute treadmill run.

Rate of perceived exertion (RPE), heart rate (HR), blood glucose, lactate, and GI distress measurements were also obtained to better understand the effect of the beverages on how the participant felt and how the participant performed.

Hypotheses

1. The consumption of CW by participants will alter performance times on the TAT as compared to the water and CE beverage trials after prolonged exercise.

H0: There would be no difference between CW, CE, and water groups on the TAT.

H1: There would be a difference between CW, CE, and water groups on the TAT.

2. The consumption of CW by participants will alter distance traveled during the 90-minute run as compared to the water and CE beverage trials.

H0: There would be no difference between CW, CE, and water groups in distance traveled.

H1: There would be a difference between CW, CE, and water groups in distance traveled.

Operational Definitions

The following is a list of operational definitions used throughout the paper.

- **Coconut water (CW) trial**: Subjects ran on a treadmill at 60-70% VO_{2max} for 90 minutes and at 15-minute increments received 8 oz of CW (Coco5, Chicago, IL) to consume. Following the 90-minute run, subjects immediately began the TAT.
- **Carbohydrate electrolyte (CE) beverage trial**: Subjects ran on a treadmill at 60-70% VO_{2max} for 90 minutes and at 15-minute increments received a 12 oz solution of 8 oz of a CE beverage (Gatorade, Chicago, IL) and 4 oz of filtered tap water to consume. Following the 90-minute run, subjects immediately began the TAT.

- **Distance traveled**: The distance in miles the participant ran during the 90-minute 60-70% VO_{2max} trial portion. The distance in miles was one of two performance dependent variables.
- **Water trial**: Subjects ran on a treadmill at 60-70% VO_{2max} for 90 minutes and at 15-minute increments received 8 oz of filtered water to consume. Following the 90-minute run, subjects immediately began the TAT.
- **Treadmill anaerobic test (TAT)**: Subjects ran until exhaustion at an incline of 20% and speed of 8 mph. The time until exhaustion was the TAT time, or one of the dependent variables.
- **VO_{2max}**: The maximum amount of oxygen taken up by the body, which was measured through a treadmill test.[6] It is expressed in mL/kg/min.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

In terms of nutrition, there is a lot to consider in relation to exercise performance. Previous researchers have considered timing of nutrients in relation to exercise and physiological factors that influence food digestion, absorption, and transport, among other topics. CHO have been studied more extensively than other macronutrients due to their primary role in extending endurance exercise, as a source of energy, and in their function as a main constituent of the diet.[6,9,29] In order for elite athletes to be able to perform their best, caloric content, macronutrient, micronutrient and water intake should be individualized. The purpose of this literature review is to discuss the beverages to be used in this study and key areas related to exercise performance including CHO, electrolytes, and hydration status.

Exercise Performance in General

Fatigue in prolonged aerobic exercise is considered to be related to a decrease in blood glucose, depletion of the body's glycogen stores, dehydration or sweat losses.[18,23] Additionally core temperature needs to be maintained, as inadequate hydration can deleteriously alter exercise performance by altering sweat capacity and compromising the body's ability to dissipate heat.[30] During exercise, endogenous glycogen stores are oxidized and used first from the liver and muscle. The body can only store a limited amount of glycogen, and in prolonged exercise, endogenous sources may become depleted thus decreasing the blood glucose level and muscles' ability to contract. Consuming exogenous glucose delays use of endogenous muscle and liver glycogen stores, reduces gluconeogenesis, and hence delays hypoglycemia.[23] Wu and Williams[31] attribute the maintenance of blood glucose concentration to better endurance capacity in running trials.

Glycogen, the stored form of glucose, can be broken down through metabolic pathways to yield ATP energy which allows muscles to contract.[29] In glycogen-compromised individuals, a carbohydrate supplement helps increase blood glucose levels and delays the utilization of glycogen stores. Considerations for an appropriate performance supplement include the quantity of the product, the time it takes for digestion to occur, and how long it takes for the product to be absorbed and assimilated into the bloodstream for use.[23]

Exercise and the corresponding muscle contractions produce heat, which increases core temperature that can be transferred to the skin and dissipated via sweat to the environment.[5] Sweat rates vary from individual to individual, depending on factors like body weight, genetics, metabolic rate, exercise, and environment.[5] The main electrolytes lost in sweat are sodium and potassium, averaging ~35 mEq/L and 5 mEq/L respectively, along with calcium, magnesium, and chloride.[5] Water and electrolytes need to be replaced to prevent dehydration. This is often the basis of sports drinks or electrolyte replacement beverages.

Overview of Carbohydrates (CHO)

CHO are one of the three macronutrients in human nutrition, along with protein and fat. They are composed of carbon, hydrogen, and oxygen and are found in foods like sugars, starches, and fibers.[29] All CHO are converted to glucose, the simple six-carbon monosaccharide sugar, and either used immediately or stored as glycogen (a polysaccharide, or many glucose molecules linked together) in the liver or muscle.[6,29] Glucose is broken down through a series of chemical reactions called glycolysis to adenosine tri-phosphate (ATP), a high-energy compound.[6,29] CHO are a main source of energy for the body and the brain.[6,29] Decreased glucose is especially costly in the brain and central nervous system, resulting in weakness, dizziness, fatigue, low blood glucose (hypoglycemia), and decreased exercise performance.[6,32,33]

The body can only store a limited amount of glycogen in the liver and muscles. Authors typically report somewhere between 2,000-2,600 calories worth, which for low-intensity exercise like distance running can last for up to 90 minutes.[6,32,34] This can be divided approximately into about 400 grams of glycogen in the muscles, 90-120 grams in the liver, and about 25 grams in blood circulation.[6,32,35] This limited storage capacity and the significant role of CHO as an energy source can thus potentially limit performance. Exercise depletes the body's glycogen stores and thus they must be replaced by exogenous food or beverage sources. Because of their key role in energy and thus exercise, CHO are often studied in order to better understand and optimize performance.

Carbohydrates in the Context of Exercise

CHO have long been known as a nutrient that provides energy and fuel for the human body. It is typically recommended that CHO be the highest percentage of the total calories consumed as compared to other macronutrients. Athletes have long realized that they need to fuel their bodies appropriately, and even since the 1920s, people have thought ingesting CHO during exercise could improve endurance performance.[15] Early in the 20th century, subjects in one study reported exercise was easier if they had consumed a high-CHO diet instead of a high-fat diet.[36] Another study in 1923-1924 tested blood glucose levels of runners at the Boston Marathon and found low levels after the race, hypothesizing that the glucose depletion was a source of fatigue.[37] One year later at the same race, the researchers provided a CHO supplement during the marathon to the same runners, and this improved performance by preventing signs of hypoglycemia.[37]

The varying of monosaccharides (CHO building blocks) in carbohydrate supplementation has been a recently studied topic. Glucose has been an ingredient in Gatorade or other CE beverages since their inception. Fructose, maltodextrin, and sucrose have also been explored as alternative sources of energy because these CHO are transported via different carriers in the body. In the intestine, glucose is absorbed by the sodium-dependent glucose transporter SGLT1, although research suggests it can become saturated and reaches a point of maximum absorption, thought to be 1g/min or 60 g CHO/hr.[15,38] Fructose uses a different transporter, known as GLUT5, so the mechanism for absorption is different and thus provides another avenue for exogenous carbohydrate absorption and more use in exercise.[15,38] Currell and Jeukendrup[15] measured eight cyclists' performances based on various transportable CHO. The ingestion rate of a glucose-fructose blend resulted in 8% higher power output compared to glucose alone, reflecting the mechanism of a saturated SGLT1 transporter for glucose, where exogenous CHO after a certain point do not result in oxidation, use, and absorption.[15] Thus in recent proposed guidelines by Jeukendrup,[38] the CHO intake recommendation for ultra-endurance exercise is 90 g CHO/hr of multiple transportable CHO (i.e., glucose and fructose).

With strictly glucose, it appears that ingesting greater than 2 g/min does not result in better performance because of the glucose absorption limit; however, using different transporters (i.e., blending glucose and fructose), carbohydrate ingestion can be increased over 2 g/min.[15,38]

The more the exogenous sources can be supplied and maximally used decreases the amount used from endogenous sources which are limited in the body. The use of liver glycogen stores appears to be limited with this glucose-fructose ingestion because fructose is taken up by the liver. This works well with the previous studies and research that shows maintaining plasma glucose levels delays fatigue, especially in exercise greater than two hours, when hypoglycemia is more likely.[9,34,38]

The exact mechanisms by which CHO act in exercise environments are complex. With a variety of forms of exercise, intensities, durations, and nutrition support available, this makes it more difficult for researchers to explain consistencies in CHO use, mechanisms, and performance in these different situations.[33] Discussion about CHO ingestion decreasing fatigue, maintaining oxidation rates, sparing muscle glycogen, decreasing exercise-induced strain, protecting cell homeostasis and electrical components of muscle have been explored, but the complex nature of exercise with numerous cells involved needs further exploration.[33] In the development of sports drinks, companies have to consider the source of the CHO (glucose versus fructose) and the manufacturing and marketing process when formulating their product.

Overall, most research points to the usefulness of CHO in extending exercise by keeping blood glucose levels elevated, thus delaying fatigue.[7,9,31,34,38] The maintenance of CHO levels allows for high CHO oxidation rates throughout exercise.[39] With many authors showcasing the value of CHO, athletes and sports dietitians can make educated decisions on their use. Researchers also need to consider how the CHO affects the gastrointestinal (GI) tract, satiety, and feeling during exercise. Jeukendrup's review[38] suggests that nutritional training is recommended and that, upon review, the gut may be trained for increased CHO absorption capacity.

Importance of Proper Hydration

Exercise which causes heavy sweating can lead to fluid losses in excess of 1-2 liters per hour.[4,14] As little as 1-2% of body mass lost to dehydration has been reported to result in an elevated heart rate, core temperature, rate of perceived exertion, and plasma osmolality.[4,5,40] The dehydration can also result in thermal stress, impaired cognition, accelerated fatigue, and impaired exercise performance.[2] The replacement of these losses is necessary for optimal cardiovascular function and thermoregulation. Additionally, if more exercise is to follow or one is in hot and/or humid conditions, fluid replacement is even more important. Plain water may not be the most effective recovery drink, as the addition of electrolytes, especially sodium, can stimulate thirst and thus promote fluid consumption.[14] Consequently, recommendations encourage water for short durations of exercise, and the ACSM recommends a sports drinks with CHO "during high-intensity exercise longer than one hour as well as lower-intensity exercise for longer periods."[2,3,5,34]

Rehydration after exercise requires replacement of fluid volume and electrolytes lost in sweat, especially sodium. The results of sodium supplementation studies on exercise performance have been mixed. Cosgrove and Black found no effect on plasma sodium concentration after a time trial performance using various levels of salt supplementation.[26] Their study of men and women found no difference in finish time between the placebo and sodium intervention trials. However, other studies have found some benefit in supplementing before and during exercise on the maintenance of plasma sodium levels.[41]

Minshull and James found that hypohydration as a result of inadequate fluid intake could potentially decrease neuromuscular performance capability, increase levels of fatigue, and slow the rate of muscle force production in a vulnerable joint position.[42] Another study by Smith, Newell, and Baker found that acute mild dehydration has an effect on cognitive performance in a golf test.[43] Likewise, in basketball, Dougherty, Baker, Chow, Kenney found that basketball skill and drills performance decreased significantly with 2% dehydration reflecting mental alterations as a result of dehydration.[44] Other studies have shown the importance of hydration in relation to performance, including Logan-Sprenger, Heigenhauser, Killian, and Spriet, who subjected participants to 120 minutes of cycling at 65% VO_2 peak with or without fluid.[40] For those who had no fluid, dehydration symptoms only became intensified throughout the trial, including increased heart rate, increased core temperature, increased lactate content, increased body mass loss, and increased carbohydrate oxidation.[39] These results indicate that dehydration deleteriously affected exercise performance and metabolism, and replenishment of fluids during exercise is necessary in a wide variety of activities, movements, and durations.

Hydration status is a primary factor that contributes to fatigue in sports and exercise performance. Dehydration decreases plasma volume, which may compromise blood flow and thus oxygen and energy to muscles.[20] Further, the decreased blood flow to the skin correspondingly decreases the dissipation of heat and sweat, potentially increasing core temperature.[5,19,20] Wong and Chen found CE beverages are more effective at restoring fluid balance than lemon tea or distilled water after exercise-induced dehydration in a study of thirteen males.[19] The beverage containing CHO predictably elevated blood glucose levels back to a normal range. The CE beverage also produced the least diuretic effect and significantly expanded the fluid content of the vascular space of cells compared to at rest, potentially due to enhanced fluid retention because of greater intestinal water absorption stimulated by the presence of CHO and sodium.[19] These authors show another angle of how CHO supplementation can be beneficial in exercise, but it still relates to the same mechanism of optimal blood glucose levels and maintenance of those instead of depleting glycogen stores. Again, the same conclusion was reached by Hulston and Jeukendrup: that blood glucose was significantly higher throughout exercise when a CE beverage was consumed as compared to water or a placebo.[17]

Osmolality may also be important to consider, as lower osmolality may restore glycogen in muscles at a faster rate, seen in Aulin, Söderlund, and Hultman.[7] Most of the research currently published consists of small sample sizes; larger studies could possibly yield less potential error and more convincing data. Further, most of the studies have been completed on males only, using cycling or running. Other forms of aerobic exercise and the use of female subjects could also provide different sources of data to either confirm or reject the mechanisms proposed. Females are often studied less because body-weight baseline levels fluctuate with menstruation cycles and affect body-water status.[5] Further, women typically have lower sweat rates and lower electrolyte losses than men, which would need to be considered.[5]

Especially during prolonged exercise when hydration is extremely important, athletes sometimes do not want to drink or do not feel like drinking whether due to fatigue, GI distress, access, taste, or other factors. Sports and nutrition professionals need to be aware of what motivates athletes to consume fluids and can use sweetened or flavored beverages to make water more palatable or appealing to the athletes. Passe, Horn, and Murray found that a flavored, sweetened beverage (a 6% CE beverage) that was an acceptable flavor to the subject resulted in significantly more voluntary fluid intake as compared to plain water during 90 and 180 minutes of exercise.[45] When creating or recommending beverages, it is important to consider physiological needs, environmental conditions, taste preferences, and palatability.[46] Taste and palatability are especially important because if an athlete does not like the taste of a product, then they will not consume it.

Coconut Water

CW, the clear liquid from young green coconuts, has long been known for roles in traditional medicine in other countries, hydration, and potential benefits in helping to treat ailments related to oxidative stress like infections, kidney and liver function, diabetes and other conditions.[47] One review found CW with the potential to decrease hypertension and increase cell proliferation.[48] Yong, Ge, Ng, and Tan also considered CW as having anti-aging and antioxidant properties, anti-platelet properties and potential cardioprotective benefits, and potential anti-cancer properties.[48] Of relevance to this study, CW may be able to replenish the body's electrolytes typically lost in sweat and rehydrate similar to a CE beverage or sports drink because the CW's electrolyte levels.[2,14,20,47]

CW contains sodium, potassium, chloride, and glucose – making it an "optimal" rehydration fluid, even used in patients needing oral rehydration due to fluid loss, diarrhea, or GI dysfunction.[14] As noted in Kalman, Feldman, Krieger, and Bloomer (2012), some studies have shown CW having similar hydrating effects to CE beverages.[2] For example, the researchers found that CW and water provided similar rehydrating effects to a CE beverage and there was no difference in treadmill exercise performance.[2] This is one of only a few studies to compare CW to CE beverages and is unique in that it considered not only hydration but also treadmill exercise as a measure of performance. The authors also gathered subjective GI measurements on thirst, bloatedness, stomach upset, and tiredness, and participants reported more stomach upset and bloating with CW post-dehydration and exercise, which is different than some other authors' conclusions.[2,14,20]

Saat, Singh, Sirisinghe, and Nawawi completed a study to compare CW, a CE beverage, and water on rehydration and restoration.[14] Participants exercised, became dehydrated, and then were given the various beverages in order to measure rehydration status and blood levels. The percent rehydration was similar in all trials, although the highest was CE beverages.[14] The rehydration status between the three trials and the percentage change of blood volume were not statistically significant; however, the serum potassium (K^+) concentration levels rose significantly in the rehydration period with CW at all intervals compared with water and a CE beverage. Plasma glucose concentrations were significantly higher in CE and CW trials after the 30- and 60-minute periods of rehydration as compared to water as well.[14] Additionally, fullness sensation and stomach sensation was also lower in CW. CW also caused less nausea, which is important in creating these rehydration beverages for consumers. With the CW trials resulting in less nausea, fullness, and stomach upset, this could be enticing to athletes who do not tolerate CE beverages very well. They concluded that ingesting a natural drink like CW is similar to drinking a CE beverage but with less deleterious gastrointestinal side effects.[14]

Pérez-Idárraga and Aragón-Vargas tested CW, water, a CE beverage, and a created potassium-rich sports drink in order to combine elements of both CW (high potassium) and CE beverages (high sodium).[49] All four beverages were tolerated well. The authors hypothesized that the new beverage would combine the best properties of each CW and CE and result in better hydration. However, the new created beverage did not result in improved hydration, as measured by subjective scales, urine output, and fluid balance. This study used 12 "apparently healthy," physically active participants, ten males and two females, and thus was one of the few studies incorporating females.[49]

Ismail, Singh, and Sirisinghe similarly tested rehydration using CW and CE beverages.[20] However, these researchers nor those discussed in the previous paragraph evaluated exercise performance after rehydration periods; running was used as a way to dehydrate participants but not tested as performance measure. Ismail and colleagues also used a fluid sensation scale for participants to evaluate thirst, sweetness, nausea, fullness, and stomach upset on a 1-5 scale. They found that CW and a created sodium-enriched CW were as good as a CE beverage at rehydration after exercise-induced dehydration but with better fluid tolerance, similar to Saat, Singh, Sirisinghe, and Nawawi.[14] Pérez-Idárraga and Aragón-Vargas, and Kalman, Feldman, Krieger, and Bloomer, however, found CW performed the same or worse as CE beverages in terms of subjective GI measures.[2,49] Of these four key CW studies, mixed results exist on whether CW is better or equal to a CE beverage. Only one, Kalman and colleagues, used a performance component with running to evaluate the product.[2]

It is important to note, however, that the coconuts used to make the CW vary in nutritional content based on the maturity, region, year, season, soil, weather, and other environmental factors that may cause slight variation in amounts from study to study.[48] However, from these four studies with CW, researchers have shown that CW performs similarly to CE beverages in terms of rehydration, with mixed results on which one is more GI tolerated. Thus there are many areas for more research to be done with CW.

Carbohydrate Electrolyte (CE) Beverages

The most prominent CE beverage on the market today is currently Gatorade. Gatorade is a hypertonic beverage, containing the standard 6% CHO solution.[50] Gatorade contains 22mmol/L sodium, potassium, and chloride.[23,28,50] The reasoning behind the inclusion of sodium in such a product appears to be due to its role as the predominant electrolyte lost in sweat and in increasing fluid stores and thirst.

Much research has been completed at or sponsored by the Gatorade Sports Science Institute (GSSI) on beverages in relation to performance, similar to results listed above. Some research relating to CHO use as an ergogenic aid show increased CHO percentage in a drink corresponds to increased performance, up to a point, as cited in Coombes and Hamilton.[23] Further, GSSI has tested the composition of the CHO for exercise performance. Most sugar in CW is glucose (i.e., "natural"); however, it does contain less sugar than products like Gatorade, which has a glucose and fructose (crystalline fructose obtained from processing corn or sugar) blend.[51] Gatorade "Thirst Quencher" claims to replace fluid lost in sweat and provide carbohydrate energy to fuel working muscles.[28] GSSI also argues that sodium must be replaced during and after activity and highlights the National Athletic Trainers' Association (NATA) recommendations of 0.3-0.7 g/L sodium added to sports drinks for enhanced palatability and retention, to stimulate thirst, and to prevent hyponatremia.[28,52] Other research they list include that a typically active person can easily lose 32 oz of sweat per hour and 920 mg sodium per quart of sweat (2.3 g NaCl). To set it apart from water, Gatorade refuels athletes with CHO to give working muscles more energy to use and helps fight fatigue and in addition includes electrolytes lost in sweat which stimulates thirst so athletes stay better hydrated.[20,28,41,53]

Gatorade also uses a 6% CHO solution, which some studies confirm as within the optimal solution range (6-8%) for hydration and performance.[5,34] For example, one study found 12- to 15-year-old basketball players improved performance and accuracy when hydrated with 6% CHO versus water.[44]

Rate of perceived exertion (RPE) is a way to measure how people feel during exercise. As one works harder, the RPE score typically increases as one exerts more energy. One study by Utter et al. found that male cyclists who consumed a 6% CHO beverage had lower RPE scores than those who consumed a placebo beverage.[52] These authors defined perceived exertion as the "subjective intensity of effort, strain, discomfort, and/or fatigue felt during exercise."[52] However, this was done with intermittent cycling exercise and recovery, and the current study used a continuous aerobic running protocol. For this research, RPE was measured on a standard 0-10 point scale similar to other studies (0 being extremely easy, 10 being extremely hard).

According to a *Sports Medicine* journal review and NutritionCalcPlus 3 software (2008, McGraw Hill Education, Columbus, OH) software, the approximate comparison of CW and Gatorade per 250 mL (~8.45 oz) serving is as follows in Table 1.[23,53] However, variations occur, especially on the CW, depending on the brand, where the coconuts were grown, the year, season, soil, the age of the harvested coconut, etc.

A review by Yong, Ge, Ng, and Tan considering the chemical composition of CW generally agrees with Table 1.[48] Additionally, these authors also considered the specific sugars contained in CW: sucrose, glucose, and fructose. The total grams of sugar varied from type of coconut (mature vs young) and location (Florida vs Dominican Republic). Further, the amounts and proportions of each sugar also varied, which potentially can be absorbed differently once in the body.

Table 1

CW and CE Beverage Comparison

	Calories	CHO (g)	Sugar (g)	Sodium (mg)	Potassium (mg)	Chloride (mg)	Calcium (mg)	Magnesium (mg)	Phosphorus (mg)
Gatorade	53-63	15	14	103-116	30	1	2	0	24
Coconut Water	46-48	9	6-10	25-266	515-634	118	60	63	51

Electrolytes

The main electrolyte lost in sweat is typically sodium (Na^+). Without adequate Na^+ replacement postexercise, a Na^+ imbalance can lead to hypohydration, hyponatremia (low Na^+ blood levels), and/or cramps.[5] Because of this Na^+ loss, especially in heavy sweaters, some argue that Na^+ replenishment is more important than any other electrolyte; thus with CW lower in Na^+ and higher in potassium (K^+) than average CE beverages, logic suggests CW may not be ideal. Heavy sweaters may lose more Na^+, which could not be supplied from CW.

Na^+ intake during exercise may help prevent Na^+ losses from sweat that can lead to hyponatremia, cramps, fluid imbalance, and electrolyte problems.[5] Anastasiou et al. found that Na^+ intake during three hours of exercise in the heat helped to prevent Na^+ losses when fluid intake matched sweat losses.[41] This is important, as other studies, such as Horswill et al. found football players who were prone to cramps experienced a decline in Na^+ levels and had a greater Na^+ imbalance than those without cramping history.[54] While more research is necessary, Na^+ as an electrolyte does play a role in cell and fluid balance and is important to consider as a facilitator of water absorption through the intestinal wall.[4] However, Gisolfi, Lambert, and Summers found that the Na^+ amount in beverages did not make a difference in the intestinal fluid absorption or the plasma volume.[55] Campbell, Prince, Braun, Applegate, and Casazza found that during cycling time trials, serum sodium and potassium levels remained similar throughout all CHO treatments (sports beans, sports drink, gel, and water control), within normal ranges and not statistically significant.[9]

Similar to Saat, Singh, Sirisinghe, and Nawawi,[14] Ismail, Singh and Sirisinghe explored rehydration with CW, a sports drink, and plain water. However, they added sodium-enriched CW as a fourth beverage in the trials, which had added sodium chloride to match the amount of sodium in the sports drink.[20] Male subjects ran at 65% VO_{2max} for 90 minutes so that they lost 3% of their body weight and then went through a 2-hour rehydration period, where one of the four beverages was consumed totaled 120% of body weight lost.[20] The authors found significantly better rehydration with the sports drink and the Na^+-enriched CW.[20] Further the use of a “fluid sensation scale” helped the researchers notice that the sodium-enriched CW was similar in sweetness to regular CW and the sports drink but interestingly caused less nausea and stomach upset than the sports drink and plain water. The authors concluded that the Na^+-enriched CW was as good as a sports drink for rehydration after exercise-induced dehydration but was better tolerated.[20]

There is also discussion on the role of a balance of K^+ and Na^+ because K^+ is the major intracellular cation and Na^+ is the major extracellular one; together both could help restore intracellular and extracellular fluid balance.[49] K^+ is lost during exercise through sweat, but in much smaller amounts than Na^+.[20,49] Pérez-Idárraga and Aragón-Vargas created a new sports drink with the K^+ content of CW and the Na^+ content of a standard sports drink and tested the rehydration ability against CW, water, and Gatorade.[49] In rehydrating at 120% body weight loss equivalent volume, the new beverage did not show any increased benefit over the other three and no difference in net fluid balance.[49] Pérez-Idárraga and Aragón-Vargas’s findings on the better tolerance of CW than CE beverages were different than Saat, Singh, Sirisinghe, and Nawawi and Ismail, Singh, and Sirisinghe; the latter two found CW more tolerable to subjects.[14,20,49] Further, like Saat and colleagues, Pérez-Idárraga and Aragón-Vargas found no significant differences in fluid retention between plain water and CW; however, Ismail, Singh, and Sirisinghe (2007) did.[14,20,49] The differences in sample size and location may contribute to the discrepancy, but there is still more research to be done.

Relationship Between Supplementation Beverages and Performance

CW has not been widely proven to be successful in enhancing exercise performance. Components such as rehydration have been shown to positively relate, but there is limited knowledge on overall performance effect from CW. However, research points to the benefit of CE beverages in exercise over 60 minutes. In prolonged and intermittent exercise (1-4 hours), evidence points to performance benefits in the use of a CHO supplement beverage because of mechanisms such as preventing hypoglycemia and delaying onset of fatigue.[2,15,23] There is not however adequate research on specific brands and current products to say one is superior over another, but overall CHO beverage solutions under 10% have shown the most benefits.[23] Other studies suggest 6-8% is best in order to minimize GI symptoms, which can be important, especially in prolonged exercise situations.[5,34] CW does contain some of the same nutrients that CE beverages contain and thus there are potential research opportunities to explore the benefits of CW, if any. Of the few CW studies completed, some authors examined GI distress and found CW more tolerable than a sports drink (Ismail, Singh, and Sirisinghe) while others did not (Kalman, Feldman, Krieger, and Bloomer).[2,14,20] Pérez-Idárraga and Aragón-Vargas found no difference between the beverages in palatability and tolerance; however, CW was ranked significantly sweeter than water, CE beverage, and a created potassium-rich sports drink.[49]

Summary

Overall, many authors have examined exercise performance in their research, although that relating to sports nutrition and supplementation is still evolving. There is a significant amount of work completed in the CHO area, reflecting support for CE beverages in endurance exercise; however, alternatives to CHO, including CW, are relatively new and still being explored.[2,15,23] While CW has shown some positive benefit in rehydration and electrolyte balance, it has yet to be consistently shown to improve exercise performance. Different types of beverages with different CHO and electrolyte content are seemingly related to performance in sport, although mechanism and proportions are not fully known. For example, the role of electrolytes, specifically the balance of Na^+ and K^+ as found in CW, could be an area for future research. CW contains these electrolytes in different amounts than typical sports drinks, and the differences may or may not improve exercise performance. Further, GI distress and palatability of beverages, which are important to athletes, may be different between CW and CE beverages. Research on this topic would allow consumers the opportunity to make a more educated and personalized choice.

CHAPTER III

METHODS

Subjects

Twenty-one physically active males aged 18-45 were recruited by posting flyers (Appendix A) within a 50-mile radius of the Northern Illinois University (NIU) campus. Fifteen of the 21 met all criteria for participation, including being of low cardiovascular risk based on ACSM guidelines and meeting VO_{2max} criteria.[56] Subjects were required to be non-smokers, run at least three times per week, have at least three years of running experience, and be comfortable performing treadmill exercise. Participants' health and exercise readiness were assessed using a medical history questionnaire (Appendix B). Participants had to be willing to participate in four running trials: one VO_{2max} and three experimental trials in a span of approximately two to four weeks. Those with more than one positive cardiovascular risk factor according to the ACSM guidelines (Appendix C) were excluded.[56] Cardiovascular risk was determined to be low if the participants answer "No" to all questions in Part I (known disease), "No" to all questions in Part II (signs and symptoms), no more than one "Yes" in Part III (coronary artery disease risk factors), and "No" to all questions in Part V (specific protocol). The principal investigators interpreted general information in Part IV to determine if exclusion was warranted, such as if they had food allergies. Those with confirmed tree nut allergies and any potential participant with electrical implants such as defibrillators or pacemakers were excluded. All subjects were informed of the risks and benefits associated with the investigation and gave written consent

(Appendix D) to participate in accordance with the Institutional Review Board (IRB) at Northern Illinois University prior to participation in the study.

Experimental Design

This study used a double-blind crossover repeated-measures ANOVA design to assess participant exercise response to CW. Subjects received all supplement beverages but in random order. The beverages were prepared by a non-biased third party and thus were blind to both participants and researchers. Trials were spaced at least 48 hours apart for the study.

Preliminary Screening

The preliminary screening using a VO_{2max} test was to determine if participants were in the excellent or superior fitness classification for their age group, based on ACSM guidelines.[56] Interested participants were asked to complete a medical history form and confirm that they were eligible and capable of performing the tasks required in this study. This included questions about food allergies, running experience, current exercise regimen, and age. Those who had food allergies, less than three years running experience, ran less than three times per week, or were outside of the 18-45 age range were excluded. Participants were asked to report to the research lab in athletic apparel, including adequate running shoes. Anthropometric measurements (height, weight, percent body fat) were taken in light clothes and bare feet using an InBody520 body composition analyzer (Cerritos, CA) and SECA 220 stadiometer (Germany), along with demographic information (Appendix E) completed by the primary researcher. Each participant was required to stand for at least 15 minutes prior to the InBody measurements to acquire proper fluid balance. Therefore, the participant completed the demographic information while standing up.

Participants were explained the risks and benefits of the study, and if consent was obtained, the participant was asked to complete a maximal oxygen uptake (VO_{2max}) test to establish a baseline for the participant to be used later in the trials when they were asked to run at 60-70% their VO_{2max}.

VO_{2max} Protocol

A maximal oxygen uptake (VO_{2max}) test was performed on a motor-driven treadmill (Woodway Treadmill, DESMO, Waukesha, WI) when the participant first came in and after consent and medical history forms were completed. The participants took part in a modified Balke test where subjects were connected to a Parvo Medics Trueone 2400 metabolic cart (Sandy, UT) to determine their VO_{2max}. Subjects also wore a Polar FT2 heart rate chest band along with a T31 coded watch to monitor heart rate during trials. The researchers explained the entire process to participants before testing began. The principal investigators had three minutes to increase or decrease treadmill speed at 0% incline in order to get the participant's RER between 0.85-0.90. Once this was reached, testing continued and every two minutes the incline of the treadmill was increased by 3% (2%, 5%, 8%, 11%, 14%) while speed remained constant. Participants were asked to run as long as they could (until volitional fatigue) and to straddle the treadmill when they felt they could no longer run. If the subject reached the 14% incline level, they continued to run for as long as they could at that incline until volitional fatigue. Researchers collected heart rate, RER, and VO_2 measurements at regular intervals throughout the trial. VO_2 was determined by averaging the values obtained during the final two minutes of exercise.

Immediately after completion of the run, blood was drawn for lactate measurements using disposable Accu-check, Safe-T-Pro lancelets, and analyzed using the YSI 2300 from Yellow Springs Instrument Company (Yellow Springs, OH). Criteria for attainment of VO_{2max} were at least two of the following: blood lactate of 8-9mmol, +/- 5 bpm of predicted maximum heart rate (220 - participant's age), a leveling off of VO_2 showing the participant was unable to take in a larger amount of oxygen, or a RER greater or equal to 1.1, according to the ACSM's Exercise Testing and Prescription Guidelines.[56] VO_{2max} was recorded as the highest 15-second average prior to volitional exhaustion and was expressed in relative terms (ml/kg/min).

Experimental Sessions

On all testing days, participants were asked to report in comfortable and appropriate running attire and shoes and follow established protocol regarding abstaining from intense exercise 24 hours prior and food two hours prior. All participants were given a choice of two standard meals consisting of approximately 870 calories and 136 grams CHO. They were asked to consume either one of the meals on their own at least two hours prior to reporting for their trial (see Table 2).

Anthropometric data was collected in light exercise clothing and bare feet. This included height using a SECA 220 stadiometer (Germany) and an InBody520 body composition analyzer (Biospace Inc.,Cerritos, CA) for weight and percent body fat. Just as with the VO_{2max} testing protocol, participants had to remain standing prior to InBody analysis, so paperwork and instruction was provided while standing. Participants also submitted the required 24-hour food recall (Appendix F) to the researchers at their report time. Participants were asked to not make any changes to their regular diet or exercise plans for the duration of the study. Nutrition data was analyzed using NutritionCalcPlus 3 software (McGraw Hill Education, Columbus, OH).

Table 2

Standardized Pre-trial Meals for Participants

		Calories	CHO (g)	Protein (g)	Fat (g)
Meal 1	2 slices whole wheat bread with 2 tbsp peanut butter, 2 tbsp strawberry jelly 18 wheat thin crackers 1 oz mozzarella string cheese 6 oz low fat yogurt 1 apple 8 oz water	884 calories	130 g	35 g	29 g
Meal 2	1 flour tortilla (8”) with 2 slices turkey, 1 slice cheddar cheese, 1 piece green leaf lettuce, 2 slices tomato, 1/5 of an avocado, 1 oz honey mustard 1 cup grapes 1 clementine orange 18 fat free pretzel twists 3 rice cakes with 1 tbsp honey 8 oz water	866 calories	135 g	37 g	23 g

In each trial, participants consumed either local filtered tap water, CW, or a diluted CE beverage as the supplement blinded to the subjects and researchers. The trials were in randomized order; CW and CE beverages were matched in color and taste and were served in opaque containers for consumption so neither the researchers nor the participants could tell what the beverage was. The CW and CE beverage were closely matched in CHO and calorie content:

12 oz CW contained 60 calories and 12 g CHO while the diluted CE solution was composed of 8 oz CE beverage and 4 oz water, which contained about 53 calories and 14 g CHO as seen in Table 3. Beverages were prepared in advance by a non-biased third party.

Table 3

Comparison of CW and CE Beverages Used in This Study

	Coconut Water (12 oz)	CE beverage (8 oz CE + 4 oz water)
Calories	60 Calories	~53 Calories
CHO (g)	12 g	14 g
Sodium (mg)	90 mg	~107 mg
Potassium (mg)	120 mg	30 mg

Participants completed a 90-minute run at a 0% incline and the investigator's choice of appropriate speed which corresponded to 60-70% VO_{2max}. Participants were connected to the metabolic cart (Parvo Medics Trueone 2400, Sandy, UT) and mask for the first three minutes to determine this appropriate speed. Once speed was appropriate, the mask was removed, and participants continued to run. For participants, the distance traveled, time, and speed on the treadmill digital display was covered to not influence behaviors. At two random points during the 90-minute run, researchers reconnected participants to the metabolic cart for approximately 3 minutes to check that the participant was running between their 60-70% VO_{2max}. During each random check, researchers adjusted the speed of the treadmill as necessary to maintain the 60-70% range. Researchers monitored compliance and recorded any changes in speed as they occurred (Appendix E). Trials took place in normal environmental conditions. At 15-minute intervals, participants were asked to step off the moving treadmill belt ("straddling" the treadmill). The participants were given 12 ounces of one of the three beverages (W, CW, CE dilution) and asked to drink all of it quickly (ideally 60 seconds or less) and to begin to run again, for a total of 60 oz of fluid during the trial. Heart rate and rate of perceived exertion (RPE) were also be recorded (Appendics E & G). This occurred at the 15-minute mark and continued at the 30, 45, 60, and 75 minute marks. At the 90-minute mark, the participant straddled the treadmill belt but did not drink any beverage. Also collected at baseline and the same 15-minute intervals were the blood samples via a standard protocol for blood glucose and lactate levels. All samples consisted of approximately 5 microL drawn from the pads of the fingers via a disposable lancet device and collected in a capillary tube. Blood glucose and lactate levels were analyzed using the YSI 2300 (Yellow Springs Instrument Company, Yellow Springs, OH). A total of 30 finger pricks were made over all the experimental trials at baseline, 15 min, 30 min, 45 min, 60 min, 75 min, immediately post-TAT, 5 min post-TAT, 10 min post-TAT (10 per session, three sessions) plus 1 pre and post VO_{2max} test for a total of 32 over the entire study.

Immediately after measurements were completed at 90 minutes, including distance traveled, the researcher raised the treadmill to 20% incline and set the speed at 8 mph for the TAT. The participant ran on that set treadmill for as long as they could, and the time was recorded. Immediately following the TAT, and 5 and 10 minutes of rest after the TAT, heart rate and RPE were collected. After completion, participants were encouraged to consume food and beverage to aid in recovery and were dismissed once stable. They were not debriefed nor were results discussed with them until all three experimental trials were completed for all twelve subjects. The same protocol was repeated for the other two beverage trials.

Data Collection

The PARVO metabolic cart provided the VO_{2max} values during the two random checks during each trial. The gas analyzers were calibrated prior to each trial. RPE was measured by asking participants to indicate a current level of perceived exertion and intensity on a scale (Appendix G). GI distress measurements were measured by asking participants to indicate current level of thirst, bloatedness, nausea, fullness, and stomach upset on a scale (Appendix H). TAT performance test times were measured in seconds. Heart rate was measured in beats per minute from a Polar monitor device that was strapped around the participant's chest for the duration of the trial. Distance traveled was measured in miles to the one-hundredths place, and collected from the treadmill display (Appendix E).

Statistical Analysis Plan

Descriptive measures were analyzed using a one-way analysis of variance (ANOVA). A repeated-measures ANOVA was conducted on the three variables (W, CW, CE beverage) to determine if there were any differences between TAT running times and distance traveled. Further, an independent-samples *t* test was conducted specifically between the CHO-containing beverages (CE and CW). Significant mean differences were analyzed using pairwise comparisons or contrast testing. The type I error was established *a priori* at $p < 0.05$, which was consistent with similar studies. The power, or type II error rate, was established *a priori* at ≥ 0.80. All data are presented as means ± standard deviations (SD). Data were analyzed using the computer software program SPSS (version 22.0, Armonk, NY).

CHAPTER IV

RESULTS

Fifteen participants qualified for the study after passing the preliminary VO_{2max} testing, and of those, 12 participants completed the study. Two did not complete the study due to injury (occurred outside of the study) and one did not complete it due to scheduling conflicts. The physical characteristics of the subjects are provided in Table 4 below. Measurements are listed as mean ± standard deviation.

Table 4

Physical Characteristics of Subjects

Characteristics	Mean ± Standard Deviation (N=12)	Range
Age (years)	24.92 ± 6.76	20-45
Height (cm)	178.17 ± 5.39	166.0-184.0
Average Weight (kg)	76.50 ± 7.49	67.37-90.23
BMI (kg/m^2)	24.08 ± 2.35	19.95-28.16
VO_2max (mL/kg/min)	56.13 ± 5.33	48.73-65.35

Dependent Variable Analysis

Dependent variables, TAT time and distance traveled were analyzed as follows. Measurements are listed as mean ± standard deviation.

TAT times for each trial (water, carbohydrate electrolyte beverage, and coconut water) were measured and the means and standard deviations calculated. The means are charted in Figure 1. For the water trial, participants averaged 57.2583 ± 21.27 seconds, which was the highest average of the three beverages but also the largest standard deviation, meaning the results varied the most of the three beverages. In other words, the average distance from the mean was greatest with the large variation. The shortest time of any of the three trials was 19.81 seconds and that occurred in a water trial. The average TAT time for the CE beverage trials was 57.2108 ± 20.47 seconds. A CE beverage trial was the longest TAT of any of the three trials at 91.75 seconds. CW trials averaged a TAT time of 52.6225 ± 18.63 seconds, which was the lowest average but also the smallest standard deviation, as listed in Table 5.

Table 5

TAT Results

Beverage	TAT time (seconds) Mean ± Standard Deviation	Range (seconds)
Water	57.2583 ± 21.27	19.81-90.26
CE Beverage	57.2108 ± 20.47	24.81-91.75
Coconut Water	52.6225 ± 18.63	29.97-84.47

Distance traveled was also recorded as a measurement of performance, and the means and standard deviations are listed in Table 6. Participants ran the 90 minutes at 60-70% their VO_2max, and thus if they were more efficient in oxygen use, mileage would increase. The average distance run during the 90-minute water trials was 9.8208 ± 0.89 miles, during the CE beverage trials 9.9283 ± 0.83 miles, and with CW 9.9050 ± 0.84 miles. The CE beverage trial had the highest distance run average and the lowest standard deviation; however, all three means are within 0.1 miles of each other, as seen in Figure 2.

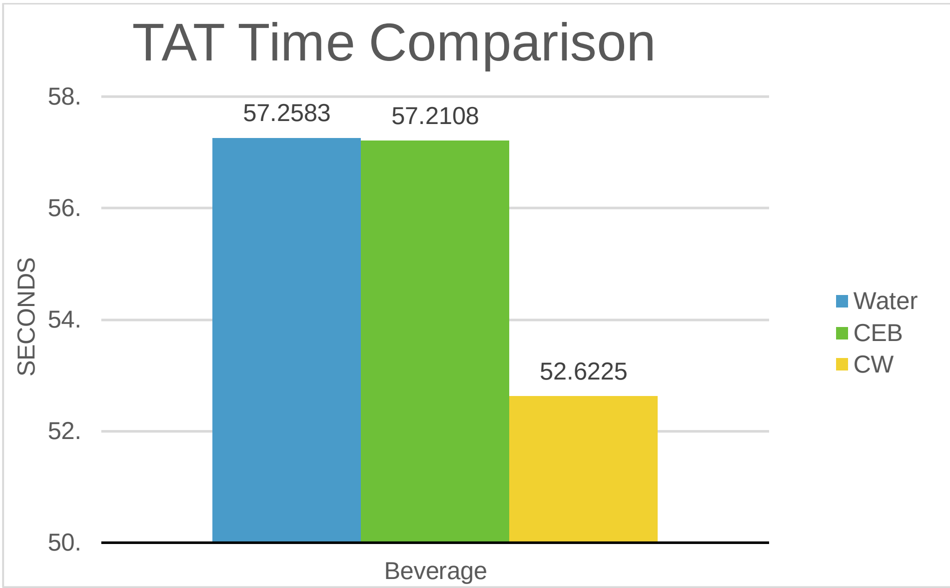

Figure 1: TAT time comparison between beverages.

Table 6

Distance Traveled Results

Beverage	Distance (miles) Mean ± Standard Deviation	Range (miles)
Water	9.8208 ± 0.89	8.81-11.55
CE Beverage	9.9283 ± 0.83	8.92-11.37
Coconut Water	9.9050 ± 0.84	8.74-11.42

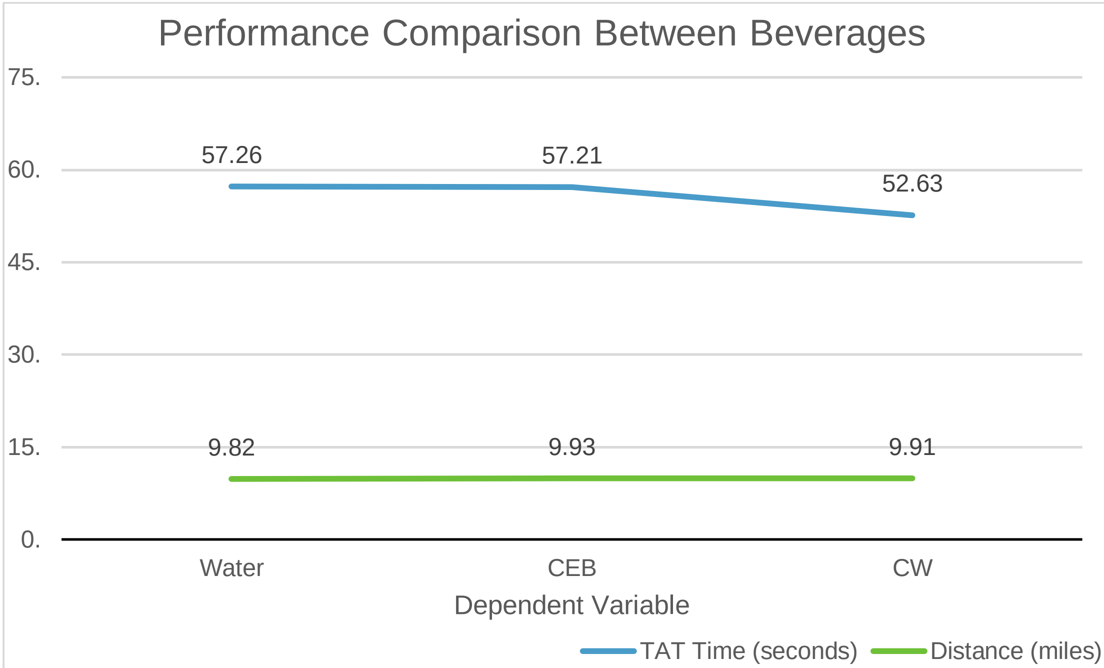

Figure 2: Performance comparison between beverages.

Statistical Analysis

First, data was analyzed to evaluate normality and sphericity. The normalcy of the dependent variables were checked due to the small sample size (N=12) and thus inability to assume normality. Normality was analyzed using skewness and kurtosis values, box plots, histograms, evaluating the mean against the standard deviation, and the Shapiro-Wilk test of normality. Skewness and kurtosis values of between -2.00 and +2.00 reflect a normally distributed data set. Box plots and histograms were evaluated for any outliers and traditional normal distribution appearance. The Shapiro-Wilk test was run with p values >0.05 indicating normality. Each variable met normality test criteria. Sphericity was evaluated using Mauchly's test of sphericity, again, where p values >0.05 are desired to allow for assumption of sphericity.

All variables resulted in p values >0.05, which meant that sphericity could be assumed and no correction factors were necessary.

A repeated-measures analysis of variance (ANOVA) was used to analyze the TAT performance times of the three beverages. This test was used to assess the within-subject effect of the beverage, in other words, whether the beverage affected performance time in each of the three trials. Each participant served as his own control because they completed all three trials. There was no significant difference in TAT time between the different beverages, as $p = 0.146$ with a power of 0.385. This means there was a 38.5% chance that the beverage was the reason for the effect on TAT time or that the beverage actually manifested its effect. In other words, there was about a 61% chance that an effect would not be manifested in this experiment due to a lack of statistical power. In order to more specifically compare the CE beverage and CW, an independent *t* test was performed between the two beverages. The *t* test resulted in a p value of 0.864, indicating no significant difference between the two beverages in TAT time. This is more specific for this study as the main purpose of the study was to compare CE and CW; water was used as a baseline control. These results indicate CW and CE beverage perform similarly.

Again, a repeated-measures ANOVA was used to analyze the distance traveled in miles during the 90-minute portion of each of the three beverage trials: $p=0.225$ (>0.05), indicating no significant difference in distance traveled between the beverages, with a power of 0.301. In addition, an independent *t* test was completed to directly compare CE and CW beverages, with a result of $p = 0.989$. Therefore, no significant difference between distance traveled exists between CE and CW. In other words, participants used oxygen with the same efficiency in both trials.

To confirm participants were eating similarly prior to each trial, 24-hour dietary recalls were collected at each trial and analyzed using a repeated-measures ANOVA for calories, carbohydrates, and protein in hopes of controlling for these nutrients so that nutrition status was not a confounding variable. The means and standard deviations are listed in Table 7. All sets of data were normal and sphericity was able to be assumed. No significant differences were noted between calories, CHO, or protein with any of the beverages.

Table 7

Nutrition Comparison Between Each Trial

Beverage	Calories (kcal/kg) Mean ± Standard Deviation	CHO (g/kg) Mean ± Standard Deviation	Protein (g/kg) Mean ± Standard Deviation
Water	41.24 ± 16.23	5.35 ± 2.05	1.57 ± 0.57
CE Beverage	42.39 ± 13.54	5.35 ± 1.81	1.81 ± 0.85
Coconut Water	37.03 ± 11.24	4.93 ± 1.66	1.81 ± 0.67

The data results are summarized in Table 8. Again, no significant difference was noted for any of the dependent variables (all p values were > 0.05). The observed F statistic values were not beyond the critical F values based on degrees of freedom, so we fail to reject the H0 and can conclude the population means (or the means from each of the different beverage trials) are equal. Thus from this study, water, CW, and a CE beverage can be considered equal for performance. It is noted that the power from each test was low, likely related to the small sample size, which makes it difficult to conclude the effect of the beverages on performance.

Table 8

Summary Statistics Table

	F statistic	P value	Power
TAT time	2.106	0.146	0.385
Distance	1.595	0.225	0.301
Calories	1.192	0.322	0.233
Carbohydrates	0.438	0.651	0.112
Protein	1.054	0.365	0.211

CHAPTER V

DISCUSSION

The purpose of this study was to examine the effects of CW on distance traveled during a 90-minute submaximal run followed by TAT performance times. Subjects randomly consumed water, CW, and a CE beverage during three separate trials to compare performance. The findings of this study suggest that consuming a CW beverage during running trials is just as effective as consuming water or a CE beverage based on distance traveled and TAT times.

The findings of this study concur with the findings of Kalman, Feldman, Krieger, and Bloomer[2] in which 12 participants who on four separate occasions completed a 60-minute run on a treadmill were rehydrated using water, CW, CW from concentrate, or a CE beverage and then completed a treadmill performance test (averaging 12 minutes) of increasing intensity until volitional fatigue. The subjects were blinded to the beverages they received, but not the researchers. No significant differences in performance times were noted between the four beverages.[2]

An unexpected finding in our study was that the group receiving the filtered tap water had TAT performance times and distance-traveled measurements equivalent to those receiving the CE and CW beverages. Although the findings of this study concur with those of Kalman and colleagues,[2] they are in direct opposition to the findings of Hulston and Jeukendrup.[17] Hulston and Jeukendrup had ten male subjects cycle for 120 minutes at 61% VO_{2max} followed by a 60-minute cycling time trial. Each subject served as his own control and was randomly assigned to consume a CE beverage or water (artificially colored and flavored to match the CE beverage).[17] Mean power output and performance times were significantly better for the CE beverage trial compared to the water beverage trial. However, this study used a cycling protocol and participants completed 120 minutes of glycogen-depleting exercise as opposed to 90 minutes running as in the present study.[17] In addition, the time trial to assess performance in Hulston and Jeukendrup's study lasted approximately 60 minutes as opposed to approximately 55 seconds in the present study.[17] The increase in exercise duration (>3 hours) would have totally depleted glycogen stores, whereas in the current study the TAT did not rely on glycogen stores. The TAT assesses anaerobic performance, while a time trial would assess aerobic performance. In aerobic exercise, more glucose is utilized as fuel and thus the CHO consumed during steady-state glycogen-depleting exercise may have added to performance. There were differences in the present study in terms of blood glucose levels between water and the CHO-containing beverages. The water trials resulted in lower blood glucose levels, but the glucose differences did not translate into TAT performance differences. An aerobic test with a time trial $\geq$ 60 minutes in nature may have yielded different results.

The participants in this study were comfortable running long distances and likely were well adapted to endurance exercise, as participants had to run at least three times per week to qualify. The 90-minute run may have not depleted glycogen stores completely, or the well-trained athletes (such as marathon runners) were potentially able to better utilize fat for oxidation. None of the runners were running at an intensity high enough for the 90-minute run to become predominantly reliant on CHO to fuel their working muscles. If participants had been asked to run longer and at a higher intensity, there may have been a more obvious difference between the CHO-containing beverages and water, with a likely continual decline in glucose with the water trial.

The discrepancies in results could also be due to the small sample size or variability in food intake. Food intake was controlled for by asking participants to not change their current diet regimen and submit 24-hour food logs prior to each trial (however, food was not provided to them). Hulston and Jeukendrup required a similar protocol with their participants.[17] Upon analysis, there was no significant difference between calories, CHO, or protein consumed with each trial, indicating adequate control of this variable.

Our study also assessed fluid tolerance with each beverage to evaluate potential GI distress differences among them. Previous research has yielded inconsistent results on whether CW or a CE beverage results in the same or different levels of distress. Ismail, Singh, and Sirisinghe[14] evaluated the same three beverages as the present study and, like Saat, Singh, Sirisinghe, and Nawawi,[20] did not include an exercise performance evaluation of the products. Rather, rehydration and gastrointestinal assessment were more the focuses of these studies. In both studies, running was used as dehydrating exercise, but no measures of exercise performance were evaluated, such as a TAT or cycling time trial. Thus the effectiveness of the beverages in terms of exercise performance was not assessed like in the present study. Ismail and colleagues assessed GI tolerance of the beverages and found CW to have more favorable results, which was similar to Saat and colleagues.[20] Both Ismail and colleagues as well as Saat and colleagues used the terms *thirst, sweetness, nausea, fullness, and stomach upset* to assess tolerance on a 1-5 scale.[14,20] CW caused less GI symptoms than a CE beverage, which would cause some participants to choose CW over CE for less GI distress during exercise. These researchers also found similar rehydration capabilities with CW compared to CE beverages and concluded that

CW is as good as a sports drink for rehydration.[14,20] This is in contrast to Kalman, Feldman, Krieger, and Bloomer[2] and Pérez-Idárraga and Aragón-Vargas[49] who found that CW was the same or in some categories worse than a CE beverage related to GI measures. Kalman and colleagues used thirst, bloatedness, stomach upset, and tiredness as their GI scale measurements, while Pérez-Idárraga and Aragón-Vargas used the terms *nausea, fullness, stomach ache, and urge to defecate* for their GI assessment.[2,49]

In our study, no significant differences were found between stomach upset, bloatedness, fullness, nausea, or thirst between water, CW, and a CE beverage. However, the studies mentioned above used slightly different measures/terms of GI tolerance so it is difficult to compare them directly to each other. The present study agrees with Saat and Ismail's work that CW can be used as a CE beverage or sports drink product. These studies allow athletes to choose based on what they are most comfortable with, knowing that either CW or CE will allow them to perform similarly. Palatability and GI distress are important considerations in creating these sports beverages. Passe, Horn, and Murray found that flavored beverages increased fluid volume intake over traditional water during exercise and thus flavor corresponded with palatability and appeal to exercisers.[45] Athletes also notice how beverages feel during digestion, the GI symptoms that result, and any negative performance effects that go along with it.

It is important to note the potential variability between beverages in the trials. This study used an industry-leading, popular commerical CE beverage and a specific brand of CW, whereas other studies used their own formulas of sports drink created exclusively for the study, the leading CE beverage in a different country, or other created products. For example, Pérez-Idárraga and Aragón-Vargas (2014) created an enriched sodium-potassium solution as one of their beverages in addition to testing water, CW, and a CE beverage for their study.[49] With CW, coconuts vary in nutritional content depending on the maturity, region, year grown, soil content, season, weather, and other factors.[48,57] This can alter the CHO composition of the beverage, and possibly absorption in the body due to the balance of fructose and glucose.[15,38] Sports drinks typically contain a combination of glucose, fructose, and/or sucrose blends, often processed (i.e., containing high-fructose corn syrup, maltodextrins, etc.) and with other additives while CW typically contains less additives and more natural sugars (glucose-fructose blend depending on coconut).[57,58]

The current study may have benefitted from further beverage nutrition composition to directly compare nutrients and percentage breakdown. The CW used in this study contained the natural sugars from coconut as well as rebiana, which is from the stevia plant, used as the sweetener.[12] The CE beverage contains "sugar, dextrose, citric acid, natural and artificial flavor...sucrose acetate isobutyrate," among other ingredients according to the nutrition label.[28] While the CE beverage is likely more consistent in composition, previous studies such as Vigliar, Sdepanian, and Fagundes-Neto suggest a range of sugar concentrations in CW depending on the coconut maturation: for example, glucose ranged from 34-45%, sucrose from 18-53%, and fructose from 12-36%.[57] The CHO source may affect absorption, as fructose and glucose utilize different transporters in the body. Glucose uses the SGLT1 transporter, which appears to have maximum absorptive capacity and threshold for optimal performance.[15,38] Conversely, fructose is absorbed using the GLUT5 transporter but is oxidized at a lower rate due to the conversion of fructose into glucose in the liver before metabolism can occur.[16] Thus sources of both glucose and fructose allow CHO to be absorbed from two different transporters and when combined in a beverage allows for higher rates of CHO oxidation.[16,38] Potentially the different ratios in the beverages would be processed in the body differently and allow for better performance, but that was not the case in this study. There was no difference in performance between CW and CE, so the assumption is that the CHO were utilized similarly in regards to fuel for exercise, or not enough CHO was provided to see a difference. It would be interesting for future research to better understand the specific CW product tested in terms of nutrient composition before testing.

While the CW and CE beverage were matched as closely as possible, the CE beverage did have 2 g more CHO per 12 oz and provided 56 g CHO/hour versus 48 g CHO/hour in CW. The latest recommendations for CHO replacement is 30-60 g/hour.[59] According to Jeukendrup's review, up to 90 g CHO/hr of a glucose-fructose mix (multiple transportable CHO) can be oxidized, and that potential was not reached in any trial.[38] CHO has been shown in previous studies to improve performance by conserving endogenous glycogen stores in the liver and muscle, sparing them for use at a later time. The ingested CHO can be used as fuel during endurance exercise and help maintain blood glucose levels, as discussed previously. Blood glucose in the CW and CE trials resulted in significantly higher glucose levels as compared to water, likely due to the CHO content. That threshold of 1-2g/min CHO was not met with the beverages in the current study (48 or 56 g/hr); therefore, potential performance benefits from CHO supplementation may not have been seen.

With recent research creating changes in CHO intake recommendations during exercise, a continued progression in the research will occur. In the most recent ACSM position statement in collaboration with the American Dietetic Association, 30-60 g CHO/hr is recommended if exercise is over 60 minutes, or 0.7 g/kg per hour.[59] However, with the use of multiple transportable CHO, it appears that increasing the amount per hour could further enhance exercise performance – up to 90 g/hr in exercise greater than 2.5 hours, as recommended in Jeukendrup's 2014 review.[38] Per these recommendations, this study's participants should have consumed

30 g/hr of single or multiple transportable CHO and had nutritional training for optimal performance with their 1- to 2-hour exercise bouts. The nutritional training component is important to allow for practice of nutrition strategies for competition to reduce the likelihood of any GI distress during competition and optimize absorptive capacity of the ingested CHO.[38] While the current study's participants consumed 48 and 56 g CHO/hr of CW and CE respectively, no difference was observed in performance following the 90-minute run. More nutritional training may have altered the performance outcomes if the participants had been more prepared to handle the larger amount of fluid and CHO provided.

CW is known for its electrolyte content, containing five main electrolytes compared to most CE beverages containing only two: sodium and potassium. One of the main reasons to consider CW as an alternative is based on the electrolyte content and more "natural" sugar. While this study did not link better performance to the alterations in electrolyte content, future studies could examine the specific electrolyte's role in sports performance. K^+ plays a role in muscle contraction and the logic is that it may impact performance in a positive regard if there is enough K^+ in the sports drink. Na^+ is also lost in sweat, so it is important to replenish that electrolyte after workouts. Further, Na^+ is involved in transporting some glucose via the SGLT1 transporter on the basolateral membrane, as Na^+ creates a concentration gradient for transportation. CW is generally higher in K^+ and lower in Na^+ than most sports drinks, and it is unknown whether the ratio of electrolytes makes a difference in performance. Because there was no significant difference between the two types of beverages in this study, it can be suggested that the mineral content may not be the determining factor in performance during endurance exercise.

Diet is an important part of an individual's training and preparation for optimal performance. It is interesting to note that participants on average consumed less calories and CHO prior to the CW trial as compared to water and CE beverages. While the difference is not significant, the difference in means could account for approximately 380 calories and 32 g CHO in the average participant, which could have been considered a snack for participants. This is something that should be considered in the future based on CHO's role in exercise performance and perhaps better controlling for intake, due to difficulty in controlling meals with the lack of a metabolic kitchen to provide food and beverages to subjects.

Most studies in this field are of experimental design; however like this one, they are limited by small sample sizes. This can influence power and make it more difficult to generalize the findings to the overall population. Often these studies are very specific to athletes or males. This study, likewise, used only athletic males (as defined by their VO_{2max} results) because using females or other types of athletes would introduced more variables into the experimental model. However, this leaves room for research to be completed to understand how these other population groups respond to the beverages, if different from what was seen here. Most studies do not report their power in the results, likely because it is also low like what was found here or it was not of concern. It is important to consider power, though, because it indicates the type II error present in the model and affects the strength of statements made.

One of the reasons this study was completed was to examine the potential alternatives to CE beverages, and CW is a leading contender based on its increased popularity and appeal to those who prefer a more "natural" product. Based on the present study and those previously mentioned, CW affected performance similar to CE products, but there is still much research needed to confirm the findings. Both CHO and electrolyte levels are different between the two beverages (CW and CE) and thus other factors besides the CHO content could make one product "better" than the other with regard to performance. With the continued evolution of CHO supplementation during exercise, including studies on CHO gels and food sources, CW may continue as an option of sports drinks for the delivery of fluid and CHO for the athlete.

This research and the studies discussed support the use of CW or CE as sports drinks in male athletes as the findings noted similar results between the two beverage types in terms of exercise performance used for this study. The findings of this study could be useful for athletes, coaches, and those in the sports medicine and management fields. Athletes can choose the best beverage for them not only based on performance and hydration ability, but palatability, tolerance, taste, and GI symptoms. The research remains mixed on the factors mentioned that are more subjectively measured. Although additional research on CW needs to be completed, consumers can be empowered to make their own decisions regarding choosing the best sports beverage for them.

CHAPTER VI

LIMITATIONS AND FUTURE RESEARCH

Limitations

First, the small sample size and the defined age range limit the ability to apply the results to a larger age range. There was limited ability to control what participants did prior to, in between, and after trials. While participants were given a standardized meal to eat 2 hours before their experimental trials, not all participants adhered to the recommendations. This meant that not all participants started with the same amount of food consumed, specifically the same amount of CHO, which is important in endurance exercise. Two participants, due to their non-compliance, had hypoglycemia at the start of the trial and therefore had to be rescheduled. With not everyone starting at the same baseline intake level, it makes it harder to specifically analyze what effects the beverages had. Further, not all participants ate the same thing or the same amount of CHO in the 24 hours leading up to the trials each time. For example, a participant could have followed the standardized meal before completing the water trial but, for whatever reason, failed to follow the same protocol prior to the CW trial as instructed. Participants potentially ran at different times of day and different days of the week for their trials due to scheduling complications, which could have impacted food and fluid intake, sleep, energy, access to food, alcohol consumption, and school/work activities.

Scheduling was an issue that created some variability between subjects. Participants were initially planned to have 2-4 days between trials; however, because of lab space and timing complications, some participants had up to 7 days between trials, which decreased consistency. The increased rest may have benefited those participants; however, because this was a repeated-measures design, each participant served as his own control. The error could potentially occur if a participant had 2 days between beverage A and B, for example, but 7 days between B and C. This also could affect the participant's schedule, in that many were marathon runners or already in training. Along with the scheduling, the trials were conducted over a 2-month period, in which weather changes did occur. While all trials occurred in the same room, the temperature and humidity were noticeably different from the beginning of the testing phase to the end. In the warmer and more humid conditions, participants may have been sweating more or perceived to be working harder, despite running in the same 60-70% VO_{2max} zone.

Future Research

There are many opportunities in research related to CW and sports beverages. This study is one of the first to compare CW and a CE beverage in terms of performance. While this study does not show that CW or CE is better than the other, there are many opportunities for further study comparing the beverages for use in the athletic population. With a different composition of vitamins and minerals, CW may have benefits that are yet to be seen. Other forms of physical activity can be tested, such as swimming or cycling, in addition to running different distances and intervals. More evaluation of hydration status can be completed, such as urine analysis, weight loss during exercise, and hydration status at multiple intervals postexercise. Running more studies similar to this with longer sample size would be key in developing greater power and validity in the effects of the beverages (if any). This study also only considered a specific population, and the study can be expanded to other populations, ages, sports, and levels. Further exploration of the CHO composition of CW would also be of interest and add to the literature on nutrition recommendations for athletes.

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APPENDIX A

RECRUITMENT FLYER AND LETTER

Do you run for exercise? Are you interested in learning your VO_{2max}?

VOLUNTEERS NEEDED!

If you are...

⇒ **Male**

⇒ **Ages 18-45**

⇒ **Comfortable running long distances**

⇒ **A Nonsmoker**

...You may qualify for a graduate student research study on beverage supplementation and running performance!

Volunteers will complete a VO_{2max} test, 3—90 minute running trials with blood drawn, 24 hour food logs, and anthropometric measurements over a 2 week period. Each of the 4 appointments will last ~120 min.

Benefits of participation:

- VO_{2max} Results & Analysis
- Body Composition Analysis

Contact
rnguyen2@niu.edu or
jalis1@niu.edu
if you are interested!

NORTHERN ILLINOIS UNIVERSITY
Kinesiology and Physical Education
College of Education

Northern Illinois University
College of Health and Human Sciences
Family, Consumer, and Nutrition Sciences
Nutrition and Dietetics

Please take one!

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Recruitment Letter

Hello!

You are invited to take part in a study regarding beverage supplementation and running performance. Dr. Judith Lukaszuk, a Professor in Nutrition and Dietetics at Northern Illinois University (NIU), Rayanne Nguyen, a graduate level nutrition student and dietetic intern at NIU, and Josh Alis, a graduate level exercise physiology student at NIU are conducting this study. We would like to determine if consuming beverages during exercise influences performance outcomes. You were selected because of your position as a physically active male and your willingness to participate.

If you decide to participate in this study, you will complete a short survey on demographics, dietary habits, vitamin and mineral supplement intake, and medical history. You will be asked to complete a series of runs on a treadmill and anthropometric measurements over a span of four weeks. You will be complete one VO_{2max} test upon your first visit followed by three 90 minutes runs at 60-70% VO_{2max} with beverage consumption at 15 minute intervals, in addition to three sprint threshold anaerobic test efforts over the 4 week span with a minimum of 48 hours between each visit. Each session in the performance lab will take approximately 2 hours to complete. The beverages consumed will vary in electrolyte and carbohydrate concentration. Blood will be drawn upon each visit via finger prick. A total of 2 finger pricks will be performed during the VO2 max test and a total of 10 finger prick blood draws will be performed during each following visit for a total of 32 finger prick blood draws. Minimal blood will be taken to fill a capillary tube for glucose and lactate measurements.
You will be asked to keep a 24 hour food lob prior to each trial and be asked not to change your diet. You will be asked to not eat anything for up to 2 hours prior to coming in for testing although you are allowed to drink water up until testing.
You will have your body composition measured upon a InBody520 which uses direct segmental measurement bioelectric impedance analysis (DSM-BIA). This will measure body fat, lean body mass, total body water, weight, and body mass index. You will be asked to be standing 15 minutes prior to using the InBody520 to assure proper fluid balance.
All information will be kept confidential; your name will not be used on the final report or associated with any data. Only Northern Illinois University qualified research personnel will see the data and/or be present at the time of the study. All names and any other identifying information will be removed upon data entry.

The risks from participating in this study include soreness, fatigue, physical exertion, and potential injury. Your participation in this study is completely voluntary and you may refuse to participate or withdraw at any time.

If you have any further questions, please don’t hesitate to contact the graduate student researcher, Rayanne Nguyen, at rnguyen2@niu.edu , Josh Alis, at jalis1@niu.edu or Dr. Judith Lukaszuk, thesis committee chair, at jmlukaszuk@niu.edu. Questions about rights of research subjects and research related injury should be directed to the Research and Compliance Integrity Office at researchcompliance@niu.edu.

You will be provided with a copy of this form to keep for your records. Your signature indicates that you have decided to participate in this study having read the information provided.

Thank you for your time.

APPENDIX B

MEDICAL HISTORY QUESTIONNAIRE

HEALTH HISTORY QUESTIONNAIRE
KINESIOLOGY AND PHYSICAL EDUCATION RESEARCH

Name: ________________________________ Email:_________________________

Phone:_______________________ Age: ______________

PART I: KNOWN DISEASES

Do you currently have:

______ Cardiovascular disease, peripheral vascular disease, and/or cerebrovascular disease?
______ Asthma?
______ Interstitial lung disease?
______ Cystic fibrosis?
______ Chronic Obstructive Pulmonary Disease (COPD)?
______ Diabetes (Type 1 or 2)?
______ Any thyroid disorders?
______ Renal or liver disease?

PART II: SIGNS AND SYMPTOMS

______ Do you experience pain and/or discomfort in the chest, neck, jaw, arms, or other areas during mild exercise?
______ Do you feel short of breath at rest, with typical, daily activities, or with mild exercise?
______ Do you feel short of breath while lying down flat?
______ Are you awoken in the middle of night due to feeling short of breath and/or severe coughing/weezing?
______ Do you often feel dizzy at rest or with mild exercise?
______ Do you suddenly pass out or lose consciousness while at rest or with mild exercise?
______ Have you experience ankle edema (swollen ankles)?
______ Do you have heart palpitations and/or tachycardia at rest or with mild exercise?
______ Do you suffer from muscle cramping, burning, numbness, or fatigue in your calf muscles at rest or with mild exercise?
______ Do you have a known heart murmur?
______ Do you have unusual fatigue with typical, daily activities?

PART III: CORONARY ARTERY DISEASE RISK FACTORS

______ Are you a male older than 45 years, or a female older than 55 years?
______ Do you have a close blood relative who has had a heart attack or heart surgery before the age of 55 (Dad, Brother) or age 65 (Mom, Sister)?
______ Do you smoke, or did you just quit smoking within the past 6 months?

_______ For the last 3 months, do you get less than 30 minutes of moderate-intense exercise, less than 3 days per week?

_______ Are you at least 20lbs overweight?

_______ Is your blood pressure over 140/90 mmHg, or are you on blood pressure medication?

_______ Is your cholesterol greater than or equal to 200 mg/dL, or are you on cholesterol medication?

_______ Is your fasting glucose greater than or equal to 100 ml/dL?

PART IV: MUSCULOSKELETAL CONDITIONS AND OTHER

_______ Do you have musculoskeletal problems that limit what/how you exercise?

_______ Have you had a major musculoskeletal injury (broken bones, torn ligaments/tendons, etc.) that has limited your ability to exercise in the past 12 months?

_______ Do you have an implanted electrical device (e.g. pacemaker)?

_______ Are you under the age of 18 or over the age of 30?

_______ Do you have allergies to carbohydrate drinks, such as Gatorade?

PART V: GENERAL SUPPLEMENTAL INFORMATION

Are you taking prescription medications? If so, please list them and for what reasons you are taking them.

____

____

Do you have any allergies (foods, latex, plants, animals, etc)? If yes, please list:

____

____

APPENDIX C

ACSM’S GUIDELINES FOR EXERCISE TESTING AND PRESCRIPTION

The CVD Risk Factor Table from ACSM's *Guidelines for Exercise Testing and Prescription* (8th ed) Published in 2009, by Lippincott, Williams, & Wilkins (Baltimore, MD).

Walter R. Thompson, Senior Editor. p. 106 Chapter 6, Table 6-2.

POSITIVE RISK FACTORS	DEFINING CRITERIA
Age	Men ≥45 yr; Women ≥55 yr
Family History	Myocardial infarction, coronary revascularization, or sudden death before 55 yr of age in father or other male first-degree relative, or before 65 yr of age in mother or other female first-degree relative
Cigarette Smoking	Current cigarette smoker or those who quit within the previous 6 months or exposure to environmental tobacco smoke
Sedentary Lifestyle	Not participating in at least 30 min of moderate intensity (40%-60% VO2R) physical activity on at least three days of the week for at least three months (20,23)
Obesity[a]	Body mass index ≥30 kg . m2 or waist girth ≥102 cm (40 inches) for men and ≥88 cm (35 inches) for women (2)
Hypertension	Systolic blood pressure ≥140 mm Hg and/or diastolic ≥90 mm Hg, confirmed by measurements on at least two separate occasions, or on antihypertensive medication (10)
Dyslipidemia	Low-density lipoprotein (LDL-C) cholesterol ≥130 mg . dL-1 (3.37 mmol - L-1) or high-density lipoprotein (HDL-C) cholesterol <40 mg . dL-1 (1.04 mmol - L-1) or on lipid-lowering medication. If total serum cholesterol is all that is available use ≥200 mg . dL-1 (5.18 mmol - L-1) (3)
Prediabetes	Impaired fasting glucose (IFG) = fasting plasma glucose ≥100 mg . dL-1 (5.50 mmol - L-1) but _126 mg . dL-1 (6.93 mmol - L-1) or impaired glucose tolerance (IGT) = 2-hour values in oral glucose tolerance test (OGTT) ≥140 mg . dL-1 (7.70 mmol - L-1) but <200 mg . dL-1 (11.00 mmol - L-1) confirmed by measurements on at least two separate occasions (8)

NEGATIVE RISK FACTOR	
High-serum HDL cholesterol[†]	≥60 mg . dL-1 (1.55 mmol - L-1)

[†] Note: It is common to sum risk factors in making clinical judgments. If HDL is high, subtract one risk factor from the sum of positive risk factors, because high HDL decreases CVD risk. [a]Professional opinions vary regarding the most appropriate markers and thresholds for obesity; therefore, allied health professionals should use clinical judgment when evaluating this risk factor. (http://certification.acsm.org/certreview3)

APPENDIX D

WRITTEN CONSENT FORM

Consent Form

I do hereby consent to take part in the study regarding the effect of beverage supplementation on exercise performance by researchers at Northern Illinois University. Rayanne Nguyen, a graduate level nutrition student and dietetic intern and Josh Alis, a graduate student in Exercise Physiology at Northern Illinois University (NIU) are conducting this study under the direction of Drs. Judith Lukaszuk in Nutrition and Dietetics and Amanda Salacinski from the Department of Kinesiology and Physical Education, at NIU. The purpose of the study is to compare beverage supplementation and running performance.

I understand that as a participant of the study, I will complete a short survey that includes information about demographics, dietary habits, vitamin and mineral supplement intake and past medical history, have my height, weight, and body composition measured. I understand this study will also involve completing a series of runs on a treadmill over a span of two weeks. There will be one maximal test of my endurance capacity (VO_{2max} test) and three 90 minutes runs at 60-70% VO_{2max} with beverage consumption at 15 minute intervals, each followed a test to measure power, called an anaerobic threshold test. The beverages will be consumed at minute 15, 30, 45, 60, and 75. I understand that all collection of this data will take place in the Human Performance Lab in 206 Anderson Hall at NIU. Each appointment will take approximately 120 minutes total.

I understand that my participation is voluntary and I may withdraw from this study at any time without penalty or prejudice and if I have any additional questions concerning this study, I may contact Rayanne Nguyen at (805) 680-1376, Josh Alis at (815) 985-7289 or the faculty advisors, Drs. Judith Lukaszuk at (815) 753-6352 or Amanda Salacinski at (815) 753-5625. I understand that if I wish to obtain further information regarding my rights as a research subject, I may contact the Office of Research Compliance at Northern Illinois University at (815) 753-8588.

I understand that all records are held in confidence and that my name will not be used on the final report or associated with any data. Only NIU qualified research personnel listed on this will see the data and/or be present at the time of the study. Any information obtained in connection with this study and that may identify me individually will be kept confidential at all times.

I understand that the benefits of this study include determining my body composition and my VO_{2max}. I will also be offered nutrition counseling at the end of the study. I understand that these tests and counseling are to be at no charge to me.

I understand that the risks from participating in this study include time, convenience, soreness, fatigue, physical exertion and alteration of dietary and activity patterns. The discomfort will go away after a few days. Northern Illinois University policy does not provide for compensation for, nor does the University carry insurance to cover injury or illness incurred as a result of participation in University sponsored research projects. Upon suffering a minor injury, subjects will be referred to their PCP, NIU Health Services, or the nearest hospital and in the event of serious injury, emergency medical services will be notified immediately.

I understand that my signature below is consent to participate in the beverage supplementation and exercise performance study. I understand that my consent to participate in this project does not constitute a waiver of any legal rights or redress I might have as a result of my participation, and I acknowledge that I have received a copy of this consent form.

Participant Name_______________________________

Participant Signature ___________________________ Date ___________________

Signature of Investigator ________________________ Date ___________________

APPENDIX E

DATA COLLECTION FORM

Data Collection Form

Participant #: _______________ Date: ______________

Trial #: ___________ Beverage: ________________

Age: ___________ Height: ___________ Weight: ___________

BMI: ___________ IWC: ___________ EWC: ___________ % Body Fat: ___________

VO_{2max}: _________

	Fluid (fl oz)	Treadmill speed (mph)	HR (BPM)	RPE	Gluc 1 (mg/dL)	Gluc 2 (mg/dL)	Lac 1 (mmol)	Lac 2 (mmol)	GI scores T	B	S	N	F
Baseline													
15 min	12												
30 min	12												
45 min	12												
60 min	12												
75 min	12												
90 min													
Post TAT													
5 min rest													
10 min rest													

VO_2 (ml/kg) Check #1: ___________________ Check #2:__________________

Distance Traveled: ___________

TAT Time: _________

APPENDIX F

SAMPLE 24 HOUR INTAKE FORM

24 Hour Dietary Intake Form

Participant: _____________________ Date: ___________________

Trial #: _______

Please complete the following by:

Indicate the time of consumption in the left column

Indicate the foods and beverages consumed along with estimated measurements (cup, ounce, tablespoon, etc) in the middle and right columns, respectively.

Please write every consumed in the past 24 hours leading up to this trial.

Time	Food/Beverage Consumed & Amount
Example: 7:15 am	2 slices whole wheat bread (HyVee brand) 8 oz 2% milk 1 medium Fuji apple 1 poached egg

Please list any supplements (including caffeine) consumed in the past 24 hours leading up to this trial below.

____

____

APPENDIX G

RPE SCALE

Instructions for ratings of perceived exertion (RPE)

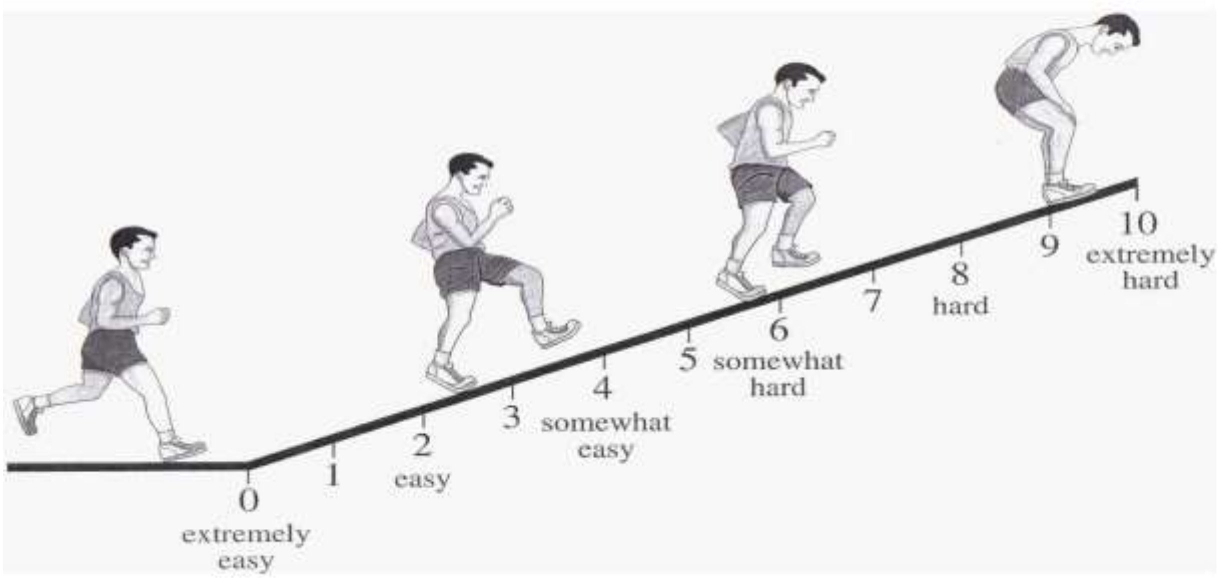
On the next pages, there are scales for you to rate your perceived exertion level. Perceived exertion is the overall effort or distress of your body during exercise. The number 0 represents no perceived exertion or discomfort and the number 10 represents the greatest amount of exertion that you have ever experienced.

At various times during the exercise test and with every time you exercise you will be asked to point at or state the number that best represents your rating of perceived exertion at the time. Remember, it is a measure of how you feel overall, not just how one part of your body might feel.

When selecting a number, look first at the words on the table and then indicate the number that corresponds to how you are feeling.

There are no right or wrong answers so simply select the number that you feel best represents how you are feeling at that point in time.

OMNI-RPE scale for aerobic exercise



APPENDIX H

GI DISTRESS SCALE

GI Distress scores
1-10 scale (1 = not at all, 10 = extremely)

Thirst (1 = not at all thirsty, 10 = extremely thirsty)	Bloatedness (1 = not at all bloated, 10 = extremely bloated)	Stomach upset (1 = not at all upset, 10 = extremely upset)	Nausea (1 = not at all nauseous, 10 = extremely nauseous)	Fullness (1 = not at all full, 10 = extremely full)

Thirst

1 2 3 4 5 6 7 8 9 10

Not thirsty at all Extremely thirsty

Bloatedness

1 2 3 4 5 6 7 8 9 10

Not at all bloated Extremely bloated

Stomach Upset

1 2 3 4 5 6 7 8 9 10

Not at all upset Extremely upset

Nausea

1 2 3 4 5 6 7 8 9 10

Not at all nauseous Extremely nauseous

Fullness

1 2 3 4 5 6 7 8 9 10

Not at all full Extremely full