ABSTRACT

Comparison of Rice-Based Versus Sucrose-Based Drinks on the Ability to Maintain Hydration Status in ROTC Cadets During a Physical Training Event

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It is well established that carbohydrates and electrolytes are needed for fueling during physical activity exceeding 1 hour. Sports drinks are commonly used to replenish carbohydrate and electrolyte losses and provide hydration. The ACSM guidelines recommend sports drinks contain 6-8% carbohydrate; however, rice-based sports drinks typically contain only 4-4.5% carbohydrates. The aim of this study was to investigate the influence the type of carbohydrate in sports drinks had on hydration status during a load-bearing 12-mile road march. To test this, CeraSport®, a rice-based drink, and Gatorade®, a sucrose-based drink, were provided to subjects. Sixteen Reserve Officer Training Corps cadets from a private university completed a blinded randomized controlled trial. Despite the difference in type and amount of carbohydrate, we hypothesized that both sports beverages would provide adequate hydration throughout the event. Hydration status was assessed by urine specific gravity measures and pre- and post-body weight.

Comparison of Rice-based versus Sucrose-based Drinks on the Ability to Maintain Hydration Status in ROTC Cadets during a Physical Training Event

by

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A Thesis

Approved by the Department of Family and Consumer Sciences

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Submitted to the Graduate Faculty of
Baylor University in Partial Fulfillment of the
Requirements for the Degree
of

Master of Science

Approved by the Thesis Committee

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December 2020

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ACKNOWLEDGMENTS

Thank you to all that allowed me to assist in the research and that have helped in data collection, interpretation, and writing of this research project. L. Funderburk, PhD, RDN, J. Heileson, MS, RDN, and R. Sturdivant, PhD.

CHAPTER ONE

Introduction

Background

Hydration is a crucial component for optimal physical performance among athletes, elite and recreational. Hydration is defined as the condition of having adequate fluid in body tissues.[1] Various factors such as environment, exercise intensity, and fluid availability influence hydration status.[2] When the body becomes dehydrated, meaning water is lost from the body, it is difficult to complete physical activities at a high level of intensity since fluids in the body are dropping or depleted. Physical and cognitive performance have been shown to decrease during periods of dehydration.[3] Athletes want to maintain a steady state of energy throughout competition to keep their intensity consistent, leading to the importance of preventing dehydration by maintaining or improving hydration status. An athlete's sweat rate influences the fluid balance in the body, which determines hydration status. During physical activity, a body mass loss of >2% has been shown to decrease exercise performance and increase the risk of heat related injuries.[4,5] Maintaining hydration should be routine practice for athletes of all levels in order to ensure the greatest potential in performance.

It has been well established that consuming carbohydrates and electrolytes before and during exercise will lead to greater physical performance when exercise is performed longer than one hour.[2,6,7] Carbohydrates are needed to maintain blood glucose levels, while electrolytes replace what has been lost through sweat and aid in fluid absorption. A

study conducted using 8 endurance-trained male runners found that intake of a 6.4% carbohydrate solution 30 minutes before and throughout a 1-hour run significantly improved running time compared to the placebo group that did not ingest carbohydrates.[8] Sports drinks have become a popular source of rehydration and energy replenishment because they contain fluid, electrolytes, and carbohydrate replacement in one, unified drink.[2,6] The carbohydrate and sodium facilitate water absorption throughout the body, replenishing fluid lost during performance and providing energy and electrolytes at the same time.[6]

When carbohydrates are mixed with fluid to meet hydration needs, concentration of the carbohydrates is related to the effectiveness of the drink. The current Position Stand concerning about carbohydrate concentrations from the American College of Sports Medicine recommends a carbohydrate concentration of 6-8%.[2] Studies have found an 8% carbohydrate threshold to be the most effective because a higher concentration can reduce gastric emptying, slowing the absorption of glucose needed for energy.[9] A more recent study conducted by Harper et al (2017) found that a sports drink with 12% carbohydrate concentration increased blood glucose levels better than water or electrolyte drinks without causing discomfort in the athletes during and post-exercise.[10] The study was conducted to see if a higher percentage of carbohydrate solution in a drink would cause adverse side effects, such as abdominal discomfort. Since the study found that consumption of a 12% carbohydrate concentration drink produces similar results to the recommended 8% carbohydrate threshold, further studies should be completed to find the maximum percentage of carbohydrates that allows for the best rate of glucose replacement without causing abdominal discomfort during digestion.

The source of carbohydrate in sports drinks has been found to impact carbohydrate oxidation rate and blood glucose values.[11] Glucose by itself has been shown to be oxidized at a peak rate of 1.0 grams per minute when 180 minutes of exercise is performed.[12] A study from 1973 showed that glucose absorption rates from maltose were 15% higher than that of a pure glucose solution.[13] Since then, investigators have researched the rate of carbohydrate oxidation when glucose is mixed with sucrose or maltose.[11] Results indicated that a 2:1 mixture of glucose and sucrose reached peak oxidation rates of approximately 1.25 grams per minute, with similar but slightly lower findings at a rate of 1.06 grams per minute for a glucose and maltose mixture. This higher oxidation rate is related to multiple GI transporters being utilized by glucose and fructose, allowing for more absorption of glucose molecules into the blood stream.[6] Whereas with glucose and maltose, both molecules are competing for the same transporter which can decrease absorption rate.[11]

A higher oxidation rate leads to a faster turn-around time of energy being utilized by the body. Although glucose and sucrose rates of oxidation were higher, maltose is still a subject of interest in sports beverages because of the ability to maintain blood glucose levels. In a study comparing maltose and trehalose in sports drinks, it was found that maltose had oxidation rates that were 27% higher than trehalose.[14] Trehalose is also a long chain of glucose molecules but differs from maltose in where the glycosidic linkages are.[14] Maltose consists of long chains of glucose molecules, which makes it more complex in comparison to sucrose. Glucose and fructose, the simple sugars found in sucrose, are absorbed in the duodenum and jejunum. It has been found that the long chains of maltose are broken down and absorbed throughout the entirety of the small

intestine, including the ileum.[15] Since maltose is utilizing the entire length of the small intestine, it can speed gastric emptying while providing less gastrointestinal disruption for athletes during performance.[15,16]

Carbohydrates are utilized in sports drinks to provide energy during exercise as well as facilitate the transport of electrolytes, while electrolytes are needed to replenish what has been lost from sweat. Sodium (Na), potassium (K), and chloride (Cl) are the main electrolytes lost through sweat, therefore, sports drinks often contain high amounts of them.[17] They play an important role in maintaining homeostasis throughout the body between the extracellular and intracellular fluid. Sodium triggers the body's physiological drive to drink and is the main cation in the extracellular fluid.[6] Chloride is the anion in the extracellular fluid that works with sodium. It is the anion found in the greatest amounts in sweat with an average rate of 30 milliequivalents per liter.[2] Therefore, consumption of chloride is necessary during and after physical activity to replenish what has been lost. However, many sports drinks do not contain enough chloride to replenish the loss. Potassium is another main electrolyte found in sports drinks. It is the major cation in the extracellular fluid and plays a role in muscle contraction and influences the concentration of sodium in the blood. Compared to chloride, potassium is lost at an average rate of 5 milliequivalents per liter.[2] Sodium and potassium work together in the body to regulate body temperature and maintain adequate fluid levels. They are both found in sports drinks to replace electrolytes that are lost during physical activity.[2]

Although it is important to consider the composition when choosing sports beverages, it is also important to pay attention to the gastrointestinal (GI) discomfort that is often associated with sports beverages. GI discomfort can be related to the rate of

gastric emptying that is occurring.[18] Common markers of GI discomfort are reflux, nausea, bloating, and cramping.[19] A study comparing GI discomfort in runners found that carbohydrate-electrolyte solutions caused more GI discomfort than water.[19] Maltose-based sports beverages are of interest due to the lower osmolality content which may allow for improved absorption and lower GI complaints.[16]

Gatorade® is a popular commercial sports drink consisting of the combination of sugar and dextrose, as well as sodium chloride and potassium. The base for Gatorade, dextrose, is a compound that is structurally similar to glucose while sugar is also known as sucrose, a mixture of glucose and fructose. Cerasport® is a rice-based sports drink that is comparable to Gatorade in carbohydrate and electrolyte content. Rice syrup solids, the main ingredient in Cerasport, is made of short, medium, and long chains of glucose to include maltose and maltodextrins. Maltodextrins are made from starch, providing energy without providing a large amount of sugar.[20] They can be broken down into maltose molecules which are then broken down to glucose molecules. Due to its long chain length, the long breakdown of maltodextrin utilizes the entirety of the small intestine. Maltodextrin also has a low osmolality, which allows it to clear from the stomach faster than sucrose. This increased gastric emptying allows the molecules to leave the stomach faster and prevent drawing fluid from the bloodstream into the small intestine.

One study found that Cerasport improved blood glucose levels as compared to Gatorade and a glucose only drink, after and during a low to moderate intensity treadmill protocol.[16] Further studies are necessary in order to determine the benefits of Gatorade versus Cerasport; because the mechanism behind why rice starch could be a better substitute for sucrose is still undetermined.

Purpose

The purpose of this study is to evaluate the effects of rice-based versus sucrose-based drinks on hydration during a long-distance physical performance event. Cerasport® will be used as the rice-based drink in order to test the efficacy of the product. The other purpose of this study is to evaluate the gastrointestinal effects both drinks have on the subjects.

Hypothesis

It is hypothesized that both sports beverages will provide adequate hydration throughout the physical performance event, even though Cerasport contains a slightly lower carbohydrate concentration at 4% versus the 6% carbohydrate content in Gatorade®. The short, medium, and long, chains of glucose in the rice starch are what will help Cerasport maintain hydration. The other hypothesis is that subjects will have fewer digestive issues with Cerasport during their participation in a physical performance event.

CHAPTER TWO

Methods

This was a randomized controlled trial completed in November 2019 approved by the Baylor University Institutional Review Board.

Subjects

Subjects recruited for this study were Reserve Officer Training Corps (ROTC) cadets attending a private university. They were recruited during their weekly ROTC platoon meetings. Sixteen ROTC cadets complete this randomized controlled trial. To be included in this study, participants had to be an active ROTC member with the ability to complete a 12-mile road march.

Sports Drinks

Gatorade® Lemon Lime and Cerasport® Citrus Flavor were the two drinks utilized during this study. Both drink mixes came in the powdered form and were mixed into individual 16-ounce bottles the night prior to the road march. Instructions were followed from each package on how to properly prepare 16 ounces. See table 2.1 for the composition of 1 liter of each sports beverage.

Table 2.1. Sports Beverage Composition

Drinks	Energy (kcals)	Carbohydrate (g)	Sugar (g)	Na (mg)	K (mg)	Cl (mg)	Osmolality (mOsm)
Gatorade®	240	61	57	460	128	389	345
CeraSport®	160	40	8	460	160	672	135

Assignment

The study was conducted on the day of the ROTC platoon's 12-mile road march. Prior to the study, the ROTC cadet's Army Physical Fitness Test (APFT) scores were reviewed in order to pair cadets. Cadets were paired into groups of two by similar APFT scores and gender. Once paired, a coin was flipped to randomly assign sport drinks for each member of the pair. One of the cadets in the pair received Cerasport® while the other received Gatorade®. Each cadet was assigned a participation number.

Location

The study took place on the grounds of a private university in the southern United States. The road march course was an outdoor one-mile loop. As cadets lapped the course, their lap number was recorded by study investigators. The course started and ended at the same location.

Procedure

On the day of the road march, participants reported up to 30 minutes prior to the road march to complete the check in process. Participants first provided a urine sample that was analyzed using the Misco Palm Abbe PA201X-093 refractometer to provide the urine specific gravity (USG). The refractometer was calibrated prior to analysis. After

providing a urine sample, participants were weighed on a calibrated scale in their physical training gear, consisting of a clean t-shirt and gym shorts. Shoes and socks were removed for weight measurements. After their weight was taken, participants were given the first 16-ounce bottle of their assigned sports drink. Participants did not know which drink they were receiving. The first drink had to be finished before starting the road march. Once the road march started, participants received 16 ounces of their assigned sports drink every two miles. The 16 ounces had to be completed before they could receive their next drink. Participants received a total of six, 16-ounce sports drinks throughout the entire testing process, for a total of 96 ounces. The 96 ounce fluid prescription was created by using the United States Army Public Health Center (USAPHC) fluid replacement guide, estimating that the cadets would complete the road march in three hours. The USAPHC chart recommends 1 quart of fluid per hour during continuous moderate exercise. The fluid replacement guide can be found in the appendix as Figure A.1.

ROTC cadets had to complete the 12-mile road march in 4 hours or less. This standard is set by the Cadet Command. The average road march pace for participants of the study is discussed in the results section.

After participants finished the 12-mile road march, they were weighed in the physical training gear worn before the road march then provided a urine sample. Participants were asked to complete a questionnaire regarding how they felt during and after the road march, as well as reported any GI complaints using the Borg Scale of Perceived Exertion.

Analysis

For statistical analysis, a two-way analysis of variance (ANOVA) was used to assess changes in USG and weight. The two factors for analysis were gender and sports beverage assignment. A means one-way ANOVA was used to compare gender to USG as well as a separate test ran to compare sports beverage to USG. The significance level for all analysis was set at $p \leq 0.05$. JMP statistical software was used for analysis.

CHAPTER THREE

Results

Participants

The distribution of participants is shown in Table 3.1. All sixteen participants completed the 12-mile road march and were used in the statistical analysis. Eight participants received Cerasport®, while the other eight participants received Gatorade®. Participants were given all 96 ounces of their assigned beverages and were compliant in consuming the 16 ounces prior to receiving their next 16 ounces.

Table 3.1. Participants

Gender (n)	Age in years Mean ± SD	Average road march time in minutes Mean ± SD	CeraSport® (Gatorade®) n
Male (9)	20.6 ± 3.3	151.2 ± 18.0	5 (4)
Female (7)	19.9 ± 1.1	194.0 ± 28.9	3 (4)

Urine Specific Gravity

Urine specific gravity (USG) was measured for all participants prior to the road march, as well as after. Difference in USG was found by subtracting the post-USG score from the pre-USG score. Table 3.2 reflects the overall change in USG for all sixteen participants. Both beverages significantly improved hydration status throughout the road march ($p = 0.04$). There was no significant difference between sports drink groups ($p = 0.28$). The female participants that were assigned Cerasport® showed a significant

improvement in USG compared to all other gender and drink assignment groups (p = 0.036).

Table 3.2. USG of All Participants

	USG
Pre-USG	1.017 ± 0.010
Post-USG	1.011 ± 0.008
p-value	0.04

Body Weight

The change in percentage of body mass change for each group is presented in Table 3.3. There was no significant weight change in participants (p = 0.54). Gender did not affect changes in body weight.

Table 3.3. Change in Percentage of Body Mass.

CeraSport®	Gatorade®	p-value
$6.41 \times 10^{-4} \pm 0.470$	0.259 ± 1.052	0.54

Exhaustion

After the road-march, participants filled out the survey as seen on Figure A.2 in the appendixes. Using the Borg Scale, participants reported the level of exhaustion to be between moderate and strong (Cerasport® = 4.15 ± 2.41, Gatorade® = 5.38 ± 1.98). The Borg Scale of Perceived Rate of Exertion used can be found on Figure A.2 in the appendixes.

Gastrointestinal Discomfort

Level of nausea, abdominal cramps, feelings of bloating, and urge to vomit were all evaluated post-road-march using the Borg Scale of Perceived Rate of Exertion. All of these measurements were markers for gastrointestinal (GI) distress. There were no significant findings when comparing these markers between groups ($p > 0.05$). In the Gatorade® group, feelings of bloating were the highest (Gatorade® = 4.44 ± 0.89, Cerasport® 2.88 ± 0.89). Out of all these markers, only feelings of bloating in the Gatorade group were found to be above a 2.88 on the Borg Scale.

Limitations

Limitations of this study include the small sample size, which limited group allocation to intervention and placebo. With a larger sample size, it would have been beneficial to compare a third sample group with an intake of only water throughout the road-march to compare the difference, if any, carbohydrates would have made on performance.

CHAPTER FOUR

Discussion

Assessment of Hydration Status

The purpose of this investigation was to determine if a rice-based drink, Cerasport®, was able to maintain or improve hydration status as well or better than a sucrose-based sports drink, Gatorade®, during moderate to intense physical activity. To properly asses the maintenance of hydration status, USG and body weight were measured. USG compares the density of urine to pure water, which is directly related to hydration status.[21] The significant increase in USG for all participants that was found in this study shows that both beverages improved hydration status.

A loss in body weight would have been an indicator of dehydration since body fluid lost through sweat causes the body's overall amount of water available to decrease.[3] Participant's body weight was not statistically affected by the type of sports drink consumed in this study. A non-significant change in body weight is an indicator that participants maintained hydration throughout the entire road march. The predicted sweat rates for individuals running at paces of 8.5 kilometers per hour to 15 kilometers per hour vary from approximately 0.4 to 1.8 liters per hour.[2] Various factors go into determining sweat rate such as gender, body weight, activity, and climate, so exact sweat rates cannot be determined for each individual, but various studies have come to these generalizations.[2,22,23]

The findings of this study indicate that Cerasport® was able to maintain hydration status as well as Gatorade®. This suggests that the lower concentration of Cerasport, at 4% carbohydrates per 1 liter, can adequately maintain hydration status during physical activity. These findings differ from the recommended 6-8% of carbohydrate concentration recommended by the ACSM.[2] Most sports beverages containing carbohydrates and electrolytes are made from sucrose. Since Cerasport is made from mainly maltose, the findings of this study align with the theory from Kuecher (2017), stating that maltose digestion occurs throughout the entirety of the small intestine, leading to sustained, longer term influx of glucose.[16] The authors speculated that this could lead to improved hydration and performance, which could be why the lower concentration of Cerasport maintained hydration status just as well as Gatorade.

An interesting finding when comparing genders was that Cerasport statistically improved hydration status in the females compared to the females assigned Gatorade. The research of gender-focused studies is very limited, but this could be an area of interest suggesting that maltose may affect females differently than males. Estradiol has been shown to play a role in energy metabolism in women.[24] It is increased during various stages of the menstrual cycle. An increased level of estradiol has been linked to the increase in fat oxidation, sparing glycogen stores.[25] These participants in this study could have been in a phase of their cycle where estradiol was lower, causing an increase in glucose utilization. There is little research on this topic, leaving it an area of exploration for further research.

GI Discomfort

When looking at both groups, the GI marker with the highest score of discomfort was associated with feelings of bloating. The other markers' mean scores were found to be at or below the "easy" indicator on the Borg Scale. Gatorade® participants reported a higher feeling of bloating. This could be related to the amount of fluids consumed throughout the study, since it was relatively large at 96 ounces. The feeling of bloating could have affected the participants finish time during this training event, causing them to slow down because of discomfort.

CHAPTER FIVE

Conclusion

The results indicate that rice-based Cerasport® improved hydration comparably to the sucrose-based Gatorade® did. Cerasport has a lower percentage of carbohydrate concentration, which makes it an area of interest in this study. The ACSM guidelines recommend 6-8% carbohydrate content in sports drinks, but this could be reevaluated to take into account novel rice-based formulations.[5] Various studies have suggested rice-based drinks are absorbed throughout the entirety of the gastrointestinal tract. Utilizing the entirety of the gastrointestinal tract allows for a lower concentration of carbohydrates to be utilized because there is more surface area for absorption. Whereas sucrose-based drinks are mainly absorbed in the duodenum, which decreases time allowed for absorption. This difference in absorption could be why the lower concentration of carbohydrates in Cerasport was able to maintain hydration status.

This study indicates there is more to be evaluated regarding type and benefits of carbohydrate in sports beverages. It is possible that a lower concentration of a maltose-based sports beverage can be equally as effective as sucrose-based sports beverages in maintaining hydration status during physical activity.

APPENDIX

Work/Rest Times and Fluid Replacement Guide

Heat Category	WBGT Index (°F)	Easy Work: Walking on hard surface, 2.5 mph, <30 lb. load; weapon maintenance, marksmanship training.		Moderate Work: Patrolling, walking in sand, 2.5 mph, no load; calisthenics.		Hard Work: Walking in sand, 2.5 mph, with load; field assaults.	
		Work/Rest (minutes)	*Fluid Intake (quarts/hour)*	*Work/Rest (minutes)*	*Fluid Intake (quarts/hour)*	*Work/Rest (minutes)*	*Fluid Intake (quarts/hour)*
1	78° - 81.9°	NL	½	NL	¾	40/20 (70)*	¾ (1)*
2 (GREEN)	82° - 84.9°	NL	½	50/10 (150)*	¾ (1)*	30/30 (65)*	1 (1¼)*
3 (YELLOW)	85° - 87.9°	NL	¾	40/20 (100)*	¾ (1)*	30/30 (55)*	1 (1¼)*
4 (RED)	88° - 89.9°	NL	¾	30/30 (80)*	¾ (1¼)*	20/40 (50)*	1 (1¼)*
5 (BLACK)	> 90°	50/10 (180)*	1	20/40 (70)*	1 (1¼)*	10/50 (45)*	1 (1½)*

NL = No limit to work time per hour.

*Use the amounts in parentheses for continuous work when rest breaks are not possible. Leaders should ensure several hours of rest and rehydration time after continuous work.

This guidance will sustain performance and hydration for at least 4 hours of work in the specified heat category. Fluid needs can vary based on individual differences (± ¼ qt/hr) and exposure to full sun or full shade (± ¼ qt/hr).

Rest means minimal physical activity (sitting or standing) in the shade if possible.

Body Armor - Add 5°F to WBGT index in humid climates.

NBC (MOPP 4) - Add 10°F (Easy Work) or 20°F (Moderate or Hard Work) to WBGT Index.

CAUTION: Hourly fluid intake should not exceed 1½ qts. Daily fluid intake should not exceed 12 qts.

USAPHC

CP-033-0615

Figure A.1. USAPHC Fluid Replacement Guide

Post-road march perception rating survey

Hydration Status Post-Consumption of a Carbohydrate-electrolyte Beverage in Army Reserve Officer Training Corps (ROTC) Cadets

Post-Road March Perception Rating Survey

Participant Number: _____

Assigned sports drink (circle one): 1 2

Using the scale provided below, choose the number that best indicates your experience with the following symptoms during today's road march.

Question	Rating (from the scale)
1. How would you rate your level of **exhaustion**?	
2. How would you rate your level of **nausea**?	
3. How would you rate your level of **abdominal cramps**?	
4. How would you rate your level of **feeling bloated**?	
5. How would you rate your level of **urge to vomit**?	

0	Nothing at all
0.3	
0.5	Extremely weak
0.7	
1	Very weak
1.5	
2	Weak
2.5	
3	Moderate
4	
5	Strong
6	
7	Very Strong
8	
9	
10	Extremely Strong
11	
…	
•	Absolute Maximum

Figure A.2. Post-Road March Perception Rating Survey

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