The Pennsylvania State University

The Graduate School

College of Health and Human Development

COMPARISON OF DIFFERENT TYPES OF HYDRATION BEVERAGES ON ANAEROBIC PERFORMANCE FOLLOWING AEROBIC FATIGUE IN PHYSICALLY ACTIVE INDIVIDUALS

A Thesis in

Kinesiology

by

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Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Master of Science

August 2015

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ABSTRACT

In athletics, performance may be inhibited by as little as a 2% decrease in body weight due to hydration loss. Water has traditionally been the primary mode of hydration, but recently, carbohydrate-electrolyte sports drinks (CESD) and carbohydrate protein drinks (CPD) have started to gain popularity due to their inclusion of nutrients that may aid in performance. This study's aim was to determine the effects of different modes of hydration on anaerobic performance following aerobic fatigue among physically active individuals. It was hypothesized that ingesting a CESD rather than water or a CPD prior to all activity would lead to lower times and greater distances. Seventeen recreationally active collegiate students were recruited for this study. This was a cross-over study that used a within-participant design in which subjects drank one of three drink conditions (300 milliliters of water, 355 milliliters of CESD (Gatorade), or 355 milliliters of CPD (Accelerade)). Following consumption of the beverage, subjects waited 30 minutes to ensure absorption, ran for 30 minutes, and then completed three trials each of three anaerobic tests: a 10-yard sprint, an agility drill, and a broad jump. One-way ANOVA revealed no significant difference in anaerobic performance under any drink condition. These data indicate that for short duration aerobic exercise followed by anaerobic activity, different types of drinks have no effect on performance in physically active individuals. Future research could investigate trained athletes instead of recreationally active or utilize a longer period of aerobic fatigue that would more closely mimic typical competition game play.

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INTRODUCTION

Dehydration of 1-2% of total body weight, which is common in physical activity, begins to compromise physiologic function and negatively affect athletic performance.[1-6] This dehydration occurs because during exercise, the body produces heat and this heat is then dissipated by the evaporation of sweat.[6-8] The sweat that is produced by the body includes water and electrolytes such as sodium and potassium.[9-11] To avoid a decrease in athletic performance, there needs to be rehydration that occurs during activity.[12-15] Historically, water has been the primary method of rehydration during athletic activity, while more recently, commercially available carbohydrate-electrolyte sports drinks and carbohydrate protein drinks have started to make an impact with their claims that they rehydrate faster than plain water.

Sports drinks claim to be more beneficial than water due to their inclusion of carbohydrates and electrolytes. These carbohydrates and electrolytes improve physiologic function by promoting water absorption, increasing plasma osmolality, which aids in fluid retention, increasing the voluntary consumption of liquid, and increasing the speed of glycogen replacement.[11,16-21] Protein-carbohydrate drinks have shown an increase in fluid retention capabilities compared to carbohydrate-electrolyte sports drinks and water.[17,22,23] Carbohydrate-protein drinks also have been shown to increase the efficiency of glycogen restoration by increasing the efficiency of carbohydrate to increase the plasma insulin concentration and promote rapid restoration of muscle glycogen.[24-26]

With all of the different options for rehydration present for physically active individuals, it is important to know if any product works better than another. It has been established that water is the best method of rehydration for anaerobic activity, while carbohydrate-electrolyte sports drinks are the best rehydration method for aerobic activity.[11,27,28] However, there is not a clear understanding about which method of hydration is best for intermittent activity that incorporates both aerobic and anaerobic activity. The purpose of this research was to compare three different types of hydration beverages and their effect on anaerobic performance measures performed after aerobic fatigue. This methodology was designed to mimic the types of activity seen in common athletic competitions. All anaerobic tests were performed after ingestion of one of three different drink conditions and 30 minutes of aerobic exercise. The anaerobic measures tested were a 10-yard sprint, agility drill, and broad jump since those are activities that mimic those seen in competition. It was hypothesized that the carbohydrate-electrolyte sports drink would lead to better anaerobic performance.

LITERATURE REVIEW

One aspect of athletic performance that some individuals might not place an emphasis on is hydration. In today's world of athletics, there are many options for hydration for athletes at all levels of competition from recreational to Olympic. When looking at all the options, it can be difficult for an athlete to decide which beverage they should choose. Part of this decision involves the specific physical demands the sport they are participating in puts on their body. The needs of a soccer athlete are different than those of a football athlete. The differences in the physiological demands of various sports require different types of hydration. Sports that are predominantly aerobic in nature have a definitive answer as to which type of hydration is best, whereas for sports that involve a mix of aerobic and anaerobic activity, the answer is not as clear.

During exercise, heat is generated by the body, which needs to be dissipated to maintain normal physiologic function. The main method by which the body dissipates this heat is through evaporation of sweat. When sweat evaporates, the body loses fluids and electrolytes that it needs to be able to perform at its' highest level. Dehydration of 1-2% of total body weight begins to compromise physiologic function and negatively influence athletic performance. This level of dehydration is common in athletics, so common that it can occur after just an hour of exercise.[6] This level of dehydration causes a series of negative physiologic effects to occur such as decreased blood volume, increased heart rate, decreased stroke volume, thermoregulatory strain, stress response, perception of effort, hypovolemia, hyperosmolality, and a decrease in percentage of total work completed.[29-38] If further dehydration occurs, more impacts on performance can be observed. Dehydration of 3-4% of total body weight attenuates muscular strength by 2%, muscular power by 3%, and high intensity endurance by 10%.[13,15] Dehydration may also exacerbate physiologic strain even more during the recovery from exercise, which has severe implications for many conventional sports since these sports have a cycle of work and rest periods.[38]

With all of these marked decreases in performance that occur with dehydration, it is clear that hydration during athletic activity needs to occur. Historically, water has been the primary method of rehydration during athletic activity. More recently, however, commercially available carbohydrate-electrolyte sports drinks and carbohydrate protein drinks have started to make an impact with their claims that they rehydrate faster than plain water. These drinks also include electrolytes, such as sodium and potassium, which are also lost through sweat.[11] Each of these types of beverages has advantages depending upon the desired effect and the type of athlete consuming them.

In an athletic event, if sweat losses are not high and the goal of consuming a beverage is solely to limit dehydration to less than 2% of body mass, water is an appropriate choice.[15] Drinking a carbohydrate-electrolyte sports drink or carbohydrate protein drink during exercise of one-hour duration or less provides no ergogenic benefit due to the fact that there is not enough time for the nutrient and electrolyte inclusion to be digested and become available to the body.[11] Drinking plain water can improve performance in endurance events, but when carbohydrates and electrolytes are included, those improvements are enhanced even further.[15] Water also provides another advantage over protein beverages or sports drinks; with those drinks, there is potential to have gastrointestinal upset, which could negatively affect athletic performance. The ingestion of water eliminates this risk.[15] Other than the avoidance of gastrointestinal upset, water provides few advantages over carbohydrate-electrolyte sports drinks or carbohydrate protein drinks in athletic events lasting longer than one hour.

Sports drinks are typically formulated to prevent dehydration, supply carbohydrates to augment available energy, provide electrolytes to replace those lost during perspiration, and to be highly palatable. However, these potential benefits depend on what components of the ingested fluid enter the vascular system and how quickly this transport takes place. This exchange is dependent on the quantity of the beverage ingested, the time it takes for the drink to be emptied from the stomach, how long the drink takes to be absorbed from the intestine. The rate of absorption and gastric emptying is largely dependent upon the specific breakdown of the quantities of carbohydrates and electrolytes in the sports drink, with some ratios being more beneficial than others.[11]

The initial factor in determining how much water and substrate an athlete's body can absorb is how much liquid they drink. It has been concluded that the sole major benefit of commercial sports drinks is an increase in voluntary fluid intake, which results in prevention of a compromised hydration status.[16] Any carbohydrate content above 10% is perceived as too sweet and will therefore lead to less voluntary consumption.[12.39] Any content over 10% has been found to not only be non-palatable, but also to provoke gastrointestinal discomfort during intermittent high-intensity exercise.[40]

In terms of gastric emptying, there is conflicting data about which percentage of carbohydrate content is most beneficial. A large volume of fluid in the stomach stimulates emptying; however, increasing the carbohydrate content in a drink increases substrate availability, but decreases the availability of water.[41] The main point of drinking a sports drink is first and foremost rehydration, so if water is not being absorbed at the expense of substrate availability, the beverage is not fulfilling its' primary purpose.[41] Carbohydrate content of 6-8%, which is the amount present in current commercially available Gatorade products, has been found to be the ideal carbohydrate content to promote both water absorption and substrate availability.[11,41]

Another physiologic factor that encourages the use of sports drinks is osmolality. Solutions hypertonic to human plasma stimulate less water absorption and more secretion into the gastrointestinal lumen, which results in a potential for dehydration.[11,27] Conversely, hypotonic and isotonic solutions promote water absorption.[11,42-44] When sodium is added to a rehydration solution, it prevents the reduction in plasma osmolality that occurs with the ingestion of a large volume of plain water. The reduction in plasma osmolality is what prevents optimal fluid retention.[17,45,46] The inclusion of sodium in a rehydration beverage allows plasma osmolality to be at its' best possible level to encourage fluid retention.[17] Having high plasma osmolality aids in fluid retention because it encourages higher levels of net movement of water into the small intestine.[47,48] This movement of water into the small intestine is what ensures rehydration.[48]

The final physiologic factor that sports drinks have an impact on is glycogen, both usage and replacement. Glycogen is the basic fuel that gives athletes' muscles the energy they need to meet the demands being asked of them.[11] A decline in physical performance is observed when individuals are in a glycogen-depleted state compared to a glycogen-sufficient state.[11,49] There are multiple places that glycogen can be found in the body and utilized during activity. Glycogen can be stored in muscle and in the liver, or it can be in the bloodstream as plasma glucose. Plasma glucose is most readily available to be used as fuel because it is already in a form that can be used for energy. The glycogen stored in muscles and the liver can also be used for fuel, but it requires additional energy from the body to turn the glycogen back into glucose through gluconeogenesis.[11] However, ingesting carbohydrates during exercise, as would occur when drinking a sports drink during a game, can decrease endogenous carbohydrate oxidation from the muscle and liver as well as increasing glucose uptake.[11,18-21] These changes may prolong time to exhaustion, and thus increase athletic performance, by increasing muscle glycogen concentration, sparing muscle and liver glycogen, and causing a reduction in gluconeogenesis.[11]

With all of the physiologic advantages sports drinks can provide, there is a question of if these advantages are present under all performance conditions i.e. short-term exercise, intermittent exercise, and endurance exercise. Previously, the need for sports drink consumption for short-term exercise has been thought to be non-existent due to the fact that although short-term exercise is usually more intense, and thus relies heavily on carbohydrate metabolism, the substrate availability provided by sports drinks is unlikely to play a significant role in limiting exercise performance. In addition, the amount of water lost through sweat during short-term exercise is also small, which makes the need for fluid replacement minimal.[11,27] However, performance improvements have been shown with the combination of fluids and carbohydrates. While improvements occur with only fluid or only carbohydrates, the improvements seen with the combination of the two indicated that the effects in performance are additive.[11,50] So, while there is not a definitive answer whether sports drinks can improve performance in short-term exercise, there is enough evidence that supports this claim to not exclude sports drinks as an effective performance enhancement tool for sports such as track or baseball.

The second activity level to be considered in the usage of sports drinks is prolonged intermittent exercise. This type of exercise is defined as exercise consisting of repeated bouts of anaerobic performance separated by active recovery periods. This type of exercise places demands on both aerobic and anaerobic energy systems and more closely represents demands associated with competition such as soccer, ice hockey, volleyball, or lacrosse.[51] The time period of highest concern in this type of activity is the time at the end of the exercise session. This is the time that fatigue and lack of energy will take their toll, and also the time that a rehydration beverage could have the greatest effect. Research on this type of activity is difficult because no criterion standard exists for measurement of anaerobic work capacity, but there have been studies that have used commonplace anaerobic tests as a measure.[51] Performance in final sprint stages of exercise increases as the carbohydrate content of a rehydration beverage increases. The higher carbohydrate content beverages also corresponded to higher plasma glucose concentrations during the later stages of exercise.[11,52] These higher plasma glucose concentrations lead to the maintenance of carbohydrate oxidation, and thus, less gluconeogenesis. So, it can be concluded that sports drinks are an effective way to encourage high levels of performance in later stages of prolonged intermittent exercise, such as the kind that can be seen during many typical sporting events.

The final type of exercise to examine sports drinks' effect on is endurance exercise. This type of exercise is activity that lasts between 1-4 hours. It is difficult to quantify sports drinks' effect on this type of exercise for a variety of reasons. First, most carbohydrate beverages used to test performance in this type of athletic setting use a carbohydrate content far higher than what would be found in a commercially available sports drink. Current commercially available Gatorade has a carbohydrate content of 6%; most carbohydrate solutions used in the testing of endurance exercise use solutions with carbohydrate contents over 10%.[11] So, while this information may help those athletes who only participate in endurance events, it is not applicable to athletes who would regularly use commercially available products. However, it has been shown that consuming a commercially available sports drink prior to a 2 hour endurance event immediately followed by a sprint, led to faster sprinting times.[28] So, while most of the evidence supporting sports drinks' improvements on endurance activity is inapplicable to the regular collegiate age athlete, it can be concluded that sports drinks do a positive effect on performance in this type of exercise.

Within the last few years, there has been another rehydration solution that has made its way onto the market: a protein-carbohydrate solution. This product has the carbohydrate and electrolyte content of a typical commercially available sports drink, but includes protein as well. The reason for the inclusion of protein is the claim that it helps with two main physiologic functions, the first being fluid retention. In carbohydrate-protein solutions made with milk protein, it has been shown that there is increased fluid retention compared to carbohydrate-electrolyte sports drinks and water.[17,22,23] Similarly, commercially available carbohydrate-protein drinks have increased fluid retention compared to sports drinks and water.[17,53] This is believed to be due to the fact that casein, a component of milk protein, clots when exposed to gastric acid and that this clotting reduced the rate at which the carbohydrate-protein solution was emptied from the stomach.[17,54-57] This slowing of gastric emptying might have reduced the rate of entrance of water into the circulatory system and offset the reduction in plasma osmolality that occurs with the ingestion of high volumes of solution.[17,45,48,58,59]

The final physiologic advantage that carbohydrate-protein drinks have shown to impact is glycogen restoration. The theory behind this mechanism is that the addition of protein to a carbohydrate supplement will increase the efficiency of carbohydrate to increase the plasma insulin concentration and promote rapid restoration of muscle glycogen.[24-26] The earlier the intake of carbohydrate once the muscles start using glycogen is key because if the intake is immediate, the carbohydrate provides an immediate source of substrate to the muscle, while also taking advantage of the increased insulin sensitivity and membrane permeability of the muscle to glucose.[25,60-62] Adding protein to a carbohydrate mixture positively influences the rate of glucose synthesis.[62-65] This impact on glucose synthesis becomes even more pronounced when repeated bouts of exercise are performed. Muscle glycogen restoration was 128% greater and exercise performance 55% greater when a carbohydrate protein drink was consumed before the second round of a repeated bout of exercise compared to a traditional sports drink.[26,62]

The problem with much of hydration testing is that protocols that are followed are normally not transferrable to competition game play. For example, many testing protocols involve fasting prior to testing.[11] Any athlete, recreational, collegiate, or professional, would never partake in an extended fast before competition, so results garnered from studies that include a fasting period cannot be applied to normal athletes. In addition, as previously stated, many of the sports drinks tested used carbohydrate concentrations that exceed the concentrations found in commercially available drinks, which is what athletes will be consuming.[11] For results to be applicable to the majority of athletes, tests need to mimic an actual competition setting as closely as possible.

MATERIALS AND METHODS

Experimental Design and Setting:

This study was completed in a standard gymnasium at a major university. Participants completed a pre-participation questionnaire to determine their eligibility for participation in this study. Inclusion criteria were: (1) subjects between the ages of 18 and 24 years old, (2) a current recreational athlete who participates in at least 30 minutes of moderate intensity aerobic exercise at least once a week, (3) capable of running continuously for 30 minutes, and (4) capable of participating in broad jump, agility, and sprint testing. Exclusion criteria were: (1) minors under age 18, (2) history of fainting related to cardiovascular events, (3) cardiovascular history such as cardiomegaly, hypertension, or arrhythmias, (4) previous upper or lower extremity injury which withheld the subject from participation in their recreational activities for greater than four weeks within the past six months, (5) allergies to any ingredients in Gatorade and/or Accelerade, and (6) allergies to eggs, wheat, tree nuts, fish, milk, soy, crustaceans, or shellfish products. Before enrolling in the study, all participants signed a written informed consent form per Institutional Review Board guidelines.

Data was collected over three testing sessions, under one of three hydration beverage conditions. For all sessions, subjects were instructed to arrive hydrated, having not consumed caffeine, and having not exercised prior to their testing session. Over three weeks, subjects arrived and consumed one of three randomized drink conditions: 300 milliliters of water, 355 milliliters of Gatorade, or 355 milliliters of Accelerade. Subjects then remained sedentary for 30 minutes, so as to ensure absorption. Following the 30-minute rest period, subjects completed a 5-minute dynamic warm-up of the lower body. Subjects were instructed to make sure to stretch and warm-up the quads, hamstrings, calves, hip flexors, and gluteal complex. Subjects then ran continuously on an indoor track for 30 minutes. Immediately following the 30-minute run, subjects completed three rounds each of sprint testing, agility testing, and broad jump testing.

Subjects:

Seventeen participants, 8 males and 9 females (age = 21 ± 1.17 years of age) met all inclusion and no exclusion criteria and were enrolled in the study. Individual demographic data for each subject is listed in Table 1. The mean height for enrolled subjects was 171.52 ± 8.32 centimeters, mean weight was 70.32 ± 11.69 kilograms, and mean body mass index was 23.72 ± 2.11. There were no subjects in the underweight or obese categories as defined by the Body Mass Index Scale. There were certain individuals in the overweight category, which is defined as having a Body Mass Index score of 25 or higher, but the average for all subjects was in the normal weight category.

Table 1: Population Demographics

	Height (cm)	Weight (kg)	Body Mass Index
Subject 1	160.02	58.96	23.0
Subject 2	167.64	66.66	23.7
Subject 3	170.18	71.65	24.7
Subject 4	182.88	90.70	27.1
Subject 5	157.48	58.96	23.8
Subject 6	167.64	65.76	23.4
Subject 7	175.26	74.83	24.4
Subject 8	165.10	55.78	20.5
Subject 9	175.26	83.90	27.3
Subject 10	170.18	58.96	20.4
Subject 11	162.56	53.51	20.2
Subject 12	170.18	63.49	21.9
Subject 13	165.10	63.49	23.3
Subject 14	187.96	83.90	23.7
Subject 15	182.88	86.17	25.8
Subject 16	180.34	86.17	26.5
Subject 17	175.26	72.56	23.6
Average	171.52 ± 8.32	70.32 ± 11.69	23.72 ± 2.11

Testing Measures:

10-Yard Sprint:

The 10-yard sprint is a measure of anaerobic power, speed, and acceleration that has been proven to be a reliable measure of athletic performance.[66,67] During 10-yard sprint testing subjects were instructed to stand just behind the starting gate of a laser timing system (Laurel Timing Systems) to prohibit a running start. They were instructed to run as fast as they could through the finishing gate, slowing down only after they had passed through this last gate. Subjects completed three successive trials of this protocol.

Agility Drill:

The proagility run test is a measure of anaerobic power, the ability to increase and decrease speed rapidly, and the ability to change direction quickly. This test has been established to be a reliable measure of athletic performance.[66,67] During the proagility run test, subjects began by straddling a middle cone, then ran in the direction opposite their dominant foot for five yards and touched a far cone with their hand. They then quickly changed direction, sprinted past the middle cone, and touched a cone ten yards away from the cone they had previously left. They quickly changed direction and finished by sprinting through the starting middle cone (Figure 1). Time was measure with a handheld stopwatch. Subjects completed three successive trials of this protocol.

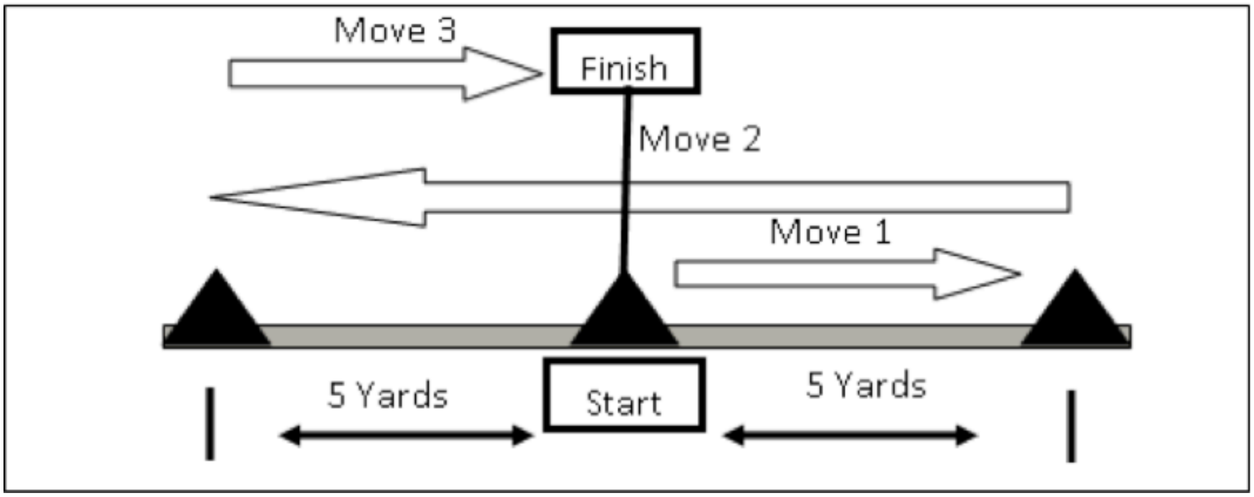


Figure 1: Movement pattern for the proagility run test

Broad Jump:

The standing broad jump is a measure of leg strength and power that has been established to be a reliable measure of athletic performance.[66,67] During the standing broad jump test, subjects were instructed to start with their toes behind a taped “start line.” When the subject was set, they jumped horizontally, taking off from both feet on their own command. The distance jumped was recorded from the start line to the point of heel contact or the closest body part measured to the nearest centimeter. Subjects completed three successive trials of this protocol.

Data Analysis:

Descriptive statistics, such as means and standard deviations were calculated using SPSS Version 21 software (SPSS IBM, New York, U.S.A.) for the dependent variables of interest. A one-way analysis of variance (ANOVA) was used to assess significance among the means. An *a priori* alpha level of $p < .05$ was used to denote statistical significance.

RESULTS

Seventeen recreationally active subjects (8 males, 9 females with a mean age of 21.0 ± 1.2 years and a mean Body Mass Index of 23.72 ± 2.11) participated in this study. Means and standard deviations of the anaerobic tests are provided in Table 2. In the anaerobic performance category of 10-yard sprint, water had a mean time of 1.76 ± 0.14 seconds, the carbohydrate-electrolyte sports drink had a mean time of 1.78 ± 0.14 seconds, and the carbohydrate protein drink had a mean time of 1.76 ± 0.15 seconds. These times lead to a .926 level of significance. In the agility drill category, water had a mean time of 5.42 ± 0.50 seconds, the carbohydrate-electrolyte sports drink had a mean time of 5.43 ± 0.44 seconds, and the carbohydrate protein drink had a mean time of 5.40 ± 0.40 seconds. These times lead to a .977 level of significance. In the broad jump category, water had a mean time of 204.51 ± 37.52 seconds, the carbohydrate-electrolyte sports drink had a mean time of 206.69 ± 36.44 seconds, and the carbohydrate protein drink had a mean time of 204.47 ± 33.57 seconds. These times lead to a .979 level of significance. The results of the ANOVA analyses showed that there were no significant differences between any of the drink conditions in any of the anaerobic performance measures. The 10-yard sprint showed the most significance in terms of performance increases with one type of beverage as opposed to the others, but it was still not statistically significant.

Table 2: Descriptive Statistics of Anaerobic Performance

	10-Yard Sprint (sec)	Agility Drill (sec)	Broad Jump (cm)
Water	1.76 ± 0.14	5.42 ± 0.50	204.51 ± 37.52
Carbohydrate-Electrolyte Sports Drink	1.78 ± 0.14	5.43 ± 0.44	206.69 ± 36.44
Carbohydrate Protein Drink	1.76 ± 0.15	5.40 ± 0.40	204.47 ± 33.57
Significance	.926	.977	.979

*denotes statistical significance ($p < 0.05$)

Figure 2: 10-Yard Sprint Performance

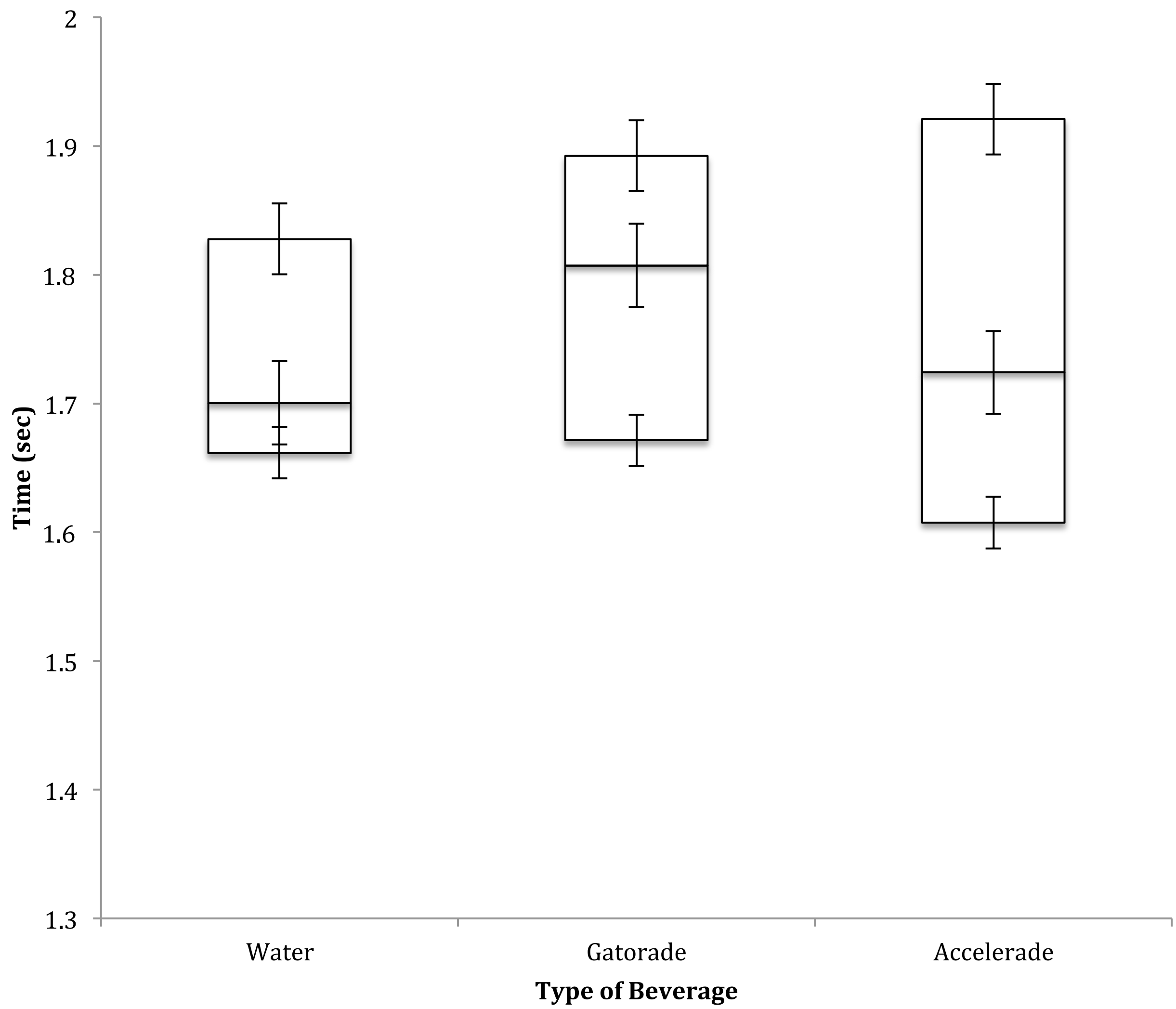


Figure 3: Agility Drill Performance

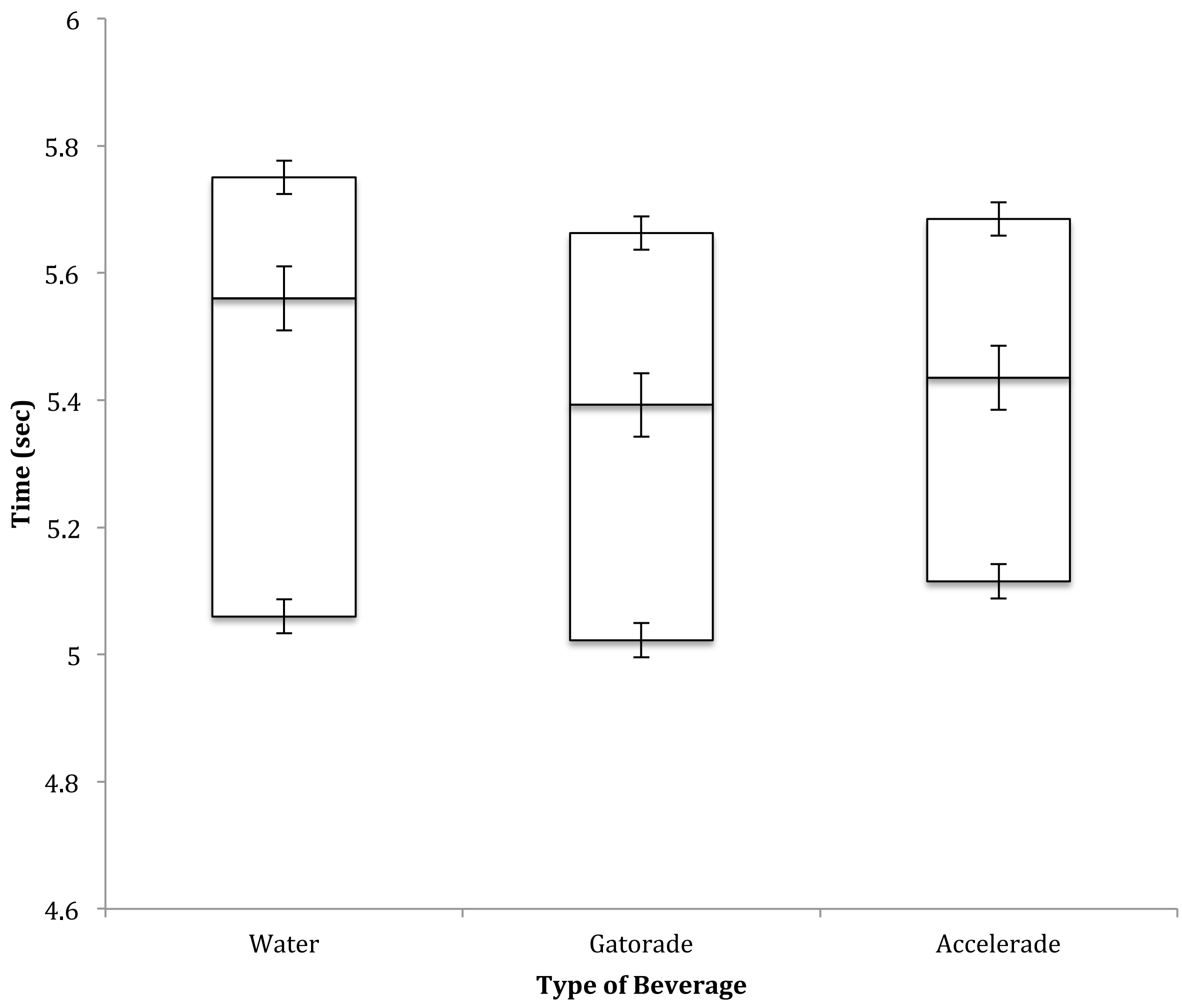
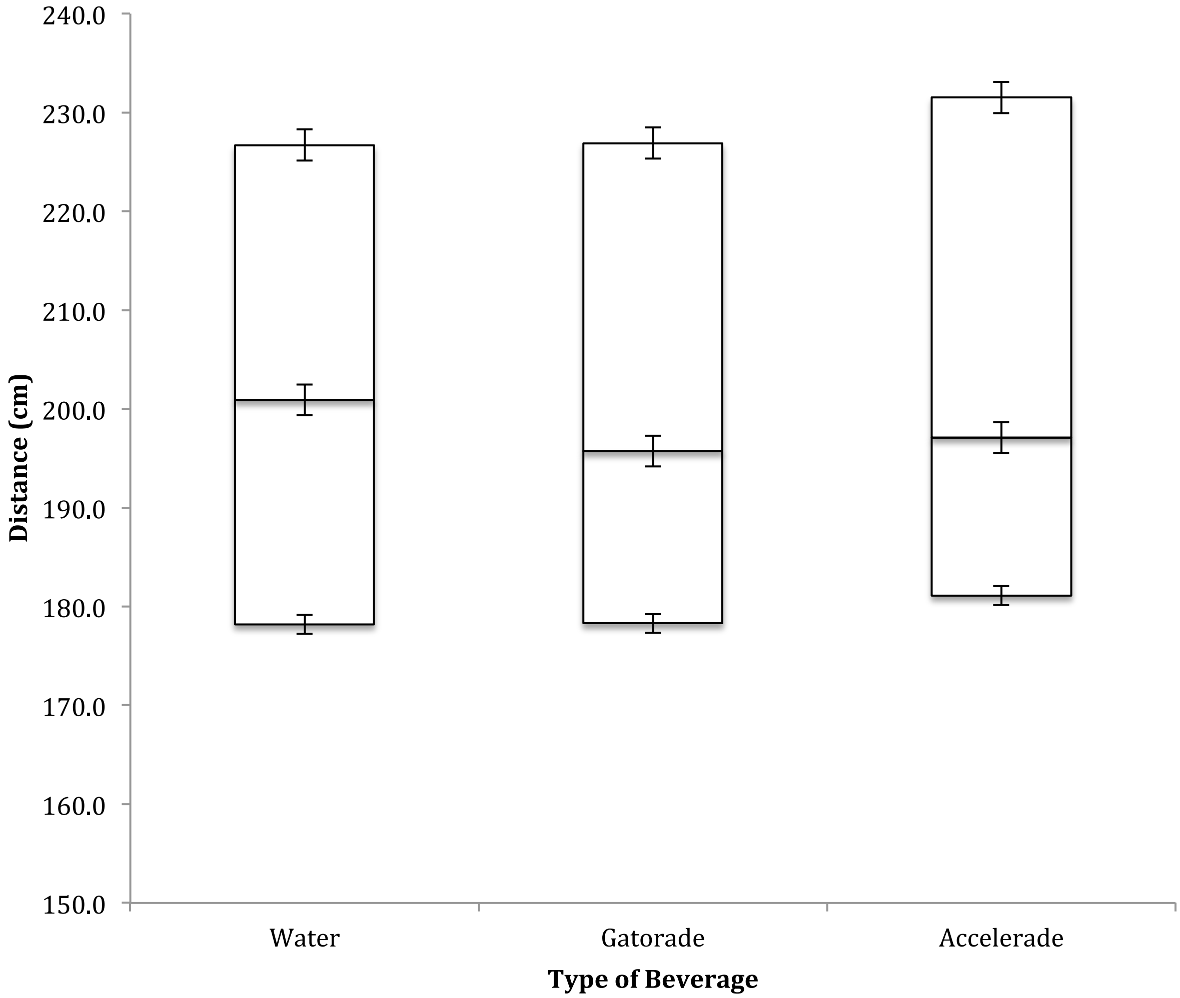


Figure 4: Broad Jump Performance



DISCUSSION

The purpose of this study was to compare three different types of hydration beverages and their effect on anaerobic performance measures performed after aerobic fatigue in physically active individuals. Active people are continually looking for ways to improve their performance, and hydration has the potential to be a factor in that improvement. In today's market, there are a myriad of beverages available that market themselves as being able to improve various aspects of athletic performance, and for an uneducated consumer, it can be confusing as to which, if any beverages actually promote improvements in athletic performance.

The identification of modifiable variables, including type of hydration beverage, that are associated with athletic performance is of interest to physically active individuals of all skill levels. Addressing hydration, which is a crucial part of athletic activity, may be an avenue to improve performance. This study sought to reveal the relation between type of hydration beverage consumed and anaerobic performance measures performed after aerobic fatigue. To this end, we assessed the relation between type of hydration beverage and three types of anaerobic athletic performance: sprint, agility, and broad jump.

Results show that there was no statistically significant difference for any anaerobic performance measure under any drink condition. This is contrary to some previous literature that shows performance improvements after consumption of a carbohydrate-electrolyte sports drink or a carbohydrate-protein drink compared to water. Past research has shown that performance in final sprint stages of exercise increases as the carbohydrate content of a beverage increases.[11,52] In addition, it has been shown that consuming a commercially available sports drink prior to a 2-hour endurance event immediately followed by a sprint led to faster sprint times than if water was consumed.[28] These results could be different from the results we found due to protocol differences. The carbohydrate content of the beverages in our study was 6%, whereas the concentration was higher in other studies. In addition, the aerobic activity in this protocol was only 30 minutes in duration compared to 2 hours.

Previous studies have shown an increase in performance when consuming a carbohydrate-protein drink compared to a carbohydrate-electrolyte sports drink in conditions that involve repeated bouts of exercise.[68] This is believed to be due to the enhanced glycogen resynthesis that occurs post-exercise.[26,68,69] However, previous research has yet to indicate that ingesting a carbohydrate-protein drink provides any performance benefits on single bouts of exercise. Our results corroborate this finding that in single bouts of exercise, ingestion of a carbohydrate-protein drink provides no ergogenic benefit over a carbohydrate-electrolyte drink or water.

The implications of this study are that for physically active individuals concerned with achieving high levels of anaerobic performance after aerobic fatigue, conditions that may occur in such activities as pick-up soccer or lacrosse, there is no need to buy expensive hydration beverages. Our study showed that in recreational athletes, if the goal is to have increased anaerobic performance, the type of beverage consumed does not have any effect on this type of performance. This information is key for physically active individuals because they are the type of athlete most commonly targeted by the marketing of these hydration products. Hydration products market themselves to every sort of athlete and lead them to believe that their consumption of a specific hydration product will lead to better athletic performance. Our results showed that is not the case.

To attempt to adjust for any variations in protocol, there were several delimitations in place. The first was the pre- and post-test food and drink guidelines. Subjects were instructed to consume no caffeine prior to testing and consume no alcohol for 24 hours prior to testing. This was to ensure that subjects were not consuming diuretics that would dehydrate them faster than normal. However, they were instructed to be sure to arrive to the data collection sessions being well hydrated. They were also instructed to eat as they normally would throughout the day to try to replicate conditions as they would occur before they would engage in their normal recreational activity. Next, the amount of liquid that was given to them during the data collection session was regulated. This was to ensure that the amount of liquid that they were consuming was in accordance with standards set by the National Athletic Trainers' Association in their position statement on hydration, which states 300 mL of liquid should be consumed 20 minutes prior to exercise. The protocol was lengthened to 30 minutes to ensure optimal absorption since no additional hydration would be provided during the remainder of the testing session. An additional delimitation was the type of beverage subjects consumed. Each subject consumed water, a carbohydrate-electrolyte beverage, and a carbohydrate-protein beverage. The carbohydrate-electrolyte beverage was the same flavor and had the same carbohydrate and electrolyte concentration for all subjects. The carbohydrate-protein beverage was the same flavor and had the same carbohydrate-to-protein ratio for all subjects.

In spite of efforts to ensure the consistency of the study, there were several limitations that could not be counteracted. The first was subject's BMI. We placed no restriction on BMI for inclusion in the study. So, people with different percentages of fat and fat free mass could react differently to the beverages given to them. Next, we could not control subjects' sweat rates. We did not measure sweat loss throughout the aerobic and anaerobic portions of the study, and we did not base the amount of drink provided off of individuals' sweat rates. A difference in sweat rate and fluid and electrolyte loss could have led to the inconsistent results that were found.

Another limitation was fitness level. While it was required for subjects to participate in moderate intensity aerobic exercise for at least 30 minutes once a week, there were no guidelines for a maximum amount of exercise an individual could participate in. So, it is possible that there were subjects who only participated in 30 minutes of exercise a week, or 300 minutes of exercise a week. This difference in fitness level could affect the level of exertion during the aerobic fatigue portion of the protocol, and thus affect sweat rates and glycogen usage as well. The final limitation was deviation from the timing of the protocol due to unforeseen complications such as illness or injury. If a subject were to be unable to participate in testing on their scheduled day, a make-up session was scheduled for the same day at the same time, but in subsequent weeks. So, while efforts were made to maintain continuity by having the testing done on the same day and at the same time, there was a longer time between sessions than was established in the original testing protocol. This was the case with two subjects who suffered illnesses during the testing protocol, so their data collection sessions had to be delayed a week.

While this study was helpful in adding to the knowledge base about hydration and its role in athletic performance, there is still much to be learned about this relationship. Future research on this topic should use trained subjects instead of recreationally active subjects. This would ensure that all subjects' fitness levels are not only equal, but that their bodies are physiologically used to strenuous demands being placed on them. This could lead to more efficient utilization of the hydration being provided to them. Next, subjects should be sport-specifically trained and the anaerobic performance measures should be tasks sport-specific to the subject pool. This would ensure that subjects are familiarized with the tasks being asked of them and would limit any training effects that could potentially be observed. Additionally, the aerobic fatigue portion of the protocol should be longer or utilize repeated bouts of aerobic activity. These types of activities would more closely mimic actual game-play conditions than one singular 30-minute bout. Testing protocols should also continue to use commercially available hydration beverages. These are the types of beverages that will be purchased by individual athletes or sports teams for use, so these are the ones that should be included in protocols looking at relationships with performance. Finally, the applicability of fasting and non-fasting protocols should continue to be examined to see if it is possible to get repeatable and reliable information from studies that use a more clinically relevant non-fasting protocol, or if fasting protocols are necessary to achieve reliable data.

CONCLUSION

Previous researchers have looked at consumption of different types of hydration beverages and their effect on athletic performance, but this is one of the few studies to use commercially available products and a protocol using clinically relevant performance methods. Although the current findings do not support a relation between type of hydration beverage and anaerobic performance measures performed after aerobic fatigue, there is more to examine in this area of study. The investigators of this study found that there were no statistically significant differences in 10-yard sprint, agility drill, or broad jump performances under any drink condition. However, type of hydration beverage still remains an easily modifiable factor that has the potential to aid in athletic performance. Further research is needed to substantiate this possibility. Continued clinically applicable studies, such as those using commercially available products and using sport-specific protocols are a likely next step to determine if a relationship exists.

APPENDICES

A: INFORMED CONSENT

CONSENT FOR RESEARCH
The Pennsylvania State University

Title of Project: Comparison of different modes of hydration on anaerobic performance following aerobic fatigue in collegiate recreational athletes

Principal Investigator: Kara Saylor

Address: 850 Toftrees Ave Apt. 931 State College, PA 16803

Telephone Number: (724) 882-0335

Advisor: Dr William Buckley

Advisor Telephone Number: (814) 863-9730

Subject's Printed Name: ______________________________

We are asking you to be in a research study. This form gives you information about the research.

Whether or not you take part is up to you. You can choose not to take part. You can agree to take part and later change your mind. Your decision will not be held against you.

Please ask questions about anything that is unclear to you and take your time to make your choice.

1. **Why is this research study being done?**

   We are asking you to be in this research because you are a healthy recreationally active college student who regularly is exposed to different modes of hydration during activity.

   This research is being done to find out if there is a mode of hydration that is best to promote anaerobic performance.

2. **What will happen in this research study?**

Initial Familiarization Meeting

- Given information of the methods to be used in the study.
- Given informed consent paperwork and instructed to read, sign, and turn in the paperwork to the PI's office in Rec Hall if you are interested in participating. You will have one week to turn in this paperwork from the time of this meeting if you wish to participate.
- If you wish to participate, at the time that you turn in the informed consent paperwork, please provide a schedule with your availability so that the PI can make a schedule of testing times.
  In addition to the informed consent paperwork and availability, please turn in your e-mail address and a phone number and indicate which is your preferred method of communication so that the PI can communicate with you to inform you of your data collection time. This information will also be used in the unlikely event that the PI would have to cancel a session.
- You will be given a Pre-Participation Questionnaire and will be instructed to go into the athletic trainer's office in the Multi Sport Facility athletic training room and complete the questionnaire with the door closed. The PI will then review the questionnaire with you to ensure that there are no issues that would exclude you from participation in this study.

Second Meeting

- The PI will contact you via your preferred method of communication to arrange this first testing session. You will keep the same time throughout the duration of the testing. For example, if you come in for this second meeting on a Monday at 7:00am, you will come every Monday at 7:00am for the remainder of the testing.
- You will be instructed that you cannot consume any alcohol, carbonated beverages, Gatorade, or protein supplement beverages prior to your testing session that day. You also will be reminded that you are not to have worked out prior to your testing session that day. These will be the limitations for every testing session for the remainder of the study.
- You will be given a cup and instructed to go to the restroom and produce a urine specimen.
- Researcher will immediately test urine specific gravity. This is a common urinalysis test to determine your hydration status. Researcher will immediately dispose of the specimen in the toiler and dispose of the cup in a biohazard container following urinalysis.
- If hydration status is adequate (1.000-1.020) and you are eligible to continue in the research you will step onto the scale in the Multi Sport Facility athletic training room with males in spandex only and females in spandex and sports bra only.
- You will then either drink 300 mL of water, 355 mL of Gatorade, or 355 mL of water and Accelerade mixture. You will drink each of the three drinks, but the order in which you drink them will be randomized across the duration of the study. The principal investigator will be unaware which drink you are consuming during which session.
- Wait 30 minutes to ensure absorption of drink, during which time you must remain sedentary.

- You will then complete a five-minute warm-up that includes jogging two laps around the track at a comfortable speed and static stretching of the quadriceps, hamstrings, hip flexor, groin, and gluteal complex.
- You will then run continuously on the Multi Sport track for 30 minutes at or above 75% of your heart rate maximum. Your heart rate will be monitored via a Polar heart rate monitor
- If you fail to complete the run, testing will be terminated for that day, and you will be given the option to come back in a week to repeat the test under the same conditions
- You will complete three broad jumps on Multi Sport turf
- You will then complete three rounds of an agility drill on the Multi Sport turf, which consists of you sprinting 5 yards in the direction of your dominant leg, 10 yards in the opposite direction, then 5 yards again in the direction of your dominant leg
- You will then complete three 10-yard sprints on the Multi Sport turf
- Return to athletic training room and step onto scale with males in spandex only and females in spandex and sports bra only.

Third Meeting

- Same protocol as in second session, only you will consume the second of the three drinks randomly assigned to you and will not complete another questionnaire.

Fourth Meeting

- Same protocol as in second session, only you will consume the last of the three drinks randomly assigned to you and you will not complete another questionnaire.

Final Meeting

- Same protocol as in second session, only no additional hydration will be provided and you will not complete another questionnaire.

The principal investigator will check in with you two days after the final meeting to ensure that you are experiencing no side effects as a result of this study.

3. What are the risks and possible discomforts from being in this research study?

Risks

- Muscle strain injury
- Allergic reaction to ingredients in Gatorade and/or Accelerade
  - Abdominal cramps
  - Watery eyes
  - Itchy skin rash
  - Hives
  - Wheezing

Discomforts

- Unpleasant taste of beverages
- Delayed onset muscle soreness

There is a risk of loss of confidentiality if your information or your identity is obtained by someone other than the investigators, but precautions will be taken to prevent this from happening.

4. What are the possible benefits from being in this research study?

4a. What are the possible benefits to you?

You can become better informed on if there is a mode of hydration that is best for promoting anaerobic performance following aerobic fatigue: a condition that may be experienced in recreational activity.

4b. What are the possible benefits to others?

The results of this research may guide the future of hydration's role on performance relating to sports that include both aerobic and anaerobic components. It can advise athletes, coaches, athletic trainers, and other individuals involved in sport as to the best mode of hydration for the type of activity they are trying to promote.

5. What other options are available instead of being in this research study?

You may choose not to be in this research study.

6. How long will you take part in this research study?

If you agree to take part, it will take you about 4 weeks to complete this research study. You will be asked to return to the research site 4 times.

7. How will your privacy and confidentiality be protected if you decide to take part in this research study?

Efforts will be made to limit the use and sharing of your personal research information to people who have a need to review this information.

- A list that matches your name with your code number will be kept in a locked file or password protected file. This file will be kept in a locked filing cabinet in the men's hockey athletic trainer's office.
- Your research records will be labeled with your code number and will be kept in a locked cabinet in the principal investigator's office.

In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared.

We will do our best to keep your participation in this research study confidential to the extent permitted by law. However, it is possible that other people may find out about your participation in this research study. For example, the following people/groups may check and copy records about this research.

- The Office for Human Research Protections in the U. S. Department of Health and Human Services
- The Institutional Review Board (a committee that reviews and approves research studies) and
- The Office for Research Protections.

Some of these records could contain information that personally identifies you. Reasonable efforts will be made to keep the personal information in your research record private. However, absolute confidentiality cannot be guaranteed.

8. What are the costs of taking part in this research study?

8a. What will you have to pay for if you take part in this research study?

You will incur no extra expense for participation in this study.

8b. What happens if you are injured as a result of taking part in this research study?

In the unlikely event you become injured as a result of your participation in this study, medical care is available. It is the policy of this institution to provide neither financial compensation nor free medical treatment for research-related injury. By signing this document, you are not waiving any rights that you have against The Pennsylvania State University for injury resulting from negligence of the University or its investigators.

9. Will you be paid to take part in this research study?

You will not receive any payment or compensation for being in this research study.

10. Who is paying for this research study?

The institution and investigators are not receiving any funds to support this research study.

11. What are your rights if you take part in this research study?

Taking part in this research study is voluntary.

- You do not have to be in this research.

- If you choose to be in this research, you have the right to stop at any time.
- If you decide not to be in this research or if you decide to stop at a later date, there will be no penalty or loss of benefits to which you are entitled.

During the course of the research you will be provided with any new information that may affect your health, welfare or your decision to continue participating in this research.

12. If you have questions or concerns about this research study, whom should you call?

Please call the head of the research study (principal investigator), Kara Saylor at (724) 882-0335 if you:

- Have questions, complaints or concerns about the research.
- Believe you may have been harmed by being in the research study.

You may also contact the Office for Research Protections at (814) 865-1775, ORProtections@psu.edu if you:

- Have questions regarding your rights as a person in a research study.
- Have concerns or general questions about the research.
- You may also call this number if you cannot reach the research team or wish to talk to someone else about any concerns related to the research.

INFORMED CONSENT AND AUTHORIZATION TO TAKE PART IN RESEARCH

Signature of Person Obtaining Informed Consent

Your signature below means that you have explained the research to the subject or subject representative and have answered any questions he/she has about the research.

______________________________	__________	______	________________
Signature of person who explained this research	Date	Time	Printed Name

(Only approved investigators for this research may explain the research and obtain informed consent.)

Signature of Person Giving Informed Consent and Authorization

Before making the decision about being in this research you should have:

- Discussed this research study with an investigator,
- Read the information in this form, and
- Had the opportunity to ask any questions you may have.

Your signature below means that you have received this information, have asked the questions you currently have about the research and those questions have been answered. You will receive a copy of the signed and dated form to keep for future reference.

Signature of Subject

By signing this consent form, you indicate that you voluntarily choose to be in this research and agree to allow your information to be used and shared as described above.

____________________	________	______	______________
Signature of Subject	Date	Time	Printed Name

B: SCREENING QUESTIONNAIRE

Pre-Participation Questionnaire

1. Do you have any known allergies to any ingredients in Gatorade and/or Accelerade?

   Yes No

2. Do you have a history of fainting related to cardiovascular events?

   Yes No

3. Do you have a cardiovascular history of conditions such as cardiomegaly, high blood pressure, or irregular heart rhythms?

   Yes No

4. Do you have any other conditions that may prevent you from participating in this study?

   Yes No

5. Do you have any known allergies to eggs, wheat, tree nuts, fish, milk, soy, crustaceans or shellfish products?

   Yes No

____
Subject Printed Name

____
Subject Signature

____
Date

Thank you! The principal investigator will discuss your answers of this questionnaire with you.

C: DATA COLLECTION SHEET

Data Collection

Subject: _________________________

Visit 1

Hydrated: Yes _______ No _______

Sprint Time (sec)

Trial 1: ________________ Trial 2: ________________ Trial 3: ________________

Agility Drill (sec)

Trial 1: ________________ Trial 2: ________________ Trial 3: ________________

Broad Jump (cm)

Trial 1: ________________ Trial 2: ________________ Trial 3: ________________

Visit 2

Hydrated: Yes _______ No _______

Sprint Time (sec)

Trial 1: ________________ Trial 2: ________________ Trial 3: ________________

Agility Drill (sec)

Trial 1: ________________ Trial 2: ________________ Trial 3: ________________

Broad Jump (cm)

Trial 1: ________________ Trial 2: ________________ Trial 3: ________________

Visit 3

Hydrated: Yes _______ No _______

Sprint Time (sec)

Trial 1: ________________ Trial 2: ________________ Trial 3: ________________

Agility Drill (sec)

Trial 1: ________________ Trial 2: ________________ Trial 3: ________________

Broad Jump (cm)

Trial 1: ________________ Trial 2: ________________ Trial 3: ________________

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