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The Physiological Effects of Gatorade® Versus Diluted Fruit Juice during Exercise: A Preliminary Study

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Abstract

Fluid replacement is an important consideration during physical activity. While a good portion of exercisers rely on prepared sports beverages, there are other consumers that may prefer more natural methods (fruit juice) of hydration. Diluted fruit juice can provide the nutrients that are found in prepared sports beverages but also provide antioxidants normally found in juices. This preliminary study (10 participants) investigated the organoleptic acceptability, economic cost and effectiveness of diluted fruit juice in sustaining and/or improving physical activity of moderate intensity. Results indicated that diluted fruit juice rated higher for fullness compared to a popular sports beverage (Gatorade ®), or water; comparable in physiological effects during exercise and was economically competitive. This study provides consumers insight into alternatives to prepared sports drinks for fluid replacement during physical activity.

Keywords: Fluid replacement; Exercise nutrition; Sports beverages

Introduction

It is well known that adequate hydration is important during exercise. There have been a number of approaches to maintain adequate hydration during exercise, including water alone and water with various supplements, such as carbohydrates and electrolytes. Sports beverages have secured a place within the health and fitness world as a supplement with numerous benefits for athletes and consumers[1-3]. There is widespread marketing of sports drinks, and consumer choice may be influenced by cultural preference and availability.

The goal of fluid replacement during exercise is to prevent extreme dehydration, to minimize changes in electrolyte balance and to maintain optimum performance. The electrolytes present in sweat serve three major functions: controlling water movement, maintaining the acid-base balance required for cell activity and providing the micronutrients necessary for the body [4].

Carbohydrate supplementation is also essential during exercise. Carbohydrate intake is recommended for intense "stop and start" sports or for exercise lasting over 60 minutes[5]. In prolonged exercise, performance is improved by the addition of an energy source in the form of a carbohydrate[6, 7]. Various studies have displayed that consuming glucose during prolonged; intense exercise will maintain or increase circulating plasma glucose and ultimately prevent hypoglycemia[8, 9]. If exercise performance is impaired by limited liver or muscle glycogen stores, exercise capacity could be improved through carbohydrate ingestion(7). In a study by Khana et al., the effects of oral-electrolyte supplementation on sports performance and cardiovascular status were tested on 10 male athletes[10].

They found that total time of endurance exercise, heart rate response and blood lactate at 70 % VO2 max for participants, increased significantly following the ingestion of 24 ounces of a 5 % carbohydrate-electrolyte drink supplement.

Carbohydrate, water and electrolyte solutions are essential for optimal performances (15). The two most identifiable factors responsible for exercise-induced fatigue are depleted carbohydrate reserves in the body and dehydration resulting from water and electrolyte losses in sweat (11). Carbohydrate-electrolyte sports drinks have been designed to address these factors. They are commonly referred to as isotonic drinks because their solute concentration is similar to that of blood (11). While there has been ample study on exercise performance and fluid intake, there are mixed reviews of beverages labeled as sports beverages. Coso et al., [11] tested seven endurance-trained cyclists with prolonged cycling in a heated environment and discovered that the use of Gatorade® preserved leg maximal voluntary isometric contractions (measure of peak force) whereas mineral water did not. Shirreffs et al., [12] took eight healthy, active participants and tested the effectiveness of three beverages in restoring fluid and electrolyte balance (Gatorade®, a carbonated water/apple-juice mixture (Apfelschorle) and San Benedetto and Evian mineral waters with intermittent exercise. The water/apple-juice mixture (Apfelschorle) is a commercially available product available in Europe and Germany. Four hours after rehydration, the participants were in significantly lower hydration status than the pretrial situation on trials with Apfelschorle (–365 ± 319 mL, P = 0.030), Evian (–529 ± 319 mL, P< 0.0005), and San Benedetto (–401 ± 353 mL, P = 0.016) but were in the same hydration status as before the dehydrating exercise on Gatorade (–201 ± 388mL, P = 0.549)[12].

Sports beverages are intended to maximize absorption of both fluid and carbohydrates to counterbalance fluid lost in sweat and as well as supplement the body's carbohydrate stores. Gisolfi et al., reported that solutions containing 2, 4, or 6% glucose, sucrose, maltodextrins, or corn syrup solids produce similar rates of water absorption within the intestines, while hypertonic solutions of 8% glucose or corn syrup solids, may reduce water absorption. Optimally, a 6% carbohydrate-electrolyte solution facilitates the delivery of carbohydrates and electrolytes and enhances digestion and absorption (16). Phillips et al., found that consumption of a 6% carbohydrate-electrolyte (CHO-E) solution on intermittent, high-intensity endurance, resulted in 24.4% increase in time to fatigue and significantly greater distance covered when the CHO-E solution was ingested versus the non-carbohydrate solution[13].

Since 50% diluted fruit juice possesses a carbohydrate percentage comparable to commercial sports beverages, it may be a sufficient means of fluid replacement during exercise. While fruit juice lacks the electrolytes present in sports beverages, these electrolytes can be fortified through the addition of table salt. Fruit juice is a drink that is easily accessible, affordable, and present in many households.

The purpose of our study is to determine if diluted fruit juices are potentially as effective as commercial sports beverages in sustaining and improving performance in a moderate, intensity activity as evaluated by the rate of perceived exertion in athletes. Our hypothesis is that there will not be a significant physiological difference in participants during exercise between those who consumed Gatorade® and those who consumed 50% diluted apple juice.

Although sports beverages have provided a great convenience for the serious athlete or physical activity participants, these commercial supplements may not be the only effective means to replenish water, electrolytes and glucose. A simple substitute for sports beverages like Gatorade® and Powerade® could be whole fruit juices diluted and mixed with table salt to provide electrolytes. Gatorade® yields a 6% carbohydrate solution while apple juice diluted 50% yields a 5.9% carbohydrate solution, a comparable amount. A diluted juice beverage that is shown to be as effective as a commercial sports supplement in sustaining and improving performance, could have financial incentive with the consumer and provide additional nutrients and beneficial phytochemicals not found in commercial sports beverages. A 64 fl oz. bottle of Gatorade® G series Thirst Quencher 02 Perform, costs $2.19 (New York State tax included) or $0.034 per fluid ounce. In contrast, a 64 fl oz. bottle of Wegman's Food Market's brand apple juice costing the same amount yields 128 fl oz. when diluted by 50% with water equates to $0.017 per fluid ounce (as diluted to equate to composition of sports beverages).

Objectives:

1.To compare the effectiveness of the juice –based sports supplement in sustaining and improving performance during a one hour session of physical activity, with the effectiveness of plain water and a commercial sports beverage.

2.To determine the organoleptic acceptability of the juice –based sports supplement as compared to a commercial sports beverage.

3.To examine the economic value of consuming 50% diluted apple juice vs. purchasing a sports beverage.

Materials & Methods

Participants

Fourteen participants, between the ages of 21-56 were recruited and 11 participants (9 females and 2 males) returned signed consent forms. A total of 10 participants were chosen based on their good health status and their personal interest in the study. Recruiting forms were created and distributed within the Buffalo State campus and also through email to individuals who showed interest in participating.

Exclusion criteria included: any present medical condition that may pose a risk for physical activity, inability to perform exercise required in study protocol, participant unwillingness to participate in the study and failure of subjects to receive medical clearance from their primary physician.

Participants were recreationally active prior to the initiation of the study protocol. Each subject received an individual orientation to the study by the primary investigator. Participants were informed of the study purpose and all questions were answered before informed consent was obtained to

participate in the study. The study protocol was approved by The Institutional Review Board for Research Involving Human Subjects.

Supplementation

Each exercise session required the participants to consume 24 fluid ounces of either water (tap or bottled per participant choice); Gatorade® or 50% diluted apple juice. The 64 ounces of fruit juice was diluted with 64 ounces of water with the addition of 1648-1698 mg (.7-.72 tsp) sodium chloride and held in 128 fluid ounce containers. Carbohydrate content is similar to Gatorade®.

The carbohydrate solution for each gallon of juice was calculated as 5.92%. The Gatorade® chosen was orange flavored because of its easy accessibility. To make the juice indistinguishable from Gatorade®, food coloring (red and yellow) was used to assure that the Gatorade® and apple juice looked identical. 6 drops of red food coloring and 10 drops of yellow food coloring were added to the 128 fluid ounces of the diluted fruit juice. Once the juice was prepared, the Gatorade® and juice were poured into the 20 water bottles. The juice and Gatorade® were differentiated by the removal of the water bottle labels from the bottles containing juice. Participants were unaware of this coding system. Study protocol informed participants that they were to consume a total of 24 ounces in the 60 minute exercise period.

Instrumentation

Prior to the exercise testing sessions, participants were instructed on the use of the Polar FT4 heart rate monitor and its settings. Baseline, exercise, and post exercise measurements were taken using the heart rate monitor and a Borg rating of perceived exertion (RPE) scale. Participants performed the exercise portion on treadmills in a fitness facility of their choosing. Participants were instructed to follow the exercise protocol. The following formula was used to estimate maximum heart rate and subsequent target heart rate based on required percent exercise intensity, as per protocol:

Maximum heart rate (HR) = 220 - age

Target HR= [(Maximum HR- Age) *Exercise intensity%]

Procedure

Prior to attendance, target heart rate was calculated based on the above formula. Each participant walked with exercise intensity between 60-85% of their heart rate reserve. The treadmill walk began at an incline grade of 5 % and speed was adjusted to reach target heart rate range. Each subject completed three separate, 60 minute treadmill, walking sessions. Each session was dedicated to water, Gatorade®, or 50% diluted apple juice consumption and the assignment of supplement order per session was randomized. Heart rate (HR) and RPE were recorded by the participants every 15 minutes during their treadmill walking. They were instructed to consume the 24 ounces of fluid during the 60 minute period of exercise.

Three assessment forms were developed for the participants to complete during the study. One form was a taste test evaluation to be performed at the end of the exercise session. The participants were to measure the three beverages (water, Gatorade®, or 50% diluted apple juice) on taste, tolerance, fullness and satisfaction of the three drinks they consumed at each session. Fullness was described as any feelings of satiety caused by consumption of the drink, tolerance was described as the palatability of each drink, and satisfaction was defined as feelings of hydration or dehydration while exercising. The second form was a performance assessment that allowed each participant to record the date and time they exercised, location, incline gradient and speed of treadmill, length of time, heart rate, and perceived exertion while exercising every 15 minutes. There was also a space provided at the bottom of the form for comments regarding each exercise session or feelings while exercising. Once each participants target heart rate range was calculated, it was written at the top of this form for reference, during the participant's exercise session. The third form was a copy of the Borg RPE Scale which was used to measure their perceived exertion while exercising. It was not specified as to how much of each drink would have to be consumed at a particular time during their exercise, however the participants were encouraged to drink throughout their exercise session and complete the 24 ounces assigned by the end of the session.

Each participant was provided study protocol prior to beginning the study. The participants were given a Polar FT4 heart monitor, 3 taste test evaluations (one for each drink), a performance assessment form, a Borg RPE Scale table and a bottle of juice, Gatorade® and water. Each drink was assigned a particular number. Gatorade® was assigned as #1, Diluted Juice #2 and Water #3. A table was constructed to record in what order each drink was assigned to each participant. For convenience, the participants were allowed to obtain 24 ounces of water from any area they desired. Usage of either the Gatorade® or fruit juice bottle for measurement was suggested because their volume was exactly 24 fl. ounces. As indicated, each participant was shown how to operate the heart monitor and then asked if they had any questions or comments.

Statistical Analyses

Using IBM SPSS and Microsoft Excel, our study compared the physiological changes between consumption of Gatorade®, water and 50% diluted apple juice during a 60-minute exercise session. The data utilized in this comparison was heart rate and rate of perceived exertion using the Borg RPE Scale.

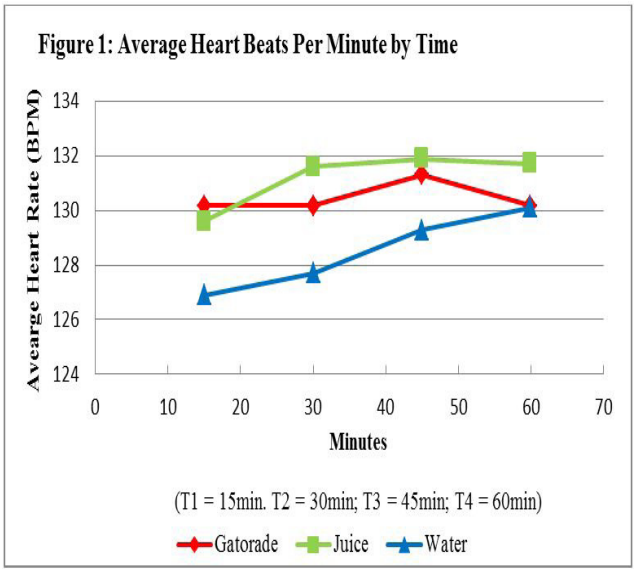
Results

The average participant heart rate for Gatorade®, juice and water was 130.5, 131.2- and 128.5 BPM (beats per minute), respectively (Table 1). The average participant Borg RPE for Gatorade®, juice and water was 11.6, 11.5 and 11.1 respectively (Table 1). The correlation between the mean heart rate and mean Borg RPE across the ten participants for Gatorade®, juice and water were .21, .18, and .45 respectively (Table 1). One-Way Repeated-Measures ANOVA (General Linear Model) was done for all six conditions: Juice, Gatorade and Water for heart beats per minute and Borg RPE Scale of perceived exertion.

Gatorade® N=10 Participants	Average HR	Average Borg	Standard Deviation HR	Standard Deviation Borg	Correlation Between HR & Borg
T1: 15 minutes	130.2	10.80	14.35	1.23	.21
T2: 30 minutes	130.2	11.10	15.06	1.73	
T3: 45 minutes	131.3	12.10	12.83	1.73	
T4: 60 minutes	130.2	12.50	14.99	2.32	
Average	130.5	11.63	13.34	1.54	
Diluted Juice N=10 Participants	Average HR	Average Borg	Standard Deviation HR	Standard Deviation Borg	Correlation Between HR & Borg
T1: 15 minutes	129.6	10.40	14.86	1.90	.18
T2: 30 minutes	131.6	11.30	14.46	1.64	
T3: 45 minutes	131.9	11.90	13.75	1.37	
T4: 60 minutes	131.7	12.40	14.64	1.35	
Average	131.2	11.50	13.43	1.14	
Water N=10 Participants	Average HR	Average Borg	Standard Deviation HR	Standard Deviation Borg	Correlation Between HR & Borg
T1: 15 minutes	126.9	9.80	16.33	1.62	.45
T2: 30 minutes	127.7	10.60	17.82	2.12	
T3: 45 minutes	129.3	11.70	15.88	1.70	
T4: 60 minutes	130.1	12.40	16.98	2.46	
Average	128.5	11.13	15.95	1.80	
HR – heart rate; Borg – Borg rating of perceived exertion (RPE)					

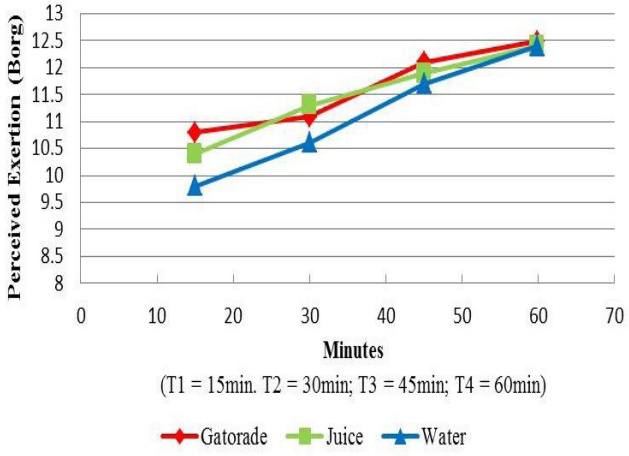
Table 1: Descriptive Statistics of Biological Measures

There was no significant difference between groups for heart rate or Borg score. Heart rate did not significantly change from T1 at 15 minutes to end of physical exercise over time in any of the conditions. Post hoc contrasts showed the greatest change, but non-significant, in heart rate was between the 15 minute and 30 minute interval for Juice and between the 30 minute and 45 minute interval for both Gatorade and Water. (Figure 1) There was a significant change in perceived exertion as measured by the Borg Scale for Juice, Gatorade and Water over the four time intervals. (Figure 2) The ANOVA showed that the Borg Score was significantly different over time for Juice, $F(3, 27) = 4.668$, $p=.009$. Repeated measures t-tests showed that participants' perceived exertion was steadily increasing for each time period, with a slightly higher increase between the 15 minute and 30 minute interval. The ANOVA showed that the Borg Score was significantly different over time for Gatorade, $F(3, 27) = 5.695$, $p=.004$. Repeated measures t-tests showed that participant's perceived exertion was steadily increasing for each time period, with a slightly higher increase between the 30 minute and 45 minute interval. The ANOVA showed that the Borg Score was significantly different over time for Water, $F(3, 27) = 13.110$, $p<.000$. Repeated measures t-tests showed that participant's perceived exertion was steadily increasing for each time period, with a slightly higher increase between the 30 minute and 45 minute interval. It is interesting to note that for



Juice, both the average heart beats per minute and Borg Score increased the greatest between the 15 and 30 minute interval, while for Gatorade and Water the greatest increase was between the 30 and 45 minute interval. A paired-samples T-Test was conducted on the following mean Heart Rate pairs: juice – Gatorade, Gatorade – water, and juice – water. There was no significant difference between any heart rate pair. A paired-sample T-test was conducted on the same pairs for mean Borg Scale scores. There was no significant difference in any Borg pair.

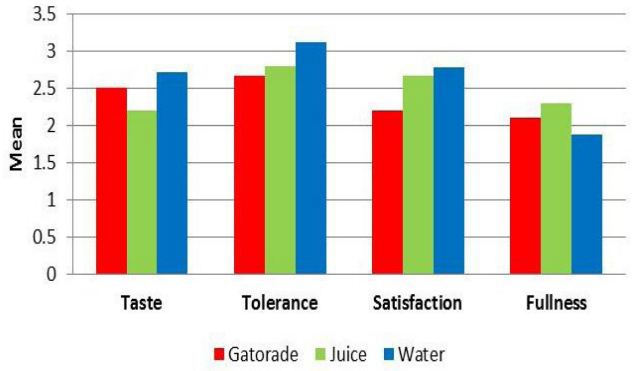
Figure 2: Perceived Exertion Scale (Borg) by Time



The 10 participants were asked to rate three beverages on taste, tolerance, satisfaction and fullness. The rating scale included "no opinion" which was recoded for "missing" so not to influence the average scores, minimal (1), average (2), good (3), and excellent (4). Paired-sample t-tests were conducted to determine if there were significant differences in the means of the three different beverages for each of the drink attributes. There were no differences in the taste, tolerance, satisfaction or fullness.

Figure 3: Drink Evaluation

Taste, Tolerance, Satisfaction and Fullness.



Fullness was described as any feelings of satiety caused by consumption of the drink, tolerance was described as the palatability of each drink, and satisfaction was defined as feelings of hydration or dehydration while exercising.

Discussion

The sports beverage industry has gained tremendous momentum over the past years in sports nutrition. Marketing of sports nutrition sources is a multimillion dollar industry but consumers interested in the health benefits of traditional foods may be uncertain of the benefits of sports nutrition through diluted fruit juice. This study investigated the effectiveness of diluted fruit juice in sustaining and/or improving sports performance during one hour sessions of physical activity as well as examining the organoleptic acceptability of the beverage and comparing the economic value of such a beverage versus water and a popular sports beverage. The results presented broaden the literature published on beverage utilization in physical exercise and provides consumers insight into alternative to prepared sports drinks and provides consumers with insight into alternatives to prepared sports drinks.

Performance Effectiveness

There was no significant difference between groups for either heart rate or Borg score in this study. Other studies show similar results. Bachle et al., showed there to be no significant effect on heart rate, rate of perceived exertion, sweat rate and power output between no water, water and Gatorade ® supplementation during 60 minute cycling sessions with 11 physically active, but not competitive, men and women participants[14]. The study results suggested that fluid replacement during 1 hour of moderately intense exercise in physically active men and women did not produce any meaningful effects on heart rate and rate of perceived exertion between groups. Bonetti et al., reported no significant differences in heart rate between hydration methods of water and hypotonic beverages (carbohydrate and electrolyte containing or carbohydrate without electrolytes) with 16 well-trained cyclists [15]. Power output in that study did increase with the carbohydrate and electrolyte beverages. The findings of the current study support diluted fruit juice as comparable to water or Gatorade® in regards to physiological effects during exercise.

It should be noted that other studies have found significant improvements in sports performance after supplementation of 5% carbohydrate-electrolyte drink during exercise at an intensity of 70% VO2max [10]. Fritzsche et al., found that carbohydrate ingestion during prolonged cycling, increased heat production, final core temperature, and whole body sweating rate. They concluded that water ingestion improves endurance performance over a prolonged period by inhibiting the increases in heart rate, core temperature, stroke volume, cardiac output, blood volume and perceived effort[16].

Organoleptic Acceptability

Taste is an important determinant in voluntary fluid intake and hydration. In the current study, water performed the best in taste, tolerance, satisfaction but was scored the lowest on a sense of fullness – meaning it did not make the participant feel the most full. Diluted juice was rated the lowest for taste, in the middle for tolerance and satisfaction and the best for fullness. Gatorade, the drink marketed for fluid replacement, rated in the middle for taste and fullness and

the lowest for tolerance and satisfaction. Similar results have shown no differences in drink pleasantness between Gatorade®, a carbonated water/apple-juice mixture (Apfelschorle) and mineral water [12].

Economic Value

Economic differences indicated apple juice can be more cost effective. Assuming moderate exercise intensity at 8 ounces of beverage per 15 minutes, cost would be $0.27 per 30 minutes of exercise for apple juice and $0.54. This does not factor in the cost of time for dilution of the apple juice and addition of sodium which are minimal. Convenience can't be overlooked in today's society. Future work in this area would benefit from investigating a convenience factor of various beverages. Perhaps frozen ice cubes of fruit juice could be a convenient method of retrieval and storage. The current study did not include this important objective in the current study.

Limitations

There are several limitations to mention with the study design, one being that we did not have a control group for comparison. Our age range was large (years ranged from 21-56) and physiological differences due to age could not be ruled out. The study also had an uneven number of males (1) versus females (9). Generalizations of our study's findings as to gender are not possible. Baseline heart rate was not recorded in this study, which may be a factor in non-significant study findings between heart rate and Borg ratings. An area we did not control for was timing of fluid intake. The participants were instructed to consume 24 ounces of their fluid in the 60 minute period, but we did not log at what time and how much of the fluid was consumed at each time point. If the prescribed ounces were not consumed at the regular intervals (say 15 minutes), it may have adversely affected the RPE of each participant. Another limitation was the lack of control of the physical environment (temperature and humidity) where participants exercised. Participants were allowed to perform each exercise session independently in an environment of their choosing, although all performed exercise on a treadmill using the same protocol as mentioned in the methods.

Summary

Fluid replacement during and after exercise is an important consideration in the successful incorporation of physical activity into a healthy lifestyle. While a good portion of exercisers rely on prepared sports beverages, there are other consumers that may prefer alternative methods of hydration. Diluted fruit juice can provide the nutrients that are found in prepared sports beverages but also provide antioxidants normally found in juices. Consumers may want to adjust their lifestyle choices to incorporate more natural foods (fruit juice) as well as assess the financial cost of fluid replacement. Our results provide valuable contributions to the literature available to consumers on alternative sources of effective fluid replacement. Further exploration into convenience, effect on "going green", physiological benefits with different exercise modalities, levels of fitness and temperatures effects of 50% diluted apple juice versus prepared sports beverages and water and would be useful.

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