The comparison of the effects of water, sports drink, and glucose polymer drink on hydration and physical performance amongst soccer athletes

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ABSTRACT

Introduction: The purpose of this study was to compare the performance and hydration between three drinks: water, a sports drink, and a glucose polymer drink.
Methods: Eight male (age 24.25 ± 2.053, 176.68 cm ± 5.896, 73.51 kg ± 7.96) participants were recruited from the soccer population at San Francisco State University, San Francisco Soccer League, and Berkeley Soccer League. The participants performed a total of three separate drink trials, with three to five days between each trial. Three different agility tests were performed, followed by a treadmill dehydration test, and followed by the ingestion of the selected drink. The participants rested for 90 minutes, followed by repeating the same three agility tests to measure physical performance.
Results: At the 90-minute resting point, urine specific gravity was significantly lower when water was used for rehydration compared to the sport drink fluid use for rehydration ($p \leq 0.007$). In the 4x5 m test, the glucose polymer and sport drink had a significantly lower performance time compared to when water was used ($p \leq 0.004$). When the glucose polymer drink was used for rehydration there were significant positive correlations between the 90-minute resting point of the total body water and the body mass variables, and the post measurement of the agility performance in the sprint test ($r = 0.81$ $r = 0.76$ respectively)
Conclusion: Evidence showed that in the agility 4x5 m test, the sport drink and glucose polymer drinks when used for rehydration had a lower performance time than when water was used for rehydration. The water drink use had a lower urine specific gravity than when the sport drink was used for rehydration.

Keywords: Hydration; Soccer players; Performance; Sports drink; Glucose polymer drink

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INTRODUCTION

Time of the onset of fatigue during a soccer match is a relevant question, as well as what is the cause of that fatigue. The amount of sprinting, jumping, and distance covered on the field are lower in the second half than the first half.[1,2,3,4,5,6] The amount of sprinting is reduced within the last 15 minutes of the game and is lower compared to earlier in the soccer game.[4,5,6,7] Soccer players lose up to 3 liters of fluid in temperate thermal environments and 4-5 liters in hot humid environments during a soccer match.[8,9] A significant reduction in sprint performance is seen when fluid loss of about 1% body mass.[10,11]

Agility tests have been developed to measure a soccer player's performance.[12,13] Countless studies have been performed which measure aerobic capability of soccer players, but few have focused on field tests.[14,15] A soccer player could change directions every 2-4 seconds and makes about 1200-1400 changes of directions a game. Instead of performing a sub-max test, an agility test may closer mimic this intermittent sport. The high validity and reliability scores for the agility tests measures the performance of soccer players while assessing the players' fatigue.[16]

Fluid losses and dehydration may be one of the major causes of fatigue.[17,18,19,20,21] During vigorous and long strenuous exercise, fluid losses are common and could result in thermal stress, decreased cardiovascular function, accelerated fatigue, impaired physical performance, and impaired cognition. This could lead to dehydration and could ultimately compromise subsequent exercises if fluid is not replaced.[22] Fluid intake is recommended before, during, and after commencing physical activity and is highly recommended if training in hot and humid environments. It is important to replenish the lost fluid and electrolytes and replenish the glycogen stores for the next bout of exercise. At a modest two percent decrease of body mass, exercise-induced dehydration affects cognitive capabilities and aerobic performance capacity.[23] Factors that play with these effects include reduced plasma volume which leads to reduced venous pressure, diastolic filling rate, elevated core temperature, and depletion of sodium and potassium within the cells.[24]

Recommendations for hydrating the body and preventing fatigue are varied. Water is recommended to hydrate the body for general fitness, while carbohydrate electrolyte sports drinks are recommended for athletes, especially aerobic athletes.[25] Scientific recommendations of the benefit of drinking carbohydrate electrolyte sports drinks do exist.[25] The addition of sodium in sports drinks increases intestinal glucose transport and increases net water uptake. Although, the ingestion of a high sodium concentration sports drink (50 mEq L^{-1}) will do the opposite and does not enhance intestinal water absorption or the assimilation of water absorption or glucose into the blood.[26] Carbohydrates could improve the rate of intestinal uptake of sodium and favors the retention of water.[26] The ingestion of carbohydrates offers a source of glucose to prevent hypoglycemia and maintain high carbohydrate oxidation rates, but carbohydrates do simultaneously inhibit the mobilization and oxidation of fat due to an increase stimulation of insulin.[26] Due to lipolysis sensitivity to insulin, even a small decrease in insulin, is associated with an increase in adipose tissue fatty acid release and oxidation. Thus, digestion and absorption of a carbohydrate source at a slower rate might have desirable effects on the metabolic and hormonal response during exercise.

A fairly new drink on the market that has a high molecular weight, low osmolality glucose polymer solution is showing promising results. Due to the lower osmolality, the carbohydrate solution will have a faster gastric emptying rate. Ingestion of this solution after glycogen depleting exercise increased glycogen re-synthesis two-to three-fold compared to post exercise carbohydrate feeding.[27,28,29] Peak blood glucose concentration following ingestion of the high molecular weight showed the glucose polymer drink is 10% greater and occurred 20 minutes earlier compared to the low molecular weight sports drink.[27,28,29,30] Additionally, the glucose polymer drink increased insulin concentration and work output. This could benefit athletes who participate in training sessions, or competitions, where rapid re-synthesis of the muscle glycogen stores is necessary and performance must be maintained during another bout of exercise.

Many researchers have conducted studies involving different methods of hydration after vigorous exercise. Two separate experimental studies provided two different drinks such as a high molecular weight - low osmolality glucose polymer solution and a sports drink, but there is little research comparing both drinks together.30 The purpose of this research was to compare performance optimization for three drinks: water, a sports drink (SD), and a glucose polymer drink (GP) and to evaluate which drink effectively optimizes performance and hydration of the athlete. The central research question was, "Which drink would be the most efficient at keeping the soccer players hydrated and fueled after vigorous exercise and maintaining performance for the agility test?"

1. It was hypothesized that the GP drink will enhance performance results better than the SD or water.
2. The GP drink will provide better hydration for the participants compared to the SD and water.

METHODS

This experimental-cross over study used a target population of recreational soccer players from the San Francisco Bay Area. The recruitment process consisted of posters and fliers posted at the turf soccer field, student service building, and the Recreation Office at San Francisco State University. Personal recruitment of soccer players during pick-up hours at San Francisco State University, San Francisco League and the Berkeley league were also employed.

Inclusion Criteria

Participants must play soccer two-three times a week. Due to limited transportation and time commitment, recruitment took place at San Francisco State University, San Francisco soccer premier league, and the Berkeley soccer league. Participants had to be able to run on a treadmill for 5 minutes at 7 mph. The participants had experience playing organized soccer due to the agility test. Furthermore, participants maintained their regular diet for the duration of the study. The age range for subjects was between 18 to 27 years.

Exclusion Criteria

The participants were free from cardiovascular, musculoskeletal, and any other major health issues due to performing the dehydration and agility test. Smokers were not permitted to participate. Participants who had food allergies to the SD or GP drink were excluded. The participants did not ingest any supplements 4 weeks prior to or during the study. Females could possibly have a large fluctuation in their hydration levels due to birth control use and their menstrual cycles, so they were excluded.

Participant Statistics

Table 1 describes a summary of the participants' height, gender, and age. Additionally, this table describes the participants' body mass index, body mass, total body water, and urine specific gravity at screening.

Procedure

A total of eight male soccer players were chosen. Participants filled out the Institutional Review

TABLE 1. Characteristics of Participants

Variable	Mean	Median	Range
Age at screening years	24.25 ± 2.053	24	22-28
Height (cm)	176.68 ± 5.896	176.53	166.37-185.42
Gender	Male (100%)		
Body mass index	23.545 ± 2.55	23.795	18.65-26.63
Body mass at screening (kg)	73.51 ± 7.96	70.15	64.11-87.15
Total body water at screening (L)	43.48 ± 6.56	42.41	35.97-56.75
Urine specific gravity at screening (kg/m^3)	1.0225 ± 0.0046	1.025	1.015-1.025
Data are mean ± SD; median in 2nd column and range in 3rd column. N=8			

Board approved consent form and the ACSM American Heart Association (AHA) health survey. The AHA survey includes questions about the participants' food and beverage allergies. The demographic information of the participants was recorded. The recorded variables were age, height, body composition (ImpediMed), and body mass index (ImpediMed).

Three counterbalancing trials were conducted at eight in the morning on five separate days. In the first trial, participants drank water flavored with sucralose.[7] In the second trial, participants drank the SD. In the third trial, participants drank the GP drink.[7] In each trial, participants drank 500 mL of water the night before and 500 mL two hours before the test. On test day, participants ingested a standardized breakfast: a bagel with one tablespoon of cream cheese. Each participant did not consume any alcohol nor perform any exercise 24 hours prior to testing.

Once the participant met the requirements, he performed the following procedure. The dependent variables were measured for each participant that lasted ten minutes. The participants were taken to an indoor-court gym to warm up for ten minutes. The agility tests were explained to each participant and allowed one practice trial. Each participant performed the three agility tests once and time was recorded. Once done, the participants performed a 70-minute dehydration test on the treadmill. Immediately after, the dependent variables were measured again within ten minutes. The participants rested for 90 minutes and finished the selected drink within the first 30 minutes of the rest period. Finally, after resting, the dependent variables were measured again. The participants completed the agility test once more and time was measured. There is a three to five-day separation between each trial.

Dehydration Test

The test consisted of two 30-minute sessions of exercise, consisting of walking/jogging with a 10-minute break between the bouts for a total of 70 minutes. The test was conducted on a treadmill at speeds of 2, 3, 4, 5, 6, and 7 mph at 0% grade. Additionally, the speeds were performed for 5 minutes at each level. The dehydration test was conducted at the San Francisco State University exercise physiology lab in a controlled temperature and humidity. The participants' fatigue and thirst were measured by the Borg scale and thirst sensation scale.[31] After the test, participants remained in the room for body measurements; drink measurements, and the ingestion of the selected trial drink, followed by a 90-minute rest after ingestion. Only two to three participants were tested at a time due to limited equipment and manpower.

Fluid Ingestion

After the dehydration test and measurements of nude weight, participants ingested the trial drink. The fluid intake for each subject was determined by the following equation: 1000 mL*kg^{-1} x kg loss = amount of beverage consumed.[31] The participants were given 30 minutes to finish the selected drink. After ingestion, participants waited 90 minutes before performing the agility test. The composition of the SD per serving included 1 2/3 Tbsp., 21 g carbs, 150 mg sodium, 45 mg potassium, 500 g per mol^{-1} and ~300 mOsmol per kg^{-1}. The GP drink composition included 2 scoop per serving, 70 g carbs, 0 mg sodium and potassium, 500,000 g per mol^{-1} and ~60 mOsmol per kg^{-1}. The composition of the drink was made to match the loss of body mass using the equation above. The drinks were not adjusted to match calorie or carbohydrate intake. The order of the drinks was randomized at each trial.

Agility Tests

An active warm-up was performed prior to the baseline and final trial of agility tests. The warm-ups consisted of light jogging and running, skips, butt kicks, high knees, cariocas, and arm swings. If the participant made a mistake that hindered his performance during either agility test, the participant was allowed a 5-minute break and a retake. The agility tests were performed in the Gymnasium building room 147 or 100. Participants were allowed to use indoor soccer shoes. The agility tests reliability α coefficients varied between 0.92 and 0.99 and have been used to measure the agility of soccer players. The order of the agility tests was randomized at each trial.

T-Test: The participants began the exercise with both of their feet behind starting point A. After the sound signal, the participant sprinted 9.14 m forward to point B and touched the cone, then shuffled 4.57 m to the left and touched cone C, shuffled 9.14 m to the right and touch cone D and 4.57 m to the left, back to point B. He then ran backwards, and passed the finish line at point A. The T-Test was performed twice: once as practice and once at maximum.

Sprint 4 x 5 m (S4 x 5): The test consisted of constant direction changes. Five cones were set up 5 m apart. The participants stood with their feet apart and the cone between their legs. Every participant started when ready and sprinted 5 m from point A to point B. After reaching point B, a 90° turn to the right was made and then shuffled 5 m to point C. At point C, another 90° turn was made to the left and he sprinted to point D, and lastly made an 180° turn and sprinted on to point E (the finish line). This test was performed twice: once as practice and once at maximum.

Sprint 9-3-6-3-9 m with 180°: The participant sprinted 9 m from starting line A to line B (the lines are 3 m long and 5 cm wide). He then touched line B with one foot, and made either 180° left or right turn. All the following turns were made in the same direction. The participant sprinted 3 m to line C, made another 180° turn, and sprinted 6 m forward. He then made another 180° turn (line D) and sprinted another 3 m forward (line B), then final turn was made and he sprinted the final 9 m to the finish line (line E). This test was performed twice: once as practice and once at maximum.

Measures

Bioelectrical Impedance: The measurements of hydration status were recorded by a 4-lead bioelectrical spectroscopy device (Impedimed, Pinkenba, Australia) at the exercise physiology lab. A scale (Cosmed, Concord, California, USA) measured the body mass of the participant. Heart rate (Polar monitor strap, Kempele, Finland) and blood pressure were also measured. These measurements were conducted prior to the baseline agility test, after the dehydration test, and 90-minutes after ingestion of the test drink. The trial drinks were measured using measuring beakers. The dehydration test was set for 70-minutes. The agility test was scored by the fastest time on each of the three.

Urine Specific Gravity: The urine provided an addition measurement of hydration and was tested by reagent test strips. Osmolality and urine specific gravity were used interchangeably to determine hydration status.[32,33] These measurements were conducted prior the baseline agility test, immediately followed of the dehydration test, and prior to the second agility test.

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) version 23 was used for statistical analysis. The dependent variables used for measurement of hydration were: body mass, urine specific gravity, and total body water. They were analyzed using a 3x3 two-way repeated measures ANOVA ($p<0.05$). In these repeated measures, ANOVA, the independent variables were water, a SD, and a GP drink. Additionally, the time points of each hydration measurement were independent variables. Each of the hydration variables were recorded before, immediately after, and 90-minutes after the dehydration test.

The three agility tests were analyzed using a 2x3 two-way repeated measures ANOVA ($p<0.05$). In these repeated measure, ANOVA, we examined performance as time difference between the baseline and final measurements of the agility test. For each participant, the times for each agility test were recorded. Each of these agility tests was recorded before and 90-minutes after the dehydration test. The independent variables were the three different drinks and time. In this analysis, any significant result required a Bonferroni post hoc to determine if there was any difference among the groups

A Pearson Correlation was run to see if there was a relationship between the agility performance variables and the hydration variables. In this analysis, the dependent variable was agility performance. Agility performance was defined as fifteen seconds minus the subject's agility test time. This transformation of the original dependent variable was used so that our statistical analysis was easier to comprehend. Although the procedure measures time, we are interested in the subject's physical performance, where shorter is better. Finally, we chose to use fifteen seconds as a ceiling in this simple transformation as no subject's timed trial was longer than fifteen seconds. This transformed variable was then correlated with the subject's hydration level.

RESULTS

Overview and Adverse Effects

All subjects successfully completed all parts of the experiment without any observable adverse effect. This included consuming the trial's specified drink within the required 30-minute timeframe, with no adverse effects. The three-hydration sources did not result in any bloating, upset stomach, diarrhea, or any other symptoms.

Performance Data

There was no significant difference between the agility sprint test measured before and after the dehydration test ($p\leq0.066$) (Figure 1). There was a significant main effect of the drinks between the various test drinks ($p\leq0.006$) ($p\leq0.002$) (Figure 2). Additionally, there was no significant difference between the SD and the GP drinks ($p\leq0.470$) (Figure 2). There was a significant main effect of time in the agility t-test, between the measurements at baseline and final ($p\leq0.044$) (Figure 3). Additionally, the SD and GP drinks showed a trend in a reduction in their time compared to the water drinks, but no significant differences were found ($p\leq0.102$) (Figure 3).

Hydration Data

Participants lost approximately ~1 kg of body mass during the dehydration exercise

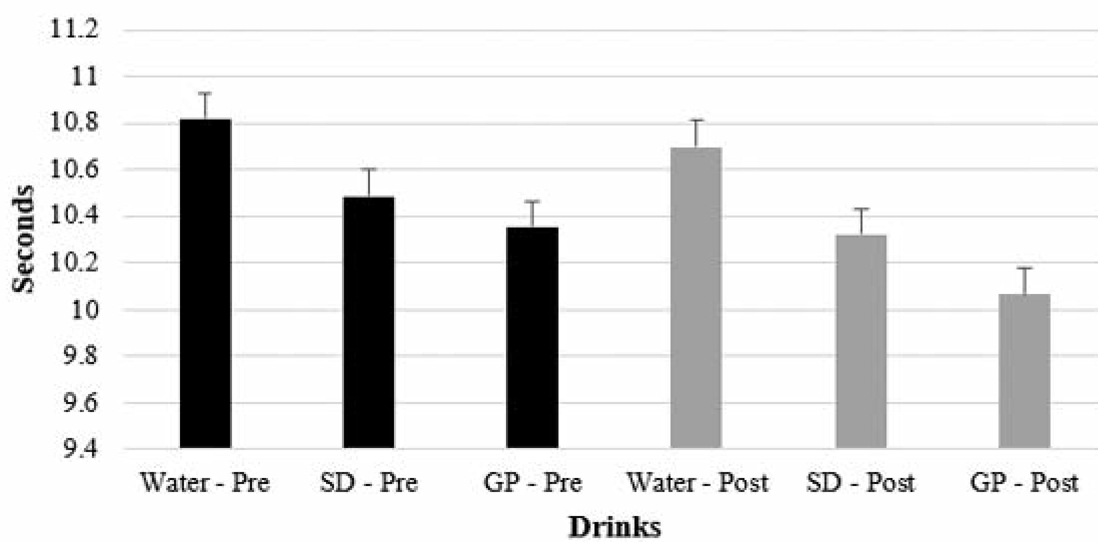

FIGURE 1. Values are mean ± SEM, n=8, agility test completion time among the three conditions: water, Sports drink (SD), and Glucose polymer drink (GP). Means are found in Appendix A, Table 7. Data are based on the baseline (black) and final (gray) time for agility test *Sprint 9-3-6-3-9 m with 180º.* No significant differences were found between drinks ($p \leq 0.098$). There was no significant difference in the main effect of time ($p \leq 0.066$). No significant interaction emerged between time and drinks ($p \leq 0.909$).

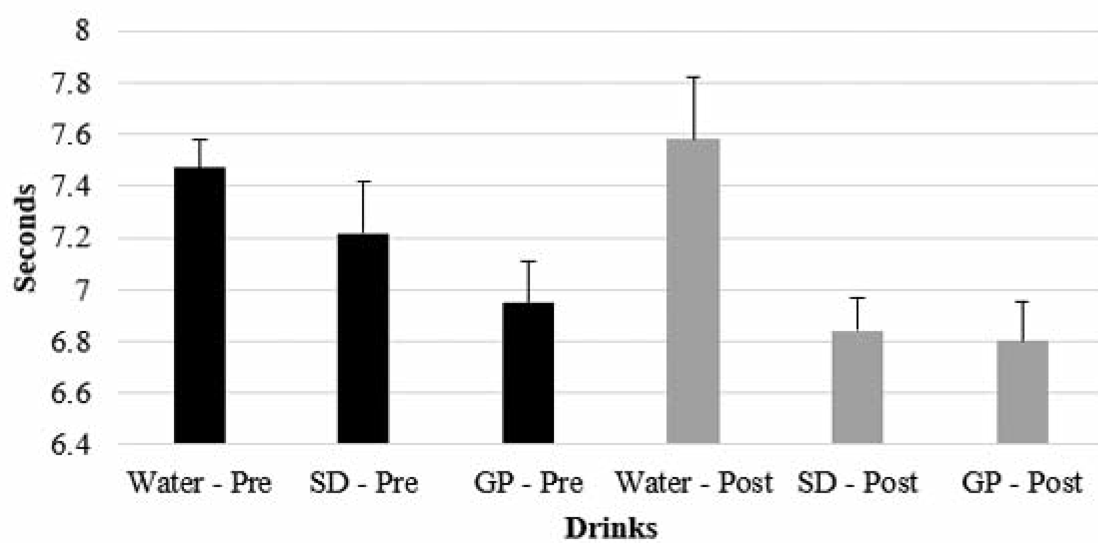

FIGURE 2. Values are mean ± SEM, n=8, agility test completion time among the three conditions: water, Sports drink (SD), and Glucose polymer drink (GP). Means are found in Appendix A, Table 7. Data are based on the baseline (black) and final (gray) time for agility test *Sprint 4x5m.* A significant main effect of the drinks was found ($p \leq 0.006$) between water and the sport drink (SD); and ($p \leq 0.002$) water and glucose polymer drink (GP). There was no significant difference between the sport drink (SD) and glucose polymer drink (GP) ($p \leq 0.470$). No significant main effect of time was found ($p \leq 0.179$). There was no significant interaction between time and drinks ($p \leq 0.174$)

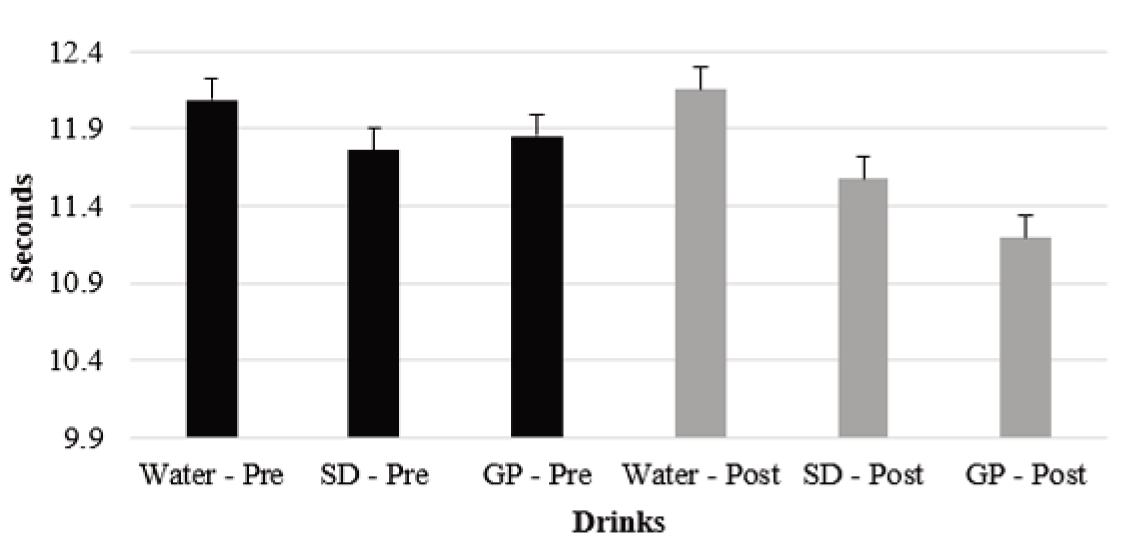

FIGURE 3. Values are mean ± SEM, n=8, agility test completion time among the three conditions: water, Sports drink (SD), and Glucose polymer drink (GP). Means are found in Appendix A, Table 7. Data are based on the baseline (black) and final (gray) time for agility test *T-Test.* No significant difference between the drinks ($p \leq 0.102$). The main effect of time was significant ($p \leq 0.044$) between the baseline and final time measurements. No significant difference between the interaction of drinks and time ($p \leq 0.422$). Means are found in Appendix D, Table 9.

(~1.35% of starting body mass), and then were able to regain the amount lost following the consumption of the three drinks (Figure 4). There was a significant main effect for time in body mass between the measurements at baseline and after the dehydration test ($p \leq 0.0005$) (Figure

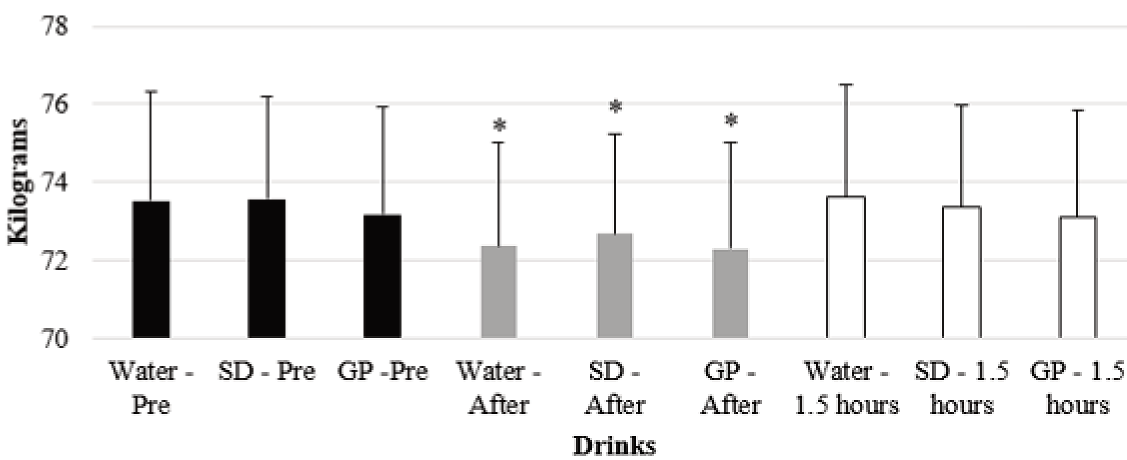

FIGURE 4. Values are the mean ± SEM, n=8, body mass measurements among the three conditions: water, Sports drink (SD), and Glucose polymer drink (GP). Means are found in Appendix A, Table 6. Data are based on three time points: prior agility test (black), after dehydration test (gray), and 1.5 hours after ingestion of drink (white). There was a significant main effect of time ($p \leq 0.001$) following the dehydration protocol for each drink. There was no significance between time points pre and 1.5-hour means ($p \leq 1.000$). No significant difference was found between the drinks ($p \leq 0.484$). No significant difference in the interaction between the drinks and time ($p \leq 0.480$).

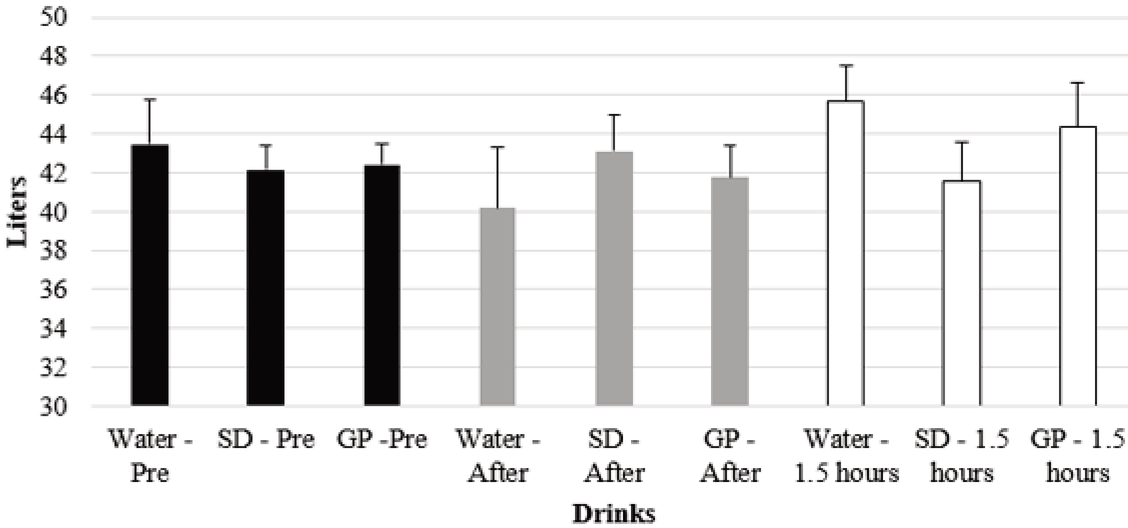

FIGURE 5. Values are the mean ± SEM, n=8, total body water measurements among the three conditions: water, Sports drink (SD), and Glucose polymer drink (GP). Means are found in Appendix A, Table 6. Data are based on three time points: prior agility test (black), after dehydration test (gray), and 1.5 hours after ingestion of drink (white) for body mass. There was no significant difference in the interaction between drinks and time in total body water ($p \leq 0.823$). No significant differences were found in time ($p \leq 0.191$) and drinks ($p \leq 0.659$).

4). There was no significant difference in total body water between the drinks or fluid retention ($p \leq 0.659$) (Figure 5). There was no significant main effect of time in total body water ($p \leq 0.191$) (Figure 5). Additionally, there was no significant main effect in the interaction in total body water ($p \leq 0.823$). The water drink used for rehydration showed a lower urine specific gravity compared

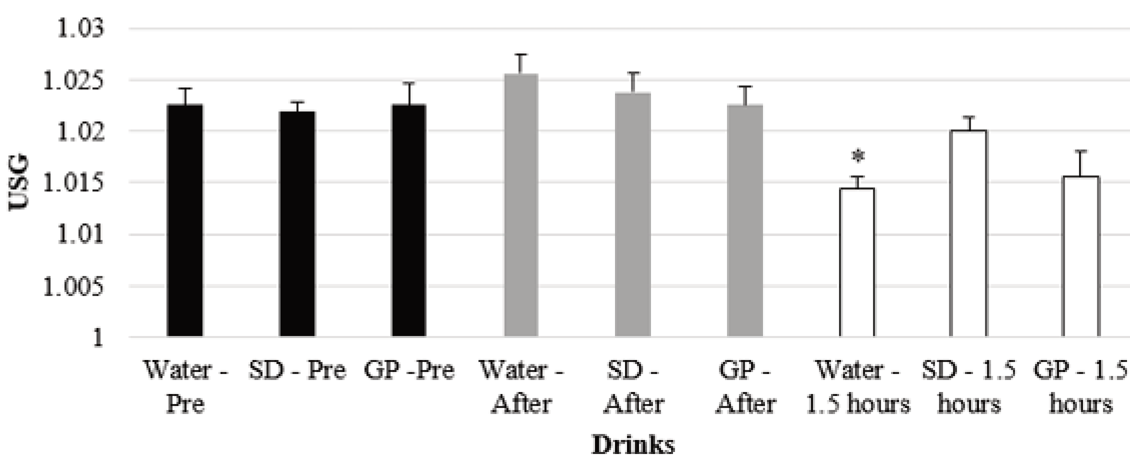

FIGURE 6. Values are the mean ± SEM, n=8, urine specific gravity measurements among the three conditions: water, Sports drink (SD), and Glucose polymer drink (GP). Means are found in Appendix A, Table 6. Data are based on three time points: prior agility test (black), after dehydration test (gray), and 1.5 hours after ingestion of drink (white) for urine specific gravity. There was a significant main effect in the interaction ($p \leq 0.007$) following the 1.5-hour time point in which water rehydrated better than Sports drink (SD). There was no significant difference between the drinks ($p \leq 0.676$).

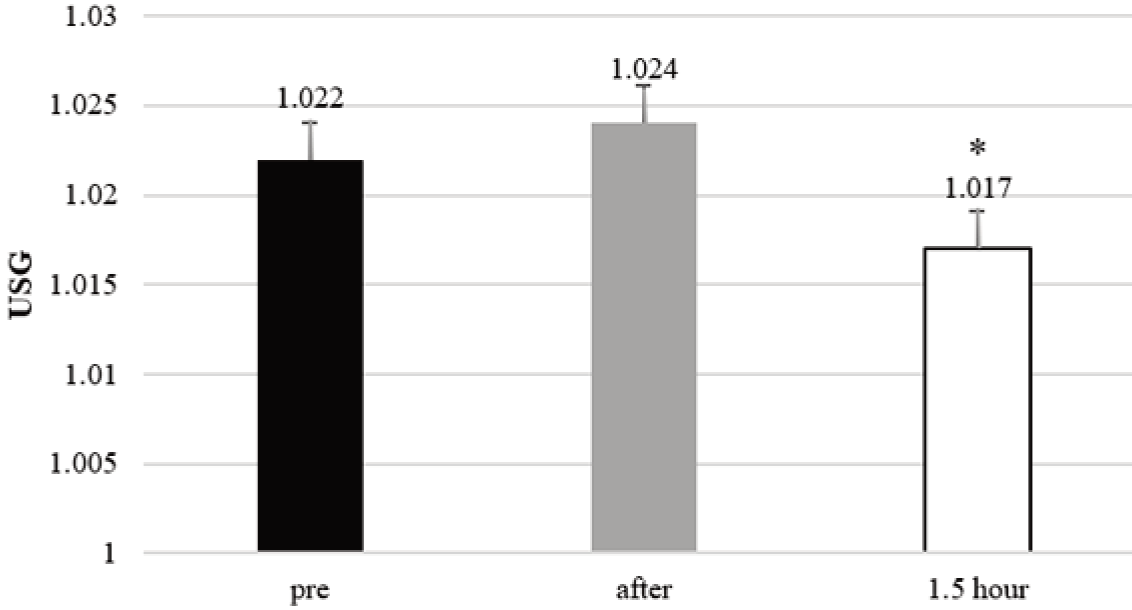

FIGURE 7. Values are the mean ± SEM, between the three time points USG was measured: pre agility test (black), after dehydration test (gray), and 1.5 hours after ingestion of drink (white). Means are found in Appendix B, Table 10. There was a significant main effect of time (p 0.007) between measurements pre and 1.5 hours ($p \leq .014$); after and 1.5 hours means ($p \leq 0.004$). No significant difference was found between pre and after means ($p \leq 0.757$).

to the SD drink used for rehydration at the 1.5-hour rest time point ($p \leq 0.007$) (Figure 6). The interaction effect of time by drink showed that the water drink was better at rehydrating than the SD drink ($p \leq 0.007$) (Figure 6). In urine specific gravity, the significant main effect of time ($p \leq 0.007$) can be seen in Figure 7, between measurements at baseline and 1.5 hours after drinking. Additionally, there was a significant difference between measurements after the dehydration test and 1.5 hour after drinking ($p \leq 0.007$).

Data Collected During the Dehydration Test

The rate of perceived exertion was measured during the dehydration test to measure if the test did manage to fatigue the participants. The thirst scale was measured during the dehydration test to measure if the test induced thirst. Participants' heart rates were measured before and after the dehydration test. There was a significant increase in heart rate ($p \leq 0.001$) following the dehydration test (Appendix B, Table 8). There were no significant changes in blood pressure between the three conditions or time (Appendix B, Table 8). Participant's rate of perceived exertion (RPE) did have a significant difference between the conditions 1 and 2 means ($p \leq 0.05$); condition 1 and 3 means ($p \leq 0.05$); but no significant difference between conditions 2 and 3 means ($p \geq 0.05$) (Table 2). RPE did increase significantly over time of the dehydration test. The thirst in the participants did significantly increase over time during the dehydration tests ($p \leq 0.05$) (Table 2).

Correlations between Performance and Hydration

A Pearson Correlation was run to identify if hydration was correlated with performance. In the water drink used for rehydration, there was no correlation between any hydration measures and

TABLE 2. Means of Subjective Measurements During Dehydration Test

	Bout 1				Bout 2			
Time	0 min	10 min	20 min	30 min	0 min	10 min	20 min	30 min
RPE Trial 1	7.75	8.63	12*	15.5*	8.25	9.38	12.75*	15.5*
±	0.70	0.71	0.73	1.12	0.73	0.89	1.16	1.40
RPE Trial 2	6.88	7.88	10.75*	13.25*	7.38	8.38	10.88*	13.5*
±	0.74	0.91	1.10	1.06	0.75	0.91	1.22	1.24
RPE Trial 3	7.13	7.63	8.75*	12.5*	6.63	7.63	10.5*	12.88*
±	0.67	0.73	0.90	0.82	0.38	0.73	1.10	1.23
Thirst Trial 1	2.75	3.00	4.88*	7.13*	3.00	3.75	5.13*	7.5*
±	0.56	0.53	0.52	0.52	0.73	0.53	0.64	0.60
Thirst Trial 2	2.00	2.38	3.63*	5.5*	2.13	2.75	4*	6.38*
±	0.50	0.56	0.60	0.53	0.35	0.45	0.53	0.46
Thirst Trial 3	2.00	2.25	3.38*	5.13*	2.25	2.75	4*	5.88*
±	0.53	0.49	0.65	0.58	0.53	0.59	0.63	0.69

Values are means (top row) ± SEM (bottom row). n=8. * Indicates significant increase over time. Significant difference found in thirst scale ($p<0.001$). Significant difference found in RPE scale among Trial 1 and 2 means; Trial 1 and 3 means; but no significant difference among Trial 2 and 3 means.

performance for any of the agility tests (Table 3). However, in the SD drink, there was a significant negative correlation ($r = -0.71$) between the time points following the 90-minute rest only for body mass and the post agility T-test ($p \leq 0.047$) (Table 4).

The GP drink has a strong positive correlation between hydration and performance. A positive correlation ($r = 0.81$) was found between the 90-minute rest in total body water and the post 9-3-6-3-9 m agility test ($p \leq 0.014$) (Table 5). The body mass also showed a significant correlation with this test ($r = 0.76$) ($p \leq 0.029$) (Table 5). The urine specific gravity following the 90-minute rest had a significant positive correlation ($r = 0.80$) with the post agility T-test ($p \leq 0.017$) (Table 5).

DISCUSSION

Findings from the present study indicate that water is capable of promoting rehydration after one hour of dehydrating exercise. The findings in urine specific gravity and total body water yielded different results in the SD and GP drinks compared to the water drink used for rehydration. In the agility t-test, there was a significant main effect in time. The 4x5 m test had a significant main effect in the drinks. These data are specific to a sample of young, exercise trained, healthy men.

Regarding the performance hypothesis, the GP drink did not significantly reduce performance time between all three drinking conditions. The 4x5 m test was the only agility test where the SD and GP drinks provided a better time compared to the water drink. In Figures 4, 5 and 6 there was a decreasing trend for the SD and GP drinks in performance time compared to their baseline. A reason for the main effect being significant is likely because the pre-test values are lower in the SD and GP drinks than the water drink used for rehydration (Figure 2). This suggests that the

TABLE 3. Correlations Between Performance & Hydration (Water)t						
Variables	T-Test		4x5 m		9-3-6-3-9 m	
	Pre	Post	Pre	Post	Pre	Post
USG Pre	0.48		0.64		0.59	
USG 1.5 Hr		0.54		0.63		0.22
TBW Pre	0.09		-0.22		-0.23	
TBW 1.5 Hr		-0.08		0.02		-0.44
BM Pre	0.11		-0.36		-0.11	
BM 1.5 Hr		-0.53		-0.38		-0.67

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed). Baseline (Pre) measurements compared with final measurement (1.5 and Post).

increase in performance did not have much to do with the drink. The American College of Sports Medicine recommends the ingestion of a 6% carbohydrate solution between 4-8 ounces every 15-20 minutes during exercise.[33] In this study, the participants were only provided rehydration after the dehydration test and not during exercise. There is a possibility that carbohydrate feeding during vigorous exercise maintained or improved performance by maintaining blood glucose levels when muscle glycogen stores are diminished.[34] The possibility of ingesting a carbohydrate drink during exercise rather than after could have yielded different results. In Stephens, Roig, Armstrong, and Greenhaff (2008), drinking a higher molecular weight, GP solution resulted in a 10% increase in work output compared to the other drinks. Mora-Rodriguez, Estevez, Del Coso, Baquero and Mora-Rodriguez (2008), found that a deficit in sodium reduced the muscle voluntary contraction suggesting the importance of sodium in preserving muscle voluntary contraction during exercise. In this study, the SD was the only drink to have sodium. Additionally, the SD had a significant effect in the 4x5 m agility test, but the GP had the same effect, though it contained no sodium.

The performance times in each agility test could have been affected by the specific position

TABLE 4. Correlations Between Performance & Hydration (Sport drink)						
Variables	T-Test		4x5 m		9-3-6-3-9 m	
	Pre	Post	Pre	Post	Pre	Post
USG Pre	-0.10		0.16		0.39	
USG 1.5 Hr		-0.39		-0.03		-0.08
TBW Pre	-0.24		0.25		-0.44	
TBW 1.5 Hr		-0.23		0.161		-0.33
BM Pre	-0.16		-0.168		-0.62	
BM 1.5 Hr		*-0.71		-0.26		-0.58

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed). $p \leq 0.47$. Baseline (Pre) measurements compared with final measurement (1.5 and Post).

each participant plays. The agility tests were appropriate for different positions in the field: t- test was appropriate for defenders, sprint with 180° turn was best for midfielders, and the sprint 4x5 m was best for attackers. In this study, there were a total of two defenders, four midfielders, and two attackers. This could possibly have affected the time as some of the participants were proficient in one agility test than the other. Although, all three conditions showed improvement in different agility tests, but only the GP and SD drinks decreased the time significantly in the 4x5 m agility test.

Based on the urine specific gravity measurement, water rehydrated the participants better. Due to the low osmolality in water, it rehydrated the body better. In previous research, the presence of glucose, maltodextrins (glucose polymers), sucrose and sodium has been shown to greatly increase fluid absorption in the small intestine. The SD is an isotonic solution with a higher osmolality compared to the GP drink, which is a hypotonic solution with a lower osmolality. In this study, the SD drink did not rehydrate as well as water. However, the GP showed a correlation ($r = 0.80$ and $r = 0.76$) in both total body water and body mass value at 90-minute rest and the final measurement value in the sprint agility test (Table 5). This suggests that in the GP drink, the hydration value was correlated with agility performance in the sprint test. Fluid absorption from a SD formulated with glucose polymers has previously been shown to be similar to the absorption of plain water. The GP condition yielded a ~1% difference than the water condition at the 90-minute measurement (Figure 6). The present study indicates that the urine specific gravity in the water drink was significantly lower than the SD, but there was no significant difference between the water and GP drinks.

In concerns with the drinks' properties and rehydration factors could had a possibility in affecting the rehydration process. As supported, fluid temperature influences the amount consumed. In regard to Casa (2000), states that 10°-15°C is recommended for ingestion.[35] The participants did not have the accessibility of individual fluid containers and flavored to their preference.[35] The only time the participants were given something to drink was after the dehydration process and only a calculated set amount. Considering the rehydration process, post exercise hydration should aim to any fluid loss during the exercise.[35] Other factors such as temperature, humidity, wind speed, and radiant energy load were not taken into account. Neither the SD nor the GP contained fructose. The GP contains a higher glucose concentration (~10%) than the SD (6%). None of the participants were hyperhydrated, but the risks could render performance. Overdrinking will normally stimulate urine production, but during exercise this compensatory mechanism is less

TABLE 5. Correlations Between Performance & Hydration (Glucose Polymer)

Variables	T-Test		4x5 m		9-3-6-3-9 m	
	Pre	Post	Pre	Post	Pre	Post
USG Pre	**0.84		*0.81		0.53	
USG 1.5 Hr		**0.80		-0.39		-0.37
TBW Pre	-0.67		-0.52		-0.34	
TBW 1.5 Hr		0.11		-0.22		*0.81
BM Pre	-0.61		-0.36		-0.23	
BM 1.5 Hr		-0.22		-0.54		*0.76

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed). $p \leq 0.014$. Baseline (Pre) measurements compared with final measurement (1.5 and Post).

TABLE 6. Means of Total Body Water, Body Mass, and Urine Specific Gravity

Variables	Water			Sport Drink			Glucose Polymer		
	Pre DH	After DH	1.5 HR After DH	Pre DH	After DH	1.5 HR After DH	Pre DH	After DH	1.5 HR After DH
Body Mass (kg)	73.5	72.4*	73.6	73.6	72.7*	73.4	73.2	72.3*	73.1
±	2.8	2.7	2.9	2.6	2.6	2.6	2.8	2.7	2.8
Total Body	43.5	40.2	45.7	42.2	43.1	41.5	42.4	41.8	44.4
Water (L) ±	2.3	3.1	1.8	1.3	1.9	2.1	1.1	1.6	2.28
Urine Specific	1.023*	1.03	1.014*	1.021*	1.02	1.02*	1.023*	1.02	1.016*
Gravity±	0.002	0.002	0.001	0.001	0.002	0.001	0.002	0.002	0.002

Values are means (top row) ± SEM (bottom row). n=8.
*Indicates significant increase over time.

effective. Taking a pre-exercise glycerol and water beverage before exercise is best if not overdone. Hyponatremia is when plasma sodium rapidly drops below ~130 mmol L^{-1}. The symptoms include headaches, vomiting, swollen extremities, fatigue, and disorientation and could lead to coma, seizure, respiratory arrest and be fatal at times.

A speculation of the participants' diet could have affected the hydration level of the athletes. Excess protein intake increases the risk of dehydration. For every gram of urea excreted, 50 ml of water are excreted in the urine. Unfortunately, the participants came in before each trial dehydrated regardless of ingesting 500 ml of water the night before and morning of testing. Popkins, D'Anci, & Rosenburg (2011), reported that American adults aged 19 and older consumed about 552 ml/day of water. To stay euhydrated, the recommended amount of water needed is ~2000 milliliters per day. However, the water drink rehydrated the body better than the SD, but hydration level did not significantly decrease time in the agility tests. A possibility is combination of hydration and the lack of carbohydrate that could have caused the decrement in performance time.

TABLE 7. Means of Agility Tests

	Water		Sport Drink		Glucose Polymer	
Agility Tests Time (s)	Pre	Post	Pre	Post	Pre	Post
T-Test	12.09	12.15	11.76	11.58*	11.85	11.19*
±	0.18	0.41	0.20	0.14	0.16	0.14
4x5 m	7.47	7.58	7.22	6.84	6.95	6.80
±	0.11	0.24	0.20	0.13	0.16	0.15
3-6-3-9-3m	10.82	10.70	10.49	10.32	10.35	10.07
±	0.24	0.22	0.20	0.13	0.20	0.13

Values are means (top row) ± SEM (bottom row). n=8.
*Indicates significant increase over time.

TABLE 8. Means of Heart Rate and Blood Pressure Prior & After Dehydration Test

Variables	Water		Sport Drink		Glucose Polymer	
	Pre	Post	Pre	Post	Pre	Post
Heart Rate	86.25	137.5*	93.25	122.38*	90.00	120.5*
±	7.27	8.43	6.53	7.65	6.93	7.09
Systolic	132.88	132.13	128.63	136.88	127.13	132.63
±	4.17	6.10	6.32	5.59	7.31	8.12
Diastolic	78.00	80.50	78.63	80.00	76.00	75.50
±	2.72	3.62	3.49	4.50	3.73	5.69

Values are means (top row) ± SEM (bottom row). n=8.
*Indicates significant increase over time.
Significant difference found in heart rate ($p<0.001$). No significant difference in change in time for blood pressure.

The agility tests mimicked the abilities that are used in a soccer match. As stated in Sporis, Jukic, Milanovic, & Vucetic (2010), to avoid the motor learning effect, at least one maximal agility test should precede the testing. In this study, a maximal agility test was given after a practice trial for each drinking procedure. The order of the agility tests and drinks were randomized to avoid the motor learning effect. One possible explanation for some of the differences in the performance time in the agility tests could be the competition amongst the participants. The participants performed the agility tests either by themselves or with another athlete. In some cases, the participants were not tested together due to conflicts in scheduling. The effect of competition might have provided faster times in the agility tests.

Another possibility is a difference in stride length. The taller participants had a longer stride length than their shorter counterparts. A longer stride length could have provided a faster time on the agility tests compared to a shorter stride length. This was accounted for by using the delta between pre- and post-times for each individual, and not the absolute values. The last possible explanation for some of our findings was the number of practice times allowed for the agility tests. The participant was only given one practice about, and one maximal trial. In future research, increasing the amount to three times on the agility test, and averaging those three, or taking the best value of those three, compared to using only one, would help insure a more accurate time.

The total body water limitations could have interfered with the results due to exercise and ingestion of the drinks. Consumption of food and beverage may decrease impedance by 4-12 Ω over a two to four-hour period after meals, representing an error smaller than 3%.[35,36] Measurements taken following exercise were shown to represent an error of ~8% in the

TABLE 9. T-Test Average Time Means

	Pre	Post
Mean	11.9	11.64*
±	0.125	0.186

Values are means (top row) ± SEM (bottom row). n=8.
*Indicates significant increase over time.

TABLE 10. USG Average Time Means

	Prior	After	1.5 hours
Mean	1.022	1.024	1.017
±	0.001	0.001	0.001

Values are means (top row) ± SEM (bottom row). n=8.
*Indicates significant increase over time.

measurements of total body water.[35,36] Total body water only showed a correlation (r = .81) in the GP drink between the values of the 90-minutes of rest and the final measurement of the sprint agility test ($p \leq 0.014$) (Table 5). After waiting for two hours after consumption of the drink and exercise, the error of the bio spectroscopy should have decreased, making the instrument's validity stronger.

The researchers supervising the athletes should have been able to recognize the basic signs of dehydration. Signs and symptoms include: thirst, irritability, headache, weakness, vomiting, cramps, chills, nausea, and decrease in performance. Although a thirst scale was presented during the dehydration process, signs and symptoms should have been thoroughly examined. This raises awareness within our community that parents and coaches should have a good understanding of dehydration and rehydration. The importance of knowing the signs of dehydration and overhydration could benefit the athlete from discomfort or their life.

Limitations

The limitations of this study included a small sample size and a recruitment process of just men limits the potential findings for women. As well as adolescents and prepubescent soccer players could also be investigated in a future project. A difficulty of the study was finding participants to commit to completing all three tests. An alternative would be to expand the recruitment process to include other colleges or the local soccer leagues and clubs. Another limitation was the manpower to help maintain the study. An alternative would be to find a research assistant or colleague to assist.

CONCLUSION

In the 4x5 m test, the SD and GP drinks increased agility performance than the water condition. Water was better at rehydration, as measured by urine specific gravity, than the other two drinks. Additional future research should include: 1) more extensive dehydration protocol that could reduce body mass greater than 2%, 2) maximal testing in the agility tests up to a multiple set of three times instead of one, to reduce the risk of a motor learning effect, 3) the recruitment of female soccer players and 4) a larger sample size.

Ethics approval and consent to participate

The Institutional Review Board at San Francisco State University consented on the collection of data involving human participants.

Consent for publication

Not applicable.

Competing interests

No funding. The authors declare that they have no competing interests.

Authors' contribution

Charles Castillo M.S. has collected and analyzed the data and in addition to writing the manuscript. Dr. Marialice Kern, Dr. Matt Lee, and Dr. Nicole Bolter assisted in analyzing the data and making corrections to the manuscript.

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REFERENCES

1. Amiri-Khorasani M, Sahebozamani M, Tabrizi K, Yusof A. Acute Effect of Different Stretching Methods on Illinois Agility Test in Soccer Players. J Strength Cond Res. 2010;24(10):2698-2704.
2. Bangsbo J, Mohr M, Krustrup P. Physical and metabolic demands of training and match-play in the elite football player. J Sports Sci. 2006;24(7):665-674.
3. Convertino VA, Armstrong L E, Coyle E F, G.W. Mack, M.N. Sawka, L.C. Senay and W.M. Sherman. American College of Sports Medicine Position Stand: Exercise and fluid replacement. Med Sci Sports Exerc. 1996;28:i – vii.
4. Maughan R J, Shirreffs S M, Merson S J, Horswill C A. Fluid and electrolyte balance in elite male football (soccer) players training in a cool environment. J Sports Sci. 2005;23:73-79.
5. Meckel Y, Einy A, Gottlieb R, Eliakim A. Repeated sprint ability in young soccer players at different game stages. J Strength Cond Res. 2014;28(9).
6. Moran D S, Heled Y, Margaliot M, Shani Y, Laor A et al. Hydration status measurement by radio frequency absorptiometry in young athletes-a new method and preliminary results. Institute of Physics Publishing. 2004;25:51-59.
7. Nicholas C, Tsintzas K, Boobis L, Williams C. Carbohydrate-electrolyte ingestion during intermittent high intensity running. Med Sci Sports Exerc. 1999;31:1280-1286.
8. Baker L, Rollo I, Stein K, Jeukendrup A. Acute Effects of Carbohydrate Supplementation on Intermittent Sports Performance. Nutr. 2015;7(7):5733-5763.
9. Baker L, Jeukendrup A. Optimal consumption of fluid-replacement beverages. J Comp Psychol. 2014; 4: 575-620.
10. Kalman D, Feldman S, Krieger D, Bloomer R. Comparison of coconut water and a carbohydrate-electrolyte sport drink on measures of hydration and physical performance in exercise-trained men. J Int Soc Sports Nutr. 2012;9(1):1.
11. Murray B. Hydration and physical performance. J Am Coll Nutr. 2013;26:542S-548S.
12. Clark M, Lucett S, Sutton B. NASM Essentials of Personal Fitness Training. 1st ed. 2012.
13. Deurenberg P, Tagliabue A, Schouten F. Multi-frequency impedance for the prediction of extracellular water and total body water. Br J Nutr. 1995;73(03):349.
14. Da Silva J, Guglielmo L, Carminatti L, De Oliveira F, Dittrich N, Paton C. Validity and reliability of a new field test (Carminatti's test) for soccer players compared with laboratory-based measures. J of Sports Sci. 2011; 29(15):1627-1628.
15. Krustrup P, Mohr M, Amstrup T, Rysgaard T, Johansen J, Steensberg A et al. The Yo-Yo Intermittent Recovery Test: Physiological Response, Reliability, and Validity. Med Sci Sports Exerc. 2003;35(4):697-705.
16. Sporis G, Jukic I, Milanovic L, Vucetic V. Reliability and factorial validity of agility tests for soccer players. J Strength Cond Res. 2010;24(3).
17. Aulin K, Söderlund K, Hultman E. Muscle glycogen resynthesis rate in humans after supplementation

of drinks containing carbohydrates with low and high molecular masses. Eur J Appl Physiol. 2000;81(4):346-351.
18. Casa D J, Armstrong L E, Hillman S K, Montain S J, Reiff R V et al. National Athletic Trainers' Association position statement: fluid replacement for athletes. J Athl Train. 2000;35:212-224.
19. Popkins B M, D'Anci K E, Rosenberg I H. Water, Hydration and Health. J Nutr Rev. 2011;68(8):439-458.
20. Sawka M, Burke L, Eichner R, Maughan R, Montain S, Stachenfeld N. Exercise and Fluid Replacement. Med Sci Sports Exerc. 2007;39: 377.
21. Shirreffs S M, Maughan R J. Rehydration and Recovery after exercise. Exerc Sport Sci Rev. 2000;28:27-32.
22. Jeukendrup A E. Carbohydrate intake during exercise and performance. Nutr. 2004;20:669–77.
23. Mora-Rodriguez R, Estevez E, Del Coso J, Baquero R, Mora-Rodriguez R. Anaerobic performance when rehydrating with water or commercially available sports drinks during prolonged exercise in the heat. Appl Physiol Nutr Metab. 2008;33:290–298.
24. Byrne C, Lim C, Chew S, Ming E. Water versus Carbohydrate-Electrolyte Fluid Replacement during Loaded Marching Under Heat Stress. Mil Med. 2005;170(8):715-721.
25. Engell D, Maller O, Sawka M, Francesconi R, Drolet L, Young A. Thirst and fluid intake following graded hypohydration levels in humans. Physiol and Behav. 1987;40(2):229-236.
26. Snell P, Ward R, Kandaswami C, Stohs S. Comparative effects of selected non-caffeinated rehydration sports drinks on short-term performance following moderate dehydration. J Int Soc Sports Nutr. 2014;7:28.
27. Leiper J B, Piehl Aulin K, Sǫderlund K. Improved Gastric Emptying Rate in Humans of a Unique Glucose Polymer with Gel-forming Properties. Scand J Gastroenterol. 2000;35(11):1143-1149.
28. Mourot J, Thouvenot P, Couet C, Antoine J M, Krobicka A, Debry D. Relationship between the rate of gastric emptying and glucose and insulin responses to starchy foods in young healthy adults. Am J Clin Nutr. 1988;48:1035–40.
29. Stephens F., Roig M, Armstrong G, Greenhaff P. Post-exercise ingestion of a unique, high molecular weight glucose polymer solution improves performance during a subsequent bout of cycling exercise. J Sports Sci. 2008;26:149-154.
30. Roberts M, Lockwood C, Dalbo V, Volek J, Kerksick C. Ingestion of a high-molecular-weight hydrothermally modified waxy maize starch alters metabolic responses to prolonged exercise in trained cyclists. J Nutr. 2011;27:659–665.
31. Judelson D, Bagley J, Schumacher J, Wiersma L. Cardiovascular and Perceptual Responses to an Ultraendurance Channel Swim: A Case Study. Wilderness Environ Med. 2015;26(3):359-365.
32. Armstrong L, Maresh C, Castellani J, Bergeron M, Kenefick R, LaGasse K et al. Urinary Indices of Hydration Status. Int J Sport Nutr. 1994;4(3):265-279.
33. Ehrman J. ACSM's resource manual for guidelines for exercise testing and prescription. 1st ed. Philadelphia: Lippincott Williams & Wilkins; 2010.
34. Cheuvront S N, Sawka M N. Hydration assessment of athletes. SSE#97 Volume 18 (2005), Number 2.
35. Kyle U, Bosaeus I, De Lorenzo A, Deurenberg P, Elia M et al. Bioelectrical impedance analysis part I: review of principles and methods. Clin Nutr. 2004;23(5):1226-1243.
36. Kyle U, Bosaeus I, De Lorenzo A, Deurenberg P, Elia M et al. Bioelectrical impedance analysis part II: review of principles and methods. Clin Nutr. 2004;23:1430-1453.