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Hydration Knowledge and Personal Assessment in Collegiate Male Soccer Athletes

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Table of Contents

Abstract.....	3
Literature Review.....	5
Introduction.....	24
Methods.....	26
Results.....	29
Discussion.....	34
Conclusion.....	38
Appendix A.....	39
References.....	41

Hydration Knowledge and Personal Assessment in Collegiate Male Soccer Athletes

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Abstract

Fluid consumption during exercise can be influenced by fluid vessel type and hydration knowledge, however athletes often are not given a choice of vessel and furthermore they are unaware of their individual fluid needs. The aim of this single-blind matched pairs laboratory study was to investigate if hydration vessel has an impact on water consumption volume and if athletes are aware of their total body fluid balance. Nineteen Division I male soccer athletes (age, 20 ± 1 year; height, 180 ± 7 cm; body mass, 78.68 ± 7.39 kg) performed a standard 60 minute sweat electrolyte test in the heat and completed a hydration knowledge and strategy questionnaire afterwards. 10 participants consumed unlimited water from 1L Gatorade™ bottles typically used in practice (BTL), while 9 participants consumed unlimited water from Camelbak™ bladder hidden above them in the ceiling, only with access to the straw (BLA). Testing was conducted in a controlled environmental chamber, ambient temperature was $29.68 \pm 5.08^{\circ}\text{C}$, relative humidity $49.32 \pm 10.65\%$, and WBGT $19.32 \pm 4.43^{\circ}\text{C}$. Primary variables of interest included actual fluid consumed, perceived fluid consumed, actual sweat rate, and perceived sweat rate. Between group differences were analyzed using paired samples t-tests ($\alpha=0.05$). There was no difference between BTL and BLA for amount of actual fluid consumed ($p=0.879$) actual fluid lost ($p=0.712$), perceived fluid consumed ($p=0.321$) or perceived fluid lost ($p=0.607$). Independent of group, perceived fluid consumption was 692 ± 572 mL and perceived sweat losses were 2244 ± 1552 mL while actual fluid consumption was 401.58 ± 334.37 mL and

actual sweat losses were 1377.89 ± 404.90 mL. When groups were combined significant differences were found between perceived and actual volumes consumed ($p=0.016$), perceived and actual volumes lost ($p=0.015$), and actual volumes consumed and lost ($p=0.000$). Although there were no differences between the type of vessel in which fluid was administered BTL vs. BLA, NCAA Division I athletes severely overestimated both the amount of fluid they consumed and their sweat losses during 60 minutes of exercise in the heat. These findings suggest that improved education regarding individual fluid needs during exercise in the heat be implemented.

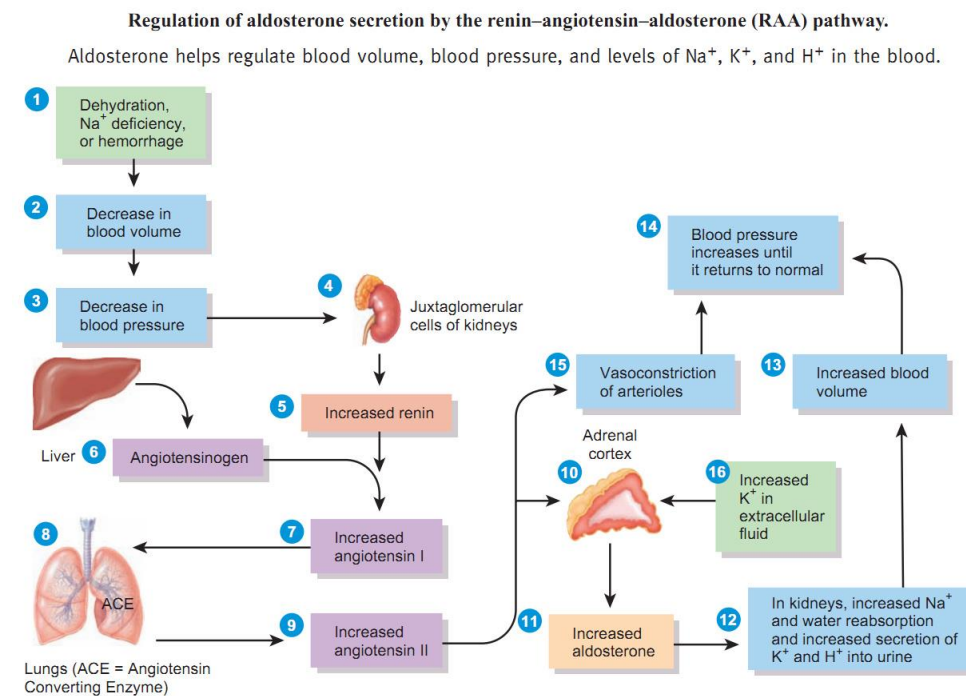
Literature Review

Regulation of Total Body Water

All of the water in the body is divided into intracellular and extracellular fluid compartments (Sawka, 2005). The intracellular compartment composes the majority of total body water, and the extracellular portion is separated into interstitial fluid and plasma (Maughan, 2001). When there is a decrease in total body water, fluid is lost from both compartments, but the proportion depleted from each space is dependent on the cause of cellular dehydration (McKinley, 2004). There are many mechanisms in place to compensate for inadequate fluid balance, one being the sensation of thirst. This is stimulated in response to increases in plasma osmolality and decreases in the extracellular fluid volume (Stanhewicz, 2015).

Osmoreceptive neurons located in the hypothalamus and forebrain have been found to control the regulation of thirst and production of urine. These neurons act based on input received from various receptors throughout the body that oversee fluctuations in osmolality, volume, and blood pressure. After evaluating the input, the brain responds with varying levels of thirst and diuresis. For example, within the intracellular fluid, solutes such as NaCl do not freely cross the membrane and therefore create an osmotic gradient. When this gradient is hypertonic, water will move out of the cell and dehydrate it. This is detected by osmoreceptors, which signal the brain and stimulate the sensation of thirst. Receptors in the brain will respond to an increase in osmotic pressures of as little as 1-2%. This sensation of thirst is also accompanied by an increased concentration of vasopressin throughout the body. Solutes that are permeable to the membrane do not stimulate thirst (Maughan, 2001).

The release of vasopressin is most commonly stimulated by small increases in plasma osmolality in the extracellular fluid and controlled by osmoreceptors in the central nervous system. Vasopressin is also released in response to increasing levels of Angiotensin II, which causes osmoreceptors in the hypothalamus to be sensitized. As vasopressin is progressively released from the posterior pituitary gland, the volume of urine produced is reduced. This occurs because vasopressin works to increase the kidneys' permeability of water, which in turn causes an increased reabsorption of water so that the urine formed has a high concentration of solute. When there is a decrease in plasma osmolality, vasopressin is inhibited, and a larger volume of urine is secreted. Changes in plasma osmolality are the main trigger for the release of vasopressin, but it can also be triggered by changes in blood volume and pressure, catecholamines, prostaglandins, and atrial natriuretic factor (Maughan, 2001; Stanhewicz 2015).



Reference for image: <https://goo.gl/CBsBWQ>

Another hormone involved in the regulation of extra cellular fluid in the body is aldosterone. Baroreceptors located within the superior and inferior vena cava as well as in the atria of the heart detect changes in plasma volume. They sense changes in vessel walls that occur in reaction to changes in blood pressure and volume. When these baroreceptors detect a decrease in the volume of plasma or extracellular fluid, the kidneys are stimulated to increase the production of renin. The larger concentration of renin increases production of Angiotensin II. This stimulates reabsorption of sodium in the kidneys in addition to an increase in aldosterone secretion from the adrenal cortex as depicted above in Figure 1. Similar to vasopressin, aldosterone acts on the kidneys to increase reabsorption of water within the nephron. Aldosterone accomplishes this through stimulating the sodium-potassium pumps throughout the collecting duct of the nephron and increasing the permeability of the nephron to both solutes. Consequently, potassium is able to follow its concentration gradient out of the nephron, in turn creating an increase in sodium reabsorption, which ultimately increases water reabsorption. Contrarily, when there is an increase in extracellular fluid volume, the reverse occurs and there is an increase in excretion of sodium. Thirst results from small reductions in intracellular fluids and larger reductions in plasma volume (Maughan, 2001; Stanhewicz, 2015; Weisinger, 1996).

Two main factors that induce these mechanisms in the body are exercise and environmental heat stress, which both cause increases in water and sodium losses due to increases in sweat production. When performing physical activity with heat stress, core temperature rises and greater heat loss must be achieved to maintain homeostasis. The most common way the body regulates this is through sweat production. The amount of fluid lost through sweating and the rate at which it is lost is determined by gender, body

size, and exercise duration, intensity, and frequency in conjunction with the state of the environment. Other factors contributing to fluid balance are urine and feces excretion, food and water ingestion, transcutaneous losses, and respiration (Maughan, 2001; Maughan, 2015). While there are many physiological systems in place to regulate total body fluid and thirst stimulation, they do not fully restore total body water to its original state. Fluid consumption is required to maintain homeostatic fluid consumption and there are many other factors that influence this (McKinley, 2004).

Gastric emptying

Consumed fluids are not immediately dispersed throughout the body to replenish dehydrated cells. Fluid is initially held in the stomach and then eventually absorbed into the body depending on the composition of the beverage. This is controlled by receptors within the duodenum and ileum that function to slow the rate of gastric emptying in an effort to reduce stress on the intestinal absorption (Leiper, 2015). This is a vital factor when developing a rehydration strategy, as gastric emptying and intestinal absorption rates regulate the accessibility of ingested fluids (Maughan, 2013). Absorption in the stomach has the ability to adapt to phases of feeding and fasting as well as to changes in the composition of the diet (Leiper, 2015).

The osmolality of fluids consumed play a key role in water regulation within the body. The concentration of solutes and the types of solutes composing a beverage determine the rate at which it is absorbed and excreted by the body. Higher osmolality will decrease the gastric emptying rate but does not have as big of an effect as energy density. While water is excreted at a fast rate, fluids with higher energy densities will inhibit gastric emptying rate. A commonly studied solute is the carbohydrate, glucose, which is known to

increase the rate at which a beverage is absorbed (Leiper, 2015). When glucose solutions are consumed, they are emptied by the stomach in two phases. First, there is rapid emptying that varies depending on the volume of the beverage consumed or the pressure within the stomach. Then, the emptying rate decreases and becomes more constant. The rate of this phase is determined by the amount of calories in the drink as well as the volume consumed (Ryan, 1989).

Gant et al. (2007) found that a 6.2% carbohydrate-electrolyte drink had the tendency to be retained in the stomach more than a non-carbohydrate flavored water drink, but not significantly. He also found that the amount of fluid emptied during the trials were not different between beverages. Similarly, Ryan et al. (1989) found that the volume of fluid excreted from the stomach was comparable for water and beverages composed of 5% glucose, 5% glucose polymer, or 3.2% glucose polymer and 1.8% fructose. Now, it is widely accepted that beverages containing less than 2.5% carbohydrate empty at a rate similar to water. Beverages with a carbohydrate content greater than 6% will inhibit gastric emptying, limit fluid delivery to and absorption by the intestine, and jeopardize physiological function. This occurs because beverages with more than 6% carbohydrate content provide an amount of carbohydrate that exceeds what can be processed at the maximum rate of exogenous substrate oxidation. Therefore, enough carbohydrate should be consumed in fluid to replenish glycogen stores, but should be limited to prevent inhibiting the gastric emptying rate (Leiper, 2015; Murray, 1999; Galloway, 1999; Duvillard, 2004). The addition of carbohydrate to the diet and consumption of fluids are individually beneficial to performance, but together their effects are additive (Maughan, 2010; Galloway, 1999).

When carbohydrate is not consumed during exercise, there is a reduction in muscle glycogen stores and this can lead to fatigue (Galloway, 1999; Maughan, 2015). However, these glycogen stores are not fully depleted at exhaustion when exercising in the heat (30-40°C) and this is accompanied by a reduction in exogenous substrate oxidation. Therefore, it has been concluded that there is a specific core temperature at which fatigue occurs, and that rehydrating to prevent the body from reaching this temperature is critical. This also suggests that fluid replacement is more important than carbohydrate replacement (Galloway, 1999).

The effects that exercise intensity has on gastric emptying rate have also been studied, but still have not been determined. Costill and Saltin et al. determined that as the intensity of exercise exceeds 75% of VO_2 max, the combination of exercise and glucose concentration may block emptying (Maughan, 2010; Galloway, 1999). However, more recent studies have failed to find similar results. Evans et al. studied the emptying rate of a 5% glucose solution after high and low intensity exercise. Ultimately, it was determined that the gastric emptying rate was not affected by the level of intensity of prior exercise. This was evident by no difference between half times for the meal to empty from the stomach, the total amount of glucose that was emptied from the stomach, as well as the amount of carbohydrate delivered to the intestine. Furthermore, Umenai et al. (2009) studied how prior hydration would affect gastric emptying rate of water, without any exercise intervention. They found that the residual gastric volume of the stomach and the emptying rate were not different when participants were and were not hydrated. Therefore, they disproved the prior theory that prior hydration would decrease the gastric emptying rate of water (Umenai, 2009). Other factors that slow gastric emptying rate

include non-neutral pH, hard exercise, and severe mental or emotional stress (Maughan, 1999).

Table 1: Summary of Trials that Examine Gastric Emptying Rate

Author	Murray	Umenai	Leiper	Gant	Ryan	Evans
Year	1999	2009	2001	2007	1989	2015
Subject n	14	15	7	9	8	8
Age	36±1	21±47	21±1	21-31	20-33	22±3
Sex	10M, 4F	11M, 4F	M	M	M	5M, 3F
Time	90 min	60 min	30 min	60 min	3 hours	30 min
Trial n	5	2	2	1	4	3
Exercise Type	Cycling	N/A [MRI]	Soccer/ walking	Shuttle running	Cycling	Continuous
Field/Lab	Lab	Lab	Field	Field	Lab	Lab
Environmental Conditions	22.8±1°C	N/A	16-22°C; 57-72%	30.4±.1°C; 31.8±.6%	33.2±0.6°C 29.8±2.8% RH	N/A
Intervention	Beverage CHO%	Pre exercise hydration status	Exercise intensity	Beverage CHO%	Beverage CHO%	Exercise intensity & Beverage CHO %
Finding	8% CHO beverage reduces gastric emptying rate, whereas lower %CHO doesn't; beverage osmolality influences emptying rate less than energy content	Water emptying rate not affected by preliminary hydration	Intensity of soccer is sufficient to slow gastric emptying	Carb-electrolyte solution raised core temp but produced similar gastric emptying rate to flavored water	During prolonged endurance exercise in heat, large quantities of water and 5%CHO can be emptied to reduce dehydration effects	Exercise has minimal effect on post-exercise gastric emptying rate of a glucose solution

Fluid Temperature

The role of the temperature at which a beverage is consumed has been widely studied. It has been observed that beverages of cold temperatures (4°C) are more palatable and increase the capacity of endurance exercise in athletes through reducing physiological strain on the body. Studies have demonstrated this finding through longer exercise time until exhaustion (Lee, 2008; Mundel, 2006; Burdon 2010), smaller increases in rectal temperature (Lee, 2008; Mundel, 2006), and decreased heart rate and therefore decreased cardiac stress (Lee 2008, Mundel, 2006)). Mundel et al. (2006) found that participants also consumed more fluid when consuming 4°C fluid ($1.3 \pm 0.3 \text{ l h}^{-1}$) compared to 19°C fluid ($1.0 \pm 0.2 \text{ l h}^{-1}$) during exercise in the heat ($33.9 \pm .2^\circ\text{C}$; $27.9 \pm .9\%$) confirming the greater palatability of cold fluid. Burdon et al. (2010) showed a higher mean power output for a 15

minute performance test when participants consumed 4°C fluid and similarly, LaFata et al. (2012) noted an improvement in performance with consumption of 4°C fluid. However in this study, participants consumed sports drinks rather than water, which could have contributed to performance enhancement as an ergogenic aid (La Fata, 2012). It is suggested that the cold fluid acts as a heat sink within the body through reducing the heat gained during exercise and therefore enabling the body have an increased capacity to store heat. This allows the athlete to mediate the rise in their core temperature throughout exercise in the heat (Mundel, 2006; Burdon, 2010; Lafata, 2012).

Contrarily, Khamnei et al. (2011) found that participants preferred 16°C fluid to 5°C fluid. The National Athletic Trainer's Association further confirms this finding through their recommendation for fluid to be consumed between 10°C and 15°C. While there is debate between the exact preferred temperature, it has been found that cool beverages below 22°C in general are proven to increase palatability, fluid consumption, and hydration (Burdon, 2012; Maughan, 2013). Jung et al. (2007) also found that in a hot environment, the absolute and relative amount of fluid consumption as well as the rate at which fluid was consumed was similar with both chilled and ambient temperature fluid. This study suggests that when conditions are hot enough, temperature of fluid does not play a role in consumption.

Table 2: Summary of Trials that Examine Fluid Temperature

Author	Lee	Mundel	Burdon	LaFata	Khamnei	Jung
Year	2008	2006	2010	2012	2011	2007
Subject n	8	8	7	45	6	10
Age	18±29	26±7	32.8±6.1	30.28±5.4	23.7±0.6	23.4±1
Sex	M	M	M	M	M	M
Time	Variable [to exhaustion]	Variable [to exhaustion]	105 min	60 min	60 min	180 min
Trials	2	2	3	2	4	2
Exercise Type	Cycling	Cycling	Cycling	Bench press, standing broad jump, bicycle	Cycling	Walking
Field/Lab	Lab	Lab	Lab	Lab	Lab	Lab
Environmental Conditions	35±.2°C; 60±1%	33.9±.2°C; 27.9±.9%	28°C; 70%	Wet bulb 14.9±15°C Dry: 24±24.2°C	38-40°C, 20-30%	WBGT=30°C; wet=25°C; dry=40°C; globe=41°C
Fluid Intervention	Beverage Temperature	Beverage Temperature	Beverage Temperature	Beverage Temp.	Beverage Temp.	Beverage Temp. & Flavor
Findings	Cold fluid ingested before and during exercise in heat reduced heat accumulation and improved endurance capacity	4°C fluid consumed during exercise in heat enhances fluid consumption and endurance	Cold beverages ingested during prolonged exercise in the heat improves body temperature and performance	Cold water ingested during exercise in moderate conditions can mediate and delay core temperature elevation	Consumption of 16°C fluid increase voluntary intake and enhances fluid state	Ambient temperature fluid consumed in the heat result in fluid consumption similar to chilled water

Dehydration

When the bodily mechanisms fail to induce the perception of thirst and to maintain total body water and the previously mentioned factors produce a poor palatability of fluid, dehydration often ensues. Dehydration is dangerous because if severe enough, it can impair both mental and physical functioning, and these effects are magnified in hot environments and in exercise performed over a long period of time. These effects can vary depending on the percentage of body mass loss (Maughan, 2010; Maughan, 2013; Maughan, 2015). Body mass reductions as little as 1% can affect the body through increased heart rate, insufficient heat loss, increased plasma osmolality, and decreased plasma volume (Duvillard, 2004). When more severe, it can result in increased core temperature, heart rate, and perception of effort. Dehydration often occurs when the

volume of sweat is not sufficiently replaced by fluid consumption. During exercise, the volume and rate of sweat loss is determined by exercise intensity and duration, weather factors such as temperature, humidity, and wind speed, as well as the factors that influence the accessibility of fluid (Maughan, 2013). Dehydration can also have negative consequences on cognitive function as well as on mood (Maughan, 2010).

While water losses are continuous throughout daily life, fluid consumption is episodic which can often result in water deficits that the body has no mechanisms to combat (Maughan, 2015). Water deficits that lower the volumes of the intracellular and extracellular fluid compartments often causes dehydration. This in turn causes a decrease in the volume of circulating blood with a lower osmotic pressure. Because of the hypotonic-hypovolemic blood, both sweat rate and skin blood flow responses are reduced and cause an increase in heat storage. The decreased skin blood flow also creates complications in maintaining the volume of blood returning to the heart as well as the ability of the heart to pump blood out, as the higher heart rate cannot counteract the lower stroke volume. Overall this causes a decrease in cardiac output and makes it hard for the body to sustain metabolism and thermoregulation (Sawka, 2001; Galloway, 1999; Maughan, 2015). While hypohydration and heat stress both add stress to cardiovascular functioning individually, together their effects are additive. Further, the the added stress from the combination of exercise and heat strain results in limited blood volume and creates too high of a demand for the body to maintain peripheral and central circulation. As the temperature of the body increases, blood vessels in the skin dilate resulting in less venous resistance and pressure, further decreasing cardiac output (Sawka, 2001; Maughan 2015).

Another impact of dehydration on the body is an increased metabolic rate that increases core temperature. 70-75% of the energy used to perform work is in the form of heat, so the body increases heat production during exercise in an attempt to meet metabolic demands. The body also attempts to facilitate heat loss to control increases in core temperature, typically through evaporative cooling (Maughan, 2015). If heat loss mechanisms cannot control for the elevation in temperature, there is the potential for exertional heat illness to occur which if left unmanaged can be fatal (Maughan, 2010; Sawka 2001). A deficit as little as 1% body weight can significantly increase core temperature, and temperature continues increasing as body weight decreases. It has been reported across many studies that for every 1% BML the core temperature increases 0.22°C or (0.5°F) (Montain and Coyle). While the total body water maintains homeostasis from day to day, exercise and warm environments will put stress on water flux to aid thermoregulation mechanisms. As exercise intensity and climate temperatures increase, there is a greater reliance on the body to release heat through evaporative cooling. While this helps to combat heat retention, the body loses significant volumes of water through sweat, as well as electrolytes (Sawka, 2001).

While hypohydration can impact the body in itself, hypohydration during long-term exercise in the heat is even worse. This can occur due to an increased volume of sweat lost which can also result in thermoregulation failure and circulatory collapse (Galloway, 1999; Sawka, 2001). Dehydration decreases blood flow to the skin and therefore restricts heat loss, which can lead to increased core temperature, increased heart rate, fatigue, headaches, muscle cramps, and more (Duvillard, 2004; Sawka, 2001). When heat acclimatized, the body is more effective at combating core temperature elevation. However,

when dehydrated, the body is even more affected by raises in core temperature when heat acclimatized, because similar temperatures are reached by those both heat acclimatized and not acclimatized (Sawka, 2001).

Dehydration can cause significant movements of fluid between compartments of water within the body, which can have a large effect on cell functioning. During short-term high-intensity exercise, glycogen from active muscles is broken down into smaller substrates, causing an increase of intracellular osmolality. While there are mechanisms within the body to maintain homeostasis, the increase in osmolality causes high intracellular osmotic pressure, which pushes extracellular water into cells, causing them to swell. This is magnified in long-term high-intensity exercise where there is a higher concentration of metabolic intermediates and a significant decrease in plasma volume. As a result of cell swelling, the body will prioritize anabolic reactions, such as protein and glycogen synthesis, rather than catabolic (Maughan, 2013).

Conclusively, water ingestion is vital in optimizing exercise performance. For example, it can improve exercise capacity through maintaining blood volume, which is pertinent in improving thermoregulation and cardiovascular function when a large volume of fluid is being lost as sweat. It is also an effective way to lowering core temperature (Galloway, 1999; Duvillard, 2004). Further, it helps to delay fatigue and prevent injuries that occur with dehydration and high sweat loss, and helps to lower submaximal heart rate, heat stress, heat exhaustion, and potentially heat stroke. Heat stroke is not directly caused by dehydration, but instead by the rate of the heat production within the body and the capability of the environment to absorb that heat (Duvillard, 2004).

Hydration and Performance

When performing exercise in temperature greater than 30°C, athletes can become dehydrated through body mass losses between 2 and 7%, which can have a negative effect on performance. However, the extent of this effect can range anywhere from 7-60% performance decrement (Maughan, 2010). For instance, when severe enough, dehydration has been known to decrease VO_2 max, which results in increased stress on thermoregulation and cardiovascular functioning, increased depletion of glycogen stores, increased metabolite concentration, and weakened psychological drive for exercise (Sawka, 2001).

Several researchers have studied the relationship between hydration method and performance in endurance athletes but all found that hydration method had no effect on performance (Armstrong, 2014; Berkulo, 2015; Dion, 2013). Nolte et al. (2013) similarly looked at hydration method and performance in military personnel and also did not find any effect on performance. Moreover, none of the studies found a significant difference in urine specific gravity, urine osmolality, total sweat loss, or change in body mass between different hydration methods.

Little research has been done on the relationship between hydration and performance in sports of high-intensity intermittent exercise. Mears et al. (2013) looked at both high-intensity intermittent exercise and continuous exercise and the water consumption that occurred after exercise. There was a greater volume of water consumption found in trials with high-intensity intermittent exercise, which was accompanied by a higher sweat loss so that overall body mass loss was similar in both trials. However, there was a greater fluid replacement in the high-intensity intermittent

exercise trials as well as a greater sensation of alleviated thirst which was shown by a decrease in sensation of thirst (Mears, 2013).

Owen et al. (2012) assessed the effect different hydration methods would have on soccer skills and performance. The different methods included no-fluid in which participants could not consume fluids, ad-libitum in which participants could consume fluids as they wished and prescribed-fluid in which participants could only consume fluid to balance out a predetermined sweat rate. They found that prescribed intake resulted in the greatest percentage of sweat replaced and that the greatest percent of body mass lost was in the ad libitum and no-fluid trials. Despite these findings, the participants' performances were similar for all trials, which suggests that mild to modest dehydration does not have a debilitating effect on performance (Owen, 2012).

Kurdak et al. (2010) studied hydration during football (soccer) matches as well. For the first match, both teams were provided with water and were not given any hydration instructions. For the second match, one team continued with that condition while the other was given access to both water and a sports drink and instructed that they had unlimited access to those drinks. There were no differences for any of the parameters between the teams for the first match, or between matches for the team that consumed only water. Further, both teams in the second match had similar hydration outcomes through similar consumption and sweat volumes. However, they did find that during the first match, 16 of the 22 players lost more than 2% body weight and only $55 \pm 19\%$ of fluids lost were replaced.

Da Silva et al. (2011) also looked at fluid consumption within soccer players, but studied ad libitum fluid consumption and sweat loss during a match. Players were allowed

to consume water ad libitum but were also told to drink 400 mL of a 6% carbohydrate-electrolyte drink throughout the game, 200 mL before the match, and 200 mL during half time as that was normal match protocol. Despite consuming 800 mL of fluids and drinking ad libitum, players only replaced about 50% of sweat losses and had no significant difference in pre- and post-game thirst sensations. Researchers concluded that limited chances to drink during a match must be a contributing factor to poor fluid replacement as well as the fact that many start matches and practices dehydrated (Da Silva, 2011).

Further, Maughan et al. (2010) reviewed studies that looked at dehydration and soccer skill performance. McGregor et al. (1999) determined that when completing a soccer skills test, performance declined when participants were not allowed to consume fluids and was accompanied by a greater percentage of body mass lost. However, when participants were allowed to consume fluids, their performance was sustained. Additionally, Edwards et al. (2007) also administered a soccer fitness test and found similar results (Maughan, 2010).

Table 3: Summary of Trials that Examine Hydration and Performance

Author	Silva	Owen	Nolte	Mears	Dion	Berkulo	Armstrong
Year	2011	2012	2013	2013	2013	2015	2014
Subject n	10	13	57	10	10	12	24
Age	17 ±0.6	22.2±3.1	N/A	22±2	28±7	34±7	44±7, 47±7
Sex	M	M	M	M	M	M	20M, 4F
Time/Distance	95 min	90 min	4 hr	150 min	21.1km	40km	164km
Trials	1	3	1	2	2	3	1
Exercise Type	Soccer match	Soccer	Military march	HIIE	Distance Running	Cycling	Cycling
Field/Lab	Field	Field	Field	Lab	Lab	Lab	Field
Environmental Conditions	31±2.0°C, 48±5%	19.4±0.8°C; 59.4±5.5%	21±28.2°C; 16±47%	19.7±1.1°C; 10.5%	30°C, 42%	35.2±0.2°C	36.1°C±6.5°C; 29%±16%
Findings	Without a provided strategy, players started match dehydrated and only replaced 50% of sweat loss	Fluid intake during exercise and dehydration had minimal and inconsistent effects on soccer performance	Hydration method had no effect on hydration indices	Greater voluntary water consumption post-HIIE was result of increased sweat loss and blood lactate concentrations	Hydration method had no effect on performance	Hydration during exercise did not influence performance	Hydration method had no effect on hydration indices

External Factors

Beyond the many physiological mechanisms in place to monitor fluid balance within the body, there are many external factors that affect voluntary hydration. Yeargin et al. (2015) looked at the effects of external and self-administration of fluid on consumption volume. While there was no significant effect of administration technique on thirst, it was determined that less fluid was consumed when fluid was externally administered. This likely occurred because participants squirted larger volumes of fluid into their mouths as a result of sensory feedback and grip force, which were not available through external administration. When fluid was received externally, participants could only use visual feedback, which made consumption more difficult and resulted in smaller volumes of fluid (Yeargin, 2015).

Another factor of water distribution that has been studied is access to fluids. Godek et al. (2010) studied the effects of constant access and limited access to fluids on fluid consumption and sweat loss. Ultimately there were no differences found in sweat rate or water consumption. Sweat losses were greater in those with limited access, but consumption volume was greater as well, so there was no difference in fluid balance. This was due to the observation that players with limited access to fluid would consume larger volumes of fluid than those with constant access (Godek, 2010).

Similarly, Wansink et al. (2005) looked at the influence of visual cues and portion sizes on consumption volume in regards to food. In order to do this, he designed a self-refilling bowl and compared the volume of soup consumed between participants with a normal bowl and those with the subtly self-refilling bowl. Participants with the self-refilling bowls consumed 73% more soup than those with normal bowls but did not believe they

had consumed anymore. Furthermore, participants with self-refilling bowls were less accurate at assessing how much they had consumed when compared to those with normal bowls. These results suggest that portion size and consumption norms can affect consumption volume and that people often rely on these visual cues rather than monitoring their own internal cues (Wansink, 2005). Wansink et al. (2010) continued studying different external cues that contributed to consumption habits. Visibility, size, and accessibility are major factors in consumption. These factors can override internal cues of thirst because people instead rely on rules-of-thumb to signal the end of consumption, such as finishing a container. People are often unaware of the influence environmental factors have on their consumption habits, so solely determining the relationships between these factors and consumption will not eradicate the associated biases (Wansink, 2010).

Maughan et al. (2001) suggested that the style of container may have an effect on consumption. He described an unpublished study in which participants had ad libitum access to fluids in 6 different containers in separate trials. Significant differences in likability were found between containers, which can be seen in the figure below. Participants liked and consumed more from the two 16-oz bottles than the 250-mL drink box. Comments from the participants explained this difference through annoyance with the small size of the box and the use of a straw. Maughan suggests that other factors such as a bladder, numerous containers, or flexibility of a bottle could increase fluid consumption (Maughan, 2001).

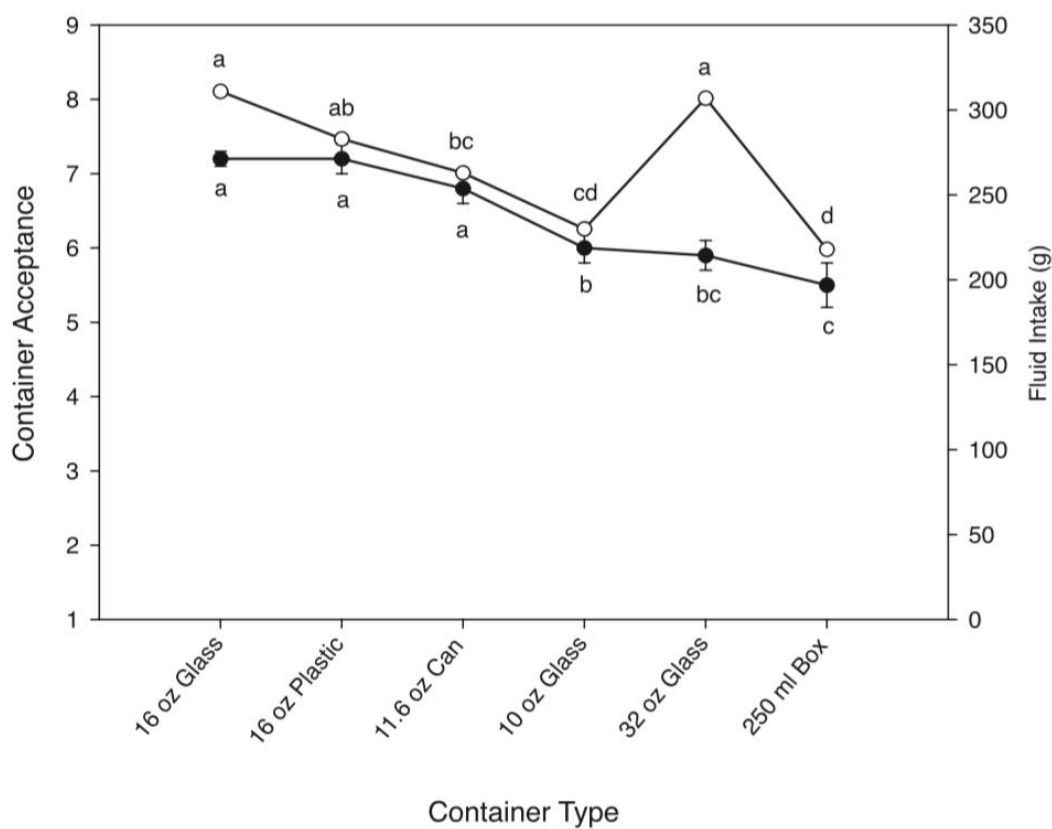


FIGURE 3.13 Beverage-package acceptance (●, 9-point scale) and fluid intake (○, g). Within each curve, points not sharing a common letter are significantly different from each other ($p < 0.05$).

Recommendations

Maughan et al. (2010) also reviewed articles regarding rehydration strategies. Noakes (2007) has suggested that athletes drink according to thirst while the most recent Position Stand from the American College of Sports Medicine has suggested that athletes should consume to combat body mass loss greater than 2% (Maughan, 2010). However, a more widely accepted recommendation to combat dehydration is that athletes should individually assess their own sweat rates and hydration needs in order to create a personal rehydration strategy that will work best for them. Factors that should be considered when developing this strategy include the type of exercise, the environment, and individual

needs. These factors should be monitored regularly during training so that rehydration strategies can be adjusted to accommodate changes. It is also vital to start exercise euhydrated as fluid deficit prior to starting to exercise can cause even greater physiological strain during exercise (Maughan, 2010; Maughan, 2013). Further, fluid ingestion should be equivalent to sweat losses during exercise (Galloway, 1999; Maughan, 2010).

Pre-exercise hydration has also been highly recommended because despite athletes being properly educated and creating an effective rehydration strategy, they rarely consume enough to prevent dehydration when in the heat. Beginning exercise euhydrated allows for a greater chance at optimal performance. Further, accounting for individual gastric emptying and intestinal absorption rates still may not account for individual sweat rate losses, so a disparity can still ensue and cause dehydration or gastrointestinal distress (Galloway, 1999).

While these recommendations are effective for endurance exercise, the success of them for intermittent exercise is not as well known, partly because it's hard to evaluate performance in team sports. As previously mentioned, gastric emptying rate has been shown to decrease as exercise intensity increases. Therefore, athletes participating in high-intensity intermittent exercise may be hindered by attempting to replace the volume of fluid lost (Galloway, 1999).

Introduction

Fluid loss is continuous throughout daily life, and increases in proportion to the length and intensity of exercise. Contrarily, fluid intake is episodic and many factors determine how well an athlete compensates for fluid deficits (Maughan, 2015). Some of these factors include individual sweat and gastric emptying rates, physiological mechanisms that produce thirst responses, temperature and carbohydrate concentration of fluids, and athlete knowledge of hydration needs (Galloway, 1999). Temperature (Mundel, 2006; Burdon, 2010; Lafata, 2012) and the addition of carbohydrate (Leiper, 2015; Murray, 1999; Galloway, 1999; Duvillard, 2004) to fluid both have been shown to increase the palatability of the drink and therefore fluid consumption. Carbohydrate concentration should not exceed 6% (Leiper, 2015; Murray, 1999; Galloway, 1999; Duvillard, 2004) and cold temperature beverages near 4°C are preferred (Lee, 2008; Mundel 2006, Burdon, 2010, La Fata, 2012). Generally, it has been recognized that fluids below 22°C will increase palatability, fluid consumption, and hydration (Burdon, 2012; Maughan, 2013).

In addition to fluid composition, researchers are investigating the effects that fluid distribution has on fluid consumption. Yeargin et al. (2015) assessed the effects of administration on water consumption and found that the total volume consumed from external administration was less than that for self-administrated fluid. Regardless, the method of administration had no effect on perception of thirst. Godek et al. (2010) examined the differences between constant and limited access to fluids during football practice, but found no differences in the amount of fluid consumed or the percent of sweat loss replaced. One factor that has yet to be addressed is the actual vessel the fluid is consumed from. In researching mindless eating, Wansink et al. (2009) suggested that

consumption is influenced by environmental factors and may even be influenced by pre-conscious or perceptual factors rather than just physiological drives. In particular, it was proposed that visual cues play a role in consumption (Wansink, 2005). This research indicates that people may also base their water consumption habits on visual cues, container size or type, or the idea of finishing a certain volume, rather than on thirst.

In addition, many researchers have highlighted the importance of athletes understanding their individual sweat rates and hydration needs in order to develop personalized rehydration strategies. The 2007 ACSM guidelines on fluid intake suggest that intake should compensate for sweat losses (Maughan, 2010; Maughan, 2013; Galloway, 1999) however, limited investigations examine the influence of visual cues and fluid vessel type on ad libitum hydration during exercise in the heat. Furthermore, most of the given recommendations have been proven to work for endurance exercise, but effectiveness within high-intensity intermittent exercise is less known. One conflict between the types of exercise is that gastric emptying rate has been shown to decrease with increasing exercise intensity, meaning that attempting to consume liquid equivalent to losses may actually hinder performance in high-intensity intermittent exercise (Galloway, 1999).

In an attempt to better understand the factors influencing hydration strategies in high-intensity intermittent exercise athletes, our research team conducted a single-blind lab investigation during a standard sweat electrolyte test, because no previous investigators have systematically investigated the ability of an athlete to assess fluid balance and hydration needs. Further, limited investigations have attempted to blind participants from the the amount of fluid in one of the vessels for rehydration during exercise in the heat. We proposed 2 hypotheses: (1) BLA will have greater fluid

consumption than BTL; and (2) athletes will poorly assess their individual volumes of fluid consumed and fluid lost. If these hypotheses are proven, rehydration strategies for those competing in high-intensity intermittent exercise could be reevaluated and updated to better meet athletes' needs.

Methods

Participants

Participants included 19 heat-acclimatized male athletes who were participating on a Division I Soccer Team. The physical characteristics (mean \pm SD) of the participants were as follows: age, 20 ± 1 year; height, 180 ± 7 cm; body mass, 78.68 ± 7.39 kg; maximum heart rate, 197 ± 8 beats \cdot min $^{-1}$; and VO_2 max, 52.08 ± 5.15 mL \cdot kg $^{-1}\cdot$ min $^{-1}$. The participants had to be planning to participate in the 2015 season. Screening information was obtained via medical history questionnaire to ensure that participants were: a) a current member of the men's soccer team participating in the 2015 season, b) between the ages of 18-30 years, c) cleared by the Sports Medicine Department and passed their pre-participation physical examination, d) not suffering a current musculoskeletal injury, at the time, that would limit their physical activity for greater than 4 months, e) not suffering from a season-ending injury or injury that would have limited their participation in team activities for greater than 4 months. Participants were free to leave the study at any time, without retribution or negative consequences. This study was approved by the University of Connecticut Institutional Review Board.

Table 1. Participant's Characteristics

Characteristic	
Gender	Male
n	19
Age, y	20 ± 1

Height, cm	180 ± 7
Pre BM, kg	78.68 ± 7.39
Max HR, beats·min ⁻¹	197 ± 8
VO ₂ Max, mL·kg ⁻¹ ·min ⁻¹	52.08 ± 5.15

Procedure

As part of a larger study, participants completed standard sweat electrolyte testing in which they exercised on a treadmill at 75% of their maximum heart rate for 60 minutes in a heat chamber maintained at 30 degrees Celsius and 45-55% humidity (ambient temperature was $29.68 \pm 5.08^{\circ}\text{C}$, relative humidity $49.32 \pm 10.65\%$, WBGT $19.32 \pm 4.43^{\circ}\text{C}$). Participant's body mass and hydration status (urine color and specific gravity) were obtained prior to exercise. Specific gravity was measured using a refractometer that was recalibrated each time with distilled water. The participant also inserted a sterile and clean flexible rectal thermometer probe (10cm) past the anal sphincter in the privacy of a bathroom. Participants with a urine specific gravity >1.020 drank 500mL of water prior to the test and if rectal temperature is $>37.22^{\circ}\text{C}$ [99.0°F] indicating a low-grade fever they were asked to reschedule the test when they were no longer ill. Therefore, all participants began the trial euhydrated. Heart rate and core body temperature were monitored every 10 minutes to ensure subject safety and participants were not left unattended. Nude body mass was taken both before and after testing.

Prior to testing, pairs of participants scheduled to test at the same time were randomly assigned either a 3-liter Camelbak™ water bladder (BLA) or a 1-liter Gatorade™ water bottle typically used during practice (BTL). For the BTL group, water bottles were placed directly on the treadmill in plain sight while Camelbak bladders were stored above the treadmill in the ceiling with the straw hanging down to the level of the

participant's mouth. Camelbak bladders were wrapped in an Igloo™Maxcold Natural Ice Sheet and placed in an insulated backpack (Camelbak, Octane 18X Hydration Backpack, Petaluma, CA) in order for the fluid to stay cool throughout exercise. Researchers told participants at the beginning of testing that the water was there for them to consume throughout exercise, but were not reminded of it or assigned a hydration strategy. Furthermore, the participants were blinded to this aim of the study and were unaware that researchers were actually measuring their hydration practices and they were not aware that fluid consumption volume was being measured. Water bottles and bladders were weighed before and after the trial. These masses were converted to volumes to determine the amount of fluid consumed. Nude body mass was taken before and after the trial. Throughout the run, the participants used a provided towel to blot dry any sweat during exercise. Immediately after the exercise, subjects will leave the hot environment and will dry themselves off and be weighed to determine the body mass loss due to sweating. This body mass change was used to calculate the volume of sweat lost. During exercise, participants were asked to rate their perception of thirst, RPE, and perception of temperature, every ten minutes. Researchers provided participants with a 9-point scale ranging from "not thirsty at all" to "very, very thirsty". Fluid volume and temperature were measured before and after exercise, using a digital scale (Ranger, OHAUS, and rectal temperature monitor (YSI401, Yellow Springs Instruments, Yellow Springs, CO) respectively. Once exercise was completed, participants completed a hydration knowledge and strategy questionnaire in order to assess their water consumption habits. Participants estimated volumes of consumed and lost fluids, using the 1-liter Gatorade™water bottle as a measurement. Other questions asked determined the importance of hydration to the

participants, their methods for consumption during the trial, as well as the frequency of their consumption during games and practices.

Results

Statistical Analysis

Differences between groups were analyzed using paired samples t-tests for the main variables of interest from PRE to POST using statistical software (IBM SPSS Statistics Version 20.0.0). An a-priori alpha level was set at 0.05.

Table 2. Combined Perceptual and Physiological Responses (n=19)

Variable	Pre-Test	Post-Test
RPE	6 ± 1	11 ± 3
Thirst Perception	2 ± 1	4 ± 2
Thermal Perception	4.0 ± 1.5	5.5 ± 1.0
Rectal Temperature, °C	37.26 ± 0.48	38.43 ± 0.39
USG Pre	1.017 ± 0.006	1.019 ± 0.008
Heart Rate, bpm	88 ± 16	149 ± 6
Urine Color Pre	4 ± 1	5 ± 2

Table 3. Hydration Factors Between Groups

Variable	Group (BLA=10, BTL=9)	Mean	P-Value
Fluid Consumed, (L)	BLA	0.44 ± 0.40	0.879
	BTL	0.39 ± 0.29	
Percent Body Mass Loss (%)	BLA	1.86 ± 0.52	0.469
	BTL	1.67 ± 0.57	
Body Mass Loss, (kg)	BLA	1.42 ± 0.37	0.712
	BTL	1.34 ± 0.45	
Sweat Rate, (mL•h ⁻¹)	BLA	1.83 ± 0.49	0.62
	BTL	1.73 ± 0.32	
USG Post	BLA	1.018 ± 0.009	0.331
	BTL	1.017 ± 0.006	
Urine Color Post	BLA	4 ± 2	0.152
	BTL	5 ± 1	
T _{rec} Post, (°C)	BLA	38.53 ± 0.34	0.284
	BTL	38.37 ± 0.42	

(*) significant difference p<0.05 between groups

Hydration and Fluid Consumption

All 19 participants were included in the statistical analysis of the data ($n=19$), and their baseline characteristics can be found in Table 2. However, 2 participants did not consume any fluid during testing and were removed to produce a second set of data ($n=17$). The two participants were in different groups. Participants ran at an average of 5.4 ± 0.61 with an average heart rate of 141 ± 8 and an average rating of perceived exertion of 10 ± 2 . These were not significantly different ($p<0.05$) between BLA and BTL at any interval. Responses concerning fluid consumption and hydration for both groups are shown in Table 3. No variables distinguished BLA from BTL. Urine color ($4 \pm 1; 4 \pm 1$; $p=0.595$) and USG (1.018 ± 0.006 ; 1.017 ± 0.006 ; $p=0.76$) at the start of the trial also were not significant between BLA and BTL confirming that participants all began in a similar state of euhydration. All variables remained insignificant when $n=17$.

Percent body mass loss significantly correlated with volume of fluid consumed ($p=0.47$, $r^2=-0.21$), suggesting that those with increased %BML are associated with reduced fluid consumption. Percent body mass loss also significantly correlated with sweat rate ($p=0.014$; $r^2=0.305$) suggesting that those with increased %BML are associated with higher sweat rates. There was a significant relationship ($p<0.05$) between fluid consumed and heart rate at 20 minutes and post-trial $r^2=(-0.324, -0.230)$. Fluid consumption was almost significantly correlated to heart rate at 10 minutes, 30 minutes, and 40 minutes $r^2=(-0.207, -0.187, -0.199)$; $p=(0.05, 0.06, 0.065)$, respectively. These results show that as heart rate increased, fluid consumption decreased, which is consistent with the literature. However, heart rate was controlled within 5 bpm of participants' heart rate at 75% VO_2 max. Further,

post urine color and post USG strongly associated with each other ($p=0.000$, $r^2=0.648$). Pre-urine color was significantly associated with the change in body mass loss ($p=0.018$, $r^2=0.286$) suggesting that urine color is a predictor of overall body mass loss.

Rectal Temperature and Speed

Baseline speed and rectal temperature at baseline, 10 minutes, 20 minutes, and 30 minutes were significantly associated $r^2=(0.251, 0.342, 0.304, 0.242)$. Speed at 10 minutes and 50 minutes were significantly associated with rectal temperature at 50 minutes and post trial $r^2=(0.223, 0.219; 0.214, 0.228)$. Speed at 20 and 30 minutes significantly associated with rectal temperature at 40 minutes, 50 minutes, and post trial $r^2=(0.214, 0.247, 0.240; 0.227, 0.278, 0.279)$. All results indicate that as speed increased, rectal temperature increased as well. This relationship was also seen between the change in rectal temperature and speed at 20, 30, and 40 minutes $r^2=(0.271, 0.163, 0.166)$.

Thirst

Thirst prior to starting the test was statistically different between BLA and BTL ($p=0.049$), however not clinically different (2 ± 1 ; 2 ± 1), respectively. When $n=17$, it was no longer significant (BLA: 2 ± 1 ; BTL: 2 ± 1 ; $p=0.80$). Both groups rated perception of thirst 2 ± 1 , “not thirsty at all”, at the start of the trial and progressed to a rating of 4 ± 2 for both, which is considered “neutral”. The difference between pre and post thirst perception was an average of 3 ± 1 , and pre and post thirst ratings were statistically significant ($p=0.001$). Therefore, thirst changed significantly between pre and post-trial, showing that all participants became thirsty.

There was a significant association ($p<0.05$) between thirst at 10 minutes and RPE at 30 minutes, 40 minutes, and 50 minutes $r^2=(0.233, 0.236, 0.002)$, as well as between

thirst at 20 minutes and RPE at 20 minutes and 30 minutes $r^2=(0.255, 0.249)$. Finally, there was a significant association between thirst at 30 minutes and 40 minutes and RPE at 30 minutes and 40 minutes $r^2=(0.223, 0.181; 0.220, 0.208)$. All of these associations were positive, showing that as thirst increased, RPE increased as well. Further, thirst at 30 minutes had a significant relationship ($p<0.05$) with rectal temperature at 40 minutes, 50 minutes, and post $r^2=(0.269, 0.262, 0.272)$. This showed that as thirst increased, rectal temperature also increased.

Hydration Knowledge and Assessment

Table 4. Actual and Perceived Fluid Consumption and Losses

	Mean (mL)
Perceived Volume Consumed	692 ± 572
Perceived Volume Lost	2244 ± 1552
Actual Volume Consumed	$401.58 \pm 334.37^*$
Actual Volume Lost	$1377.89 \pm 404.90^{*#}$

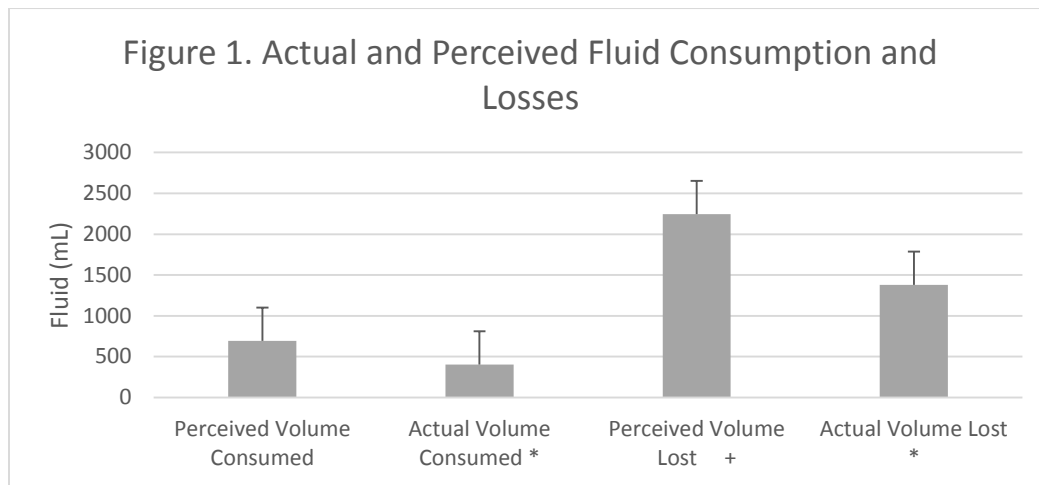
(*) significant difference $p<0.05$ compared to perceived

(#) significant difference $p<0.05$ compared to actual consumed

Combined all participants perceived they consumed 692 ± 572 mL of fluid during the trial. Perception was not statistically significant between BLA and BTL ($565 \pm 462; 833 \pm 673; p=0.321$). All participants actually consumed 401.58 ± 334.37 mL, which also was not statistically significant between groups (BLA: 390 ± 288 ; BTL: 414 ± 397 ; $p=0.978$). Further, all participants perceived losing 2244 ± 1552 mL of sweat, which was not statistically significant between groups (BLA: 2063 ± 1778 ; BTL: 2444 ± 13333 ; $P=0.607$). Finally, all participants actually lost 1377.89 ± 404.90 mL (BLA: 1344 ± 452 ; BTL: 1416 ± 369 ; $p=0.712$).

As displayed in Figure 1, athletes perceived that they consumed more and lost more fluid than they actually do. Both perceived and actual volumes consumed and perceived and actual volumes lost were statistically significant ($p=0.016$; $p=0.015$) respectively and

had significantly positive correlations ($p=0.014$, $p=0.036$). The actual volumes consumed and lost had a significant relationship ($p=0.000$).



* Actual significantly different than perceived

+ Lost significantly different than consumed

Questionnaire

Table 5. Questionnaire (n=18)

Questionnaire Item ^{ab}	Response
How important was staying hydrated during this exercise trial to you? ^c	3.68 ± 1.53
How important was staying hydrated during practice to you?	4.16 ± 1.26
How important was staying hydrated during a game to you?	4.36 ± 1.33
In a normal practice, how frequently do you drink?	A: 1, B: 12, C: 3, D: 2
In a normal game, how frequently do you drink?	A: 2, B: 12, C: 4, D: 4

^a 1 = Not important at all, 5 = Very important

^b A = Whenever I want, B = Only during breaks, C = When not playing, D = When coach tells us

^c n=19

Responses for several open-ended questions from the Hydration Questionnaire can be found in Table 5. For the question, ‘Did you have a strategy to drink during the test?’, only 3 (n=19) answered yes. In regards to the strategy they employed, one participant wrote “Drink while body started heating up”, while the other 2 participants selected the

option, “To drink periodically throughout exercise (for example: drink every 15 min).

Further, when asked if hydration is important during exercise, all (n=18) selected yes.

Reasons why hydration is important included fluid balance such as “because it replaces the liquid you lose during exercise”, performance enhancement such as “dehydration decreases performance”, cramp prevention such as “Don’t cramp and use it to replace sweat you lose”, increased energy, and “so you don’t pass out.”

Discussion

We hypothesized that because participants in the BLA group were blind to the amount of fluid that was in the 3-liter bladder directly above their head that they would “mindlessly” consume more than those in the BTL group who were only provided a new bottle when they completed the first that was placed in plain sight, but not directly next to their mouth. Furthermore, we hypothesized that all participants would not accurately assess their hydration needs. Our results indicated that our first hypothesis was not supported while our second was. We found minimal differences between groups related to physiological variables, perception responses, and water consumption, demonstrating that the water vessel does not have an effect on hydration level. This is consistent with the literature in which hydration and distribution methods do not have an effect on hydration (Armstrong, 2014; Berkulo, 2015; Dion, 2013; Nolte, 2013; Mears, 2013; Owen, 2012; Kurdak, 2010; Silva, 2011; Yeargin, 2015; Godek 2010). However, most studies define groups of participants based on hydration method (i.e. ad libitum vs. restricted), but none have allowed participants to consume mindlessly. Therefore, it is hard to compare results. However, Silva et al. (2012) suggests that fluid intake in soccer is affected by factors such as individual bottles, proximity to bottles, drink palatability, duration and number of

opportunities to drink. We were able to eliminate all of these factors, except for palatability, through running the trial in a controlled lab environment. This strengthens the results showing that water vessel does not influence consumption as there were few other factors affecting their motivation to drink.

Nolte et al. (2013) studied ad libitum vs. restricted fluid replacement and similarly found that even with significant body mass loss by one group, there were still not significant differences between groups besides sweat rate. Therefore, it makes sense that our groups would be similar with insignificant body mass loss. Burkulo et al. (2015) similarly found no effect of hydration status on any variable besides thirst sensation. They argued that this proved that thirst is an effective signal for hydration through a feedback signal system that could also result in reduced exercise intensity. Though our hydration measures did not have an effect on thirst, thirst was associated with increased RPE and rectal temperature. This indicates that increased rectal temperature and RPE are associated with decreased hydration because dehydration inhibits the body's ability to dissipate heat and causes an increased core temperature. Further, dehydration causes a decrease in circulating blood which in turn decreases sweat rate and skin blood flow responses, which all leads to an increase in heat storage. This also makes it harder for the body to maintain proper blood volume returning to and be pumped from the heart, leading to decreased cardiac output and makes the body work harder to sustain metabolism and thermoregulation (Sawka, 2001; Galloway, 1999; Maughan, 2015). As the body temperature increases, blood vessels throughout the skin dilate and further reduce cardiac output (Sawka, 2001; Maughan 2015).

Percent body mass loss increased as fluid consumption decreased and sweat rate increased. Percent body mass is a common measure of hydration and demonstrates that dehydration occurs with less fluid intake and greater sweat loss. The results indicated an almost significant association between fluid consumption and sweat rate ($p=0.079$ $r=.412$), which was also seen by Nolte et al. (2013) who found that fluid intake increased as sweat rate increased. Despite these associations, body mass loss did not significantly correlate with any hydration indices such as urine color, USG, or rectal temperature, which is common in the literature. This suggests that these values may not be accurate measures of hydration within the present study.

The participants estimated both their fluid consumption and losses to be much more than they were. Further, even though they thought they lost more fluid, they still did not come close to consuming their actual losses. Despite these disparities, all participants unknowingly stayed adequately hydrated ($<2\%$) throughout the trial ($\%BML\ 1.76 \pm 0.54\%$) which may have been due to their euhydrated arrival or heat acclimatization status, both factors known to assist in the maintenance of hydration during exercise. There was also a significant relationship between the volume of fluid consumed and the volume of sweat lost ($p=0.000$), whereas Silva et al. (2011) failed to find this relationship significant and stated that no other studies had been able to find a significant relationship in adult soccer players. This suggests that perhaps those players in our study who present with increased sweat rate have an increased knowledge of their individual needs or that their thirst mechanism may be increased compared to other players with lower sweat rates. They also failed to find a significant difference in pre- and post-trial thirst sensation, which was observed in this study (Silva, 2011).

One reason the participants could have misjudged fluid consumed and lost, is they could have lacked consumption monitoring, which is closely observing what you're consuming. Wansink et al. (2005) suggests that consumption monitoring reduces the discrepancies between perceived and actual consumption (Wansink, 2005). Our participants were blind to the fact that researchers were examining their fluid ingestion and therefore were not pressured to be actively aware of their consumption habits. However, advising athletes to partake in consumption monitoring would be contrary to the suggestion that athletes should consume fluids ad libitum so that they don't focus on evaluating their thirst (Armstrong, 2014). Further, Galloway et al. (1999) found that even if all factors surrounding fluid consumption are addressed, most athletes still do not match consumption with losses to prevent from becoming dehydrated when in hotter environments (20-30°C).

In soccer specifically, lack of rehydration could be attributed to several other factors. For example, while importance of hydration during practice was rated 4.16 ± 1.26 , only 1 (n=18) hydrates when he wants, while the remaining hydrate during breaks, when not playing, or when coach tells them too. Similarly, the importance of hydrating during a game was rated 4.36 ± 1.33 , but only 2 (n=18) hydrate whenever they want. This presents a common problem in high-intensity intermittent sports in which athletes do not adequately hydrate because they only have the option to do so during breaks, and the only athletes who are able to drink when they want are substitutes because they have more and longer breaks. Further, while the participants rated importance of hydration during the trial as 3.68 ± 1.53 out of 5, only 3 (n=19) responded yes to having a hydration strategy for the trial. This could be due to the fact that the trial was continuous and participants felt they

could only hydrate if they had a break. This is problematic for top players who are rarely taken out of games for breaks.

Current rehydration strategies recommend athletes to consider a plethora of factors including sweat rate, gastric emptying rate, environment, exercise type, and more because strategies have to be individual and not general. Beyond educating athletes on the different factors that affect their hydration status, they also need to be educated how to assess their hydration beyond looking at urine color, which may not be possible during sports where there are not breaks during exercise. More research is needed to find effective ways for athletes to accomplish this.

Limitations

Many participants in the BLA had not seen or used a Camelbak bladder before, which could have created a learning curve for their fluid consumption. Further, a few international participants completed this trial within a few days of arriving to the United States and English was not their primary language. In all of these situations another participant was available to translate questionnaire questions to these participants and instructions, but was not available during the exercise trial when asking the perceptual ratings. This could have skewed results for the questionnaire, RPE, thirst perceptions, and thermal ratings. Finally, one participant neglected to fill out the second page of the questionnaire, decreasing an already small sample size for half of the questions.

Conclusion

In conclusion, water vessel had no effect on participants' consumption habits during the trial, though this could have been a result of unfamiliarity with the bladder. However, participants were found to significantly overestimate both fluid consumption and losses

while also failing to adequately rehydrate. This suggests that more instruction is needed regarding personal hydration assessment in the heat or that coaches and trainers should work to provide proper hydration during session to athletes.

Appendix A

Hydration Questionnaire

Subject #: _____ Date: _____ Time: _____

1. Approximately how many water bottles of fluid do you think you drank during this trial?

_____ water bottles of fluid



2. Approximately how many bottles of sweat do you think you lost during this trial?

_____ water bottles of sweat



3. Do you think that you arrived hydrated to the test?

- a. No
- b. Yes

4. If you answered “yes to #3” please tell us why you think you were hydrated?

5. When did you drink during this trial?

- a. When I was thirsty
- b. Whenever I could (ad lib)
- c. I didn't drink because I arrived hydrated
- d. I didn't drink because I wasn't thirsty
- e. I didn't drink because the trial was only 60min

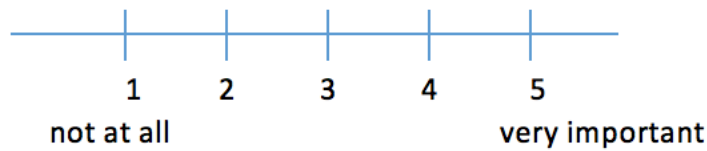
6. Did you have a strategy to drink during the test?

- a. No
- b. Yes

7. If you answered yes to #6, what was your strategy?

- a. To drink periodically throughout exercise (for example: drink every 15 min)
- b. To drink more in the beginning of the test
- c. To drink more in the middle of the test
- d. To drink more towards the end of the test
- e. Other: Please explain to us below:

8. How important was staying hydrated **during this exercise** trial to you?



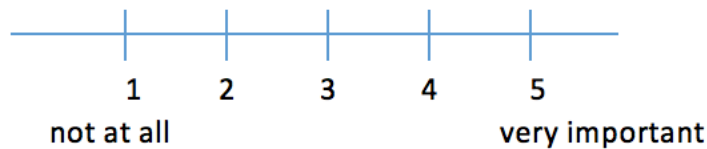
9. Do you think hydration is important during exercise?

- a. No
- b. Yes: Please explain why you think it's important?

10. In a normal practice, how frequently do you drink? (Choose the best answer that applies to you)

- a. Whenever I want
- b. Only during breaks
- c. When not playing
- d. When coach tells us

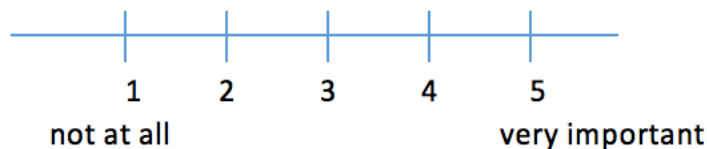
11. How important was staying hydrated **during practice** to you?



12. In a normal game, how frequently do you drink? (Choose the best answer that applies to you)

- a. Whenever I want
- b. Only during breaks
- c. When not playing
- d. When coach tells us

13. How important was staying hydrated **during a game** to you?



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