IDENTIFICATION AND COMPARISON OF HYDRATION PRACTICES IN MARATHON RUNNERS DURING INTENDED TRAINING, AN INTENDED MARATHON, AND SELF-REPORTED HYDRATION PRACTICES DURING A MARATHON EVENT

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Title

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

DOCTOR OF PHILOSOPHY

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ABSTRACT

Title**:** Comparing hydration practices of long-distance runners during intended training, an intended event, and an actual event during COVID-19.

Context**:** Prior studies on long-distance runners have yet to compare hydration practices intended in training to an actual event. Optimal hydration strategies and knowledge of EAH was assessed.

Objective: The purpose of this research was to assess and compare the self-reported hydration practices of long-distance runners during an intended training run, an intended event, and during an event.

Design: Cross-sectional online survey design

Setting: 2020 Hyannis, Massachusetts Marathon; Connecticut trail races; online.

Participants*:* There were 46 participants in the Hyannis, 26 participants in the Connecticut trail races, and 203 participants in the long-distance running studies.

Main outcome Measure(s): Survey questions addressed hydration practices, including hydration strategies, and volumes consumed before and during a run. Additional data included demographics, training experience, sources of hydration information, and knowledge of EAH.

Results: When comparing volumes consumed, higher correlations were found when comparing intended events in all three studies. In other words, runners intended to drink the same in an intended training run and an intended event. More variation was found when comparing intended volumes to actual volumes. All studies showed strong agreement in the selected hydration strategies between the scenarios and most were statistically significant. The “drinking to thirst hydration strategy”, was selected on average 17% of the time for Hyannis marathoners, 30% of the time for Connecticut trail runners, and 23% of the time for long-distance runners. This hydration strategy is recommended to decrease the risk of EAH in lieu of a personalized hydration plan. EAH awareness among runners was reported between 50-59% of the time in all studies. However, there was inconsistency in recognizing contributing and preventive EAH factors.

Conclusion: There were differences in hydration practices when comparing an intended training run, an intended event, and an event. This indicates a need for ongoing education on hydration practices and EAH. If runners mimic appropriate hydration practices during training when running in an event, the risk of EAH may be decreased. The limitation of this research is the self-reported nature of historical data.

ACKNOWLEDGEMENTS

I would like to thank my committee for not only their support, but also their expertise and willingness to work with me through the disquisition process. I would especially like to thank my adviser, Dr. Stastny. She was instrumental in my success and completion of this research study.

DEDICATION

I would like to dedicate this disquisition to my husband Ken. He has not only been supportive throughout this process, but has also picked up the slack on the home front during these years. Also, I want to acknowledge my friends, especially Colleen, who have been there for me during this journey.

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LIST OF ABBREVIATIONS

ANOVA ....One-way analysis of variance

AVP...Arginine vasopressin or antidiuretic hormone

Cl..Chloride

COVID-19...Severe acute respiratory syndrome coronavirus 2

EAH ....Exercise-associated hyponatremia

K..Potassium

kg..Kilogram

L ....Liter

lb ....Pound

LTR ....Long training run

mEq ....Milli-equivalent

mg ....Milligram

ml ....Milliliter

mmol ....Millimoles

mOsm/L ....Particles per liter of solution

MTC..Multiple transportable carbohydrates

Na..Sodium

NDSU..North Dakota State University

CHAPTER 1. INTRODUCTION

Approximately 0.5% or about 600,000 individuals in the United States have run in a marathon, and less than 0.1% an ultramarathon (Douglas, 2014). In fact, there has been an increase in the type of participant, from elite athletes and well-trained runners to less trained runners, leading to mass participation (Williams, Tzortziou-Brown, Malliaras, Perry, & Kipps, 2012). As a result, event planners nationally have been trying to enhance and sell their events through marketing to all types of participants. In addition, significant growth in ultramarathons and ultra-endurance events in recent years has increased the number of ultra-race participants (Douglas, 2014). Ultra-marathon events are races longer than standard marathon distance of 42 kilometers or 26.2 miles. The top ten marathons in the United States based on the number of finishers (most to least) include the INC New York City Marathon, Bank of America Chicago Marathon, Boston Marathon, Marine Corps Marathon in Washington, DC., Honolulu Marathon, the Walt Disney World Marathon in Orlando, FL, Los Angeles Marathon, Rock ‘n’ Roll San Diego Marathon, Medtronic Twin Cities Marathon in Minneapolis/Saint Paul, MN and Portland Marathon, in Portland, OR. (Active.com, n.d).

Proper hydration is important in successful completion of a marathon or an ultramarathon. With the increase in overall participation in endurance events, the number of recreational and untrained athletes increases as well. The untrained or less experienced athlete may not have proper hydration knowledge or practices. Thus, associated conditions from improper hydration, such as dehydration, hypohydration, hyperhydration, and exercise-associated hyponatremia (EAH) are an ongoing concern for distance events, especially ultramarathon events. Specifically, the etiology of EAH is primarily associated with overhydration and weight gain during exercise (Hew-Butler, Loi, Pani, & Rosner, 2017;

McDermott et al., 2017; Murray & Eichner, 2004). In EAH, an overconsumption of fluids complicates the balance of sodium in the cells and dilutes the blood sodium levels below the normal range. In other words, when the liquids consumed during exercise exceed sweat and renal fluid losses, EAH may occur. Drinking more than the body can excrete may cause increased swelling of cells in the body and brain.

Exercise-associated hyponatremia (EAH) is an important topic in the sports and race medicine field and a growing concern to athletic and sport event directors nationally due to the seriousness of the condition. Exercise-associated hyponatremia (EAH) was initially reported in the 1980's in ultra-marathon runners and Ironman triathletes (Hew-Butler et al., 2017). Awareness of EAH increased in the 2000's with the death of two charity marathon runners in 2003 (Hew-Butler et al., 2017). Scientific interest and research paralleled the growing EAH incidence rates worldwide. Although there is global concern about the condition, EAH has been reported to be higher in the USA than in Europe, Asia, or Africa which may be due to more extreme temperatures and conditions nationally (Knechtle et al., 2019).

Although the EAH associated mortality rate is very low and often hard to predict (Rosner, 2015), the National Athletic Trainers' Association (NATA) suggests that EAH has been identified among individual marathon runners at a rate of 10-20% after finishing an event (McDermott et al., 2017). Elsewhere, the incidence of EAH can range between 3-28% of marathon participants and the severity is greater in longer endurance events in general (Krabak, Lipman, Waite, & Randall, 2017). In a more recent review, EAH is reported in less than 1% of symptomatic marathon runners and 23-38% in ultra-marathon events (Bennett, Hew-Butler, Rosner, Myers, & Lipman, 2020). Also, more EAH is occurring in shorter events such as half marathons and sprint triathlons (Bennett et al., 2020). Finally, there were two reported cases in

2014 of high school football players who died from hyponatremia due to overhydration (Hew-Butler, 2018) and at least five deaths due to EAH in marathon running reported in the past 20 years (Williams et al., 2017).

In one of the earlier cohort studies, Almond et al. (2005) found that in the 2002 Boston Marathon, an estimated 13% of the runners had experienced hyponatremia, and 0.6% had suffered from critical hyponatremia based on a sample of 488 participants. Although EAH had been defined as early as 1985 (Speedy, Noakes, & Schneider, 2001), Almond, et al. (2005) used the term hyponatremia in the paper, even though they were actually referring to EAH. Exercise-associated hyponatremia is a subset of hyponatremia that is specific to exercise conditions (both during and 24 hours after exercise) and pathology. Almond et al. (2005) followed the current criteria to determine hyponatremia and critical hyponatremia (McDermott et al., 2017). Of the sample participants (n = 488) in this study (Almond et al., 2005), 22% of those identified with hyponatremia were women (37 of 166) and 8% were men (25 of 322). The 488 participants completed a survey before running the race which included basic information, such as demographic, medical history, and potential hydration strategies. Weight for the volunteer participants was obtained before and after the race. In addition, after the race, blood samples were collected, centrifuged onsite and frozen immediately. After the race, participants completed a second survey. If these percentages of hyponatremic cases found within the sample group were extrapolated to the entire group of Boston Marathon runners (over 15,000 finishers), nearly 1,500 runners would have experienced hyponatremia and 90 runners would have had critical hyponatremia. Also, the weather conditions that day were described as mostly cloudy with temperatures between 53-56 degrees Fahrenheit, with a very heavy mist reducing visibility (Boston Athletic Association, 2016). Thus, the weather did not appear to be a major influence on running conditions that day. In this study, the researchers reported that the racers who experienced hyponatremia were generally not elite runners, had a race time of over four hours, had an extreme body-mass index (either very low or very high), and had weight gain due to overhydration (Almond et al., 2005). Other research has shown a similar profile of someone susceptible to hyponatremia including being female, having a marathon running time greater than four hours, and/or having a very high or very low BMI (Hew-Butler et al., 2017, Murray & Eichner, 2004; Williams et al., 2012). Although the female sex was once considered an EAH risk factor, a more recent EAH review suggests when the data is adjusted for body mass index and racing times between sexes, it is not considered a risk factor (Bennett et al., 2020). Finally, the researchers reported no association between the type of solution (water or sports drinks) consumed (self-reported) during the race and hyponatremia (Almond et al., 2005). They assumed that the amount of sodium content of most sports drinks is negligible compared to the total volume of fluid ingested in regards to developing hyponatremia and that the total volume of fluids ingested was the most important contributing factor. Similar to most commercial sports drinks, the researchers suggested that sports drinks provided at aide stations were estimated at 18 mmols/L of sodium per serving (Almond et al., 2005). However, the type of drink or amount of sodium was not measured in the sports drinks provided in the study. This is a limitation of this study. Another limitation was that the volumes consumed were self-reported.

According to Hew-Butler et al. (2017), there is a need for further research to determine the optimal number and spacing of hydration stops during an event. Are runners hydrating more on race day than they do during their training? According to survey research on hydration patterns of runners in the London Marathon, 12% of the runners planned to hydrate in amounts that would put them at risk for EAH (Williams, Tzortziou, Malliaras, Perry, & Kipps, 2012). In

Williams et al. (2012), 20.7 % of the runners had planned to drink from all 24 hydration stops. A marathon is 26.2 miles. The London Marathon has a total of 24 water stops, with one at every mile between miles 3 and 25. Sports drinks available at every 5 miles (5, 10, 15, and 20) and at the 23-mile station. The researchers concluded that marathon runners' lack knowledge of EAH. This indicates that educational interventions are needed. Similarly, the Chicago Marathon is planned with 20 aide stations with both water and sports drinks on the course and other large U.S. marathons vary between stops every mile and every other mile or less.

The possible impact of this study (Williams et al., 2012) was to further educate marathon runners on hydration methods and on EAH in general. It may also provide evidence for water/hydration stop recommendations during an event. There continues to be a need to increase EAH education at events and across the exercise community (Beltrami, Hew-Butler & Noakes, 2009; Hew-Butler, Valentina, & Rosner, 2017; Williams et al., 2012). Although there are several influencing factors on hydration during an event, including age, sex, sweat rate, environmental conditions, exercise duration and intensity, experience, and body size (McDermott et al., 2017), standards could be refined nationally for the racing community. Understanding the differences and similarities of how marathon runners' hydrate during training compared to an event will assist in creating appropriate, personalized hydration intervention plans to prevent EAH.

While several studies have investigated hydration patterns and beliefs in runners (Beis, Wright-Whyte, Fudge, Noakes, & Pitsiladis, 2012; Chlibkova et al., 2017; O'Neal et al., 2011; Williams et al., 2012; Yates, Ellis, Butts, McDermott, Williamson, and Armstrong, 2018), little is known about how runners hydrate during training when compared to an event. Yates et al. (2018) found that training plays a significant role in the development of an individualized hydration plan in middle-aged cyclists. In addition to hydration, a long training run is one of the most important factors in predicting performance for ultra-recreational athletes (Knectle, Knectle, Rosmann, & Lepers, 2011). Thus, the intention of this exploratory study is to compare hydration practices of marathoners in intended training, an intended marathon, and on race day. Based on anecdotal evidence and the extensive review of this topic, the researchers hypothesized that there will be differences between the three scenarios, and that race day will typically result in more hydration for the majority of the surveyed runners. Thus, this would create more potential risk for EAH.

Purpose of the Literature Review

The literature review is essential to understand the topic at hand and what has been done to date in the field. Literature was reviewed to primarily evaluate exercise and hydration, beliefs on hydration, exercise-associated hyponatremia (EAH), and the impact on long-distance endurance events. In addition, a review and evaluation of the current literature on EAH was essential to understand the gaps and need for additional research.

Definitions

Ad libitum drinking. Consuming fluid whenever and in whatever volume desired (Bennett et al., 2020); Drink at one’s pleasure (McDermott et al., 2017).

Arginine vasopressin. A hormone secreted by cells of the hypothalamic nuclei and stored in the posterior pituitary for release as necessary; known as antidiuretic hormone (Bennett et al., 2020).

Critical hyponatremia. Having a blood serum sodium level under 120 mmol/L (McDermott et al., 2017).

Dehydration. Process of losing body water and can lead to hypohydration (Thomas et al., 2016) or deprivation of water; process of losing body water, progressing either from the hyperhydrated state to euhydration or from euhydration downward to hypohydration (Dirckx, 2001)

Drinking to thirst. The use of thirst sensation as the stimulus to drink fluids for hydration (Bennett et al., 2020); Consume fluids as thirst dictates (McDermott et al., 2017).

Euhydration. A normal fluctuation in body water content; also referred to as normovolemia (Bennett et al., 2020); State of optimal total body water content as regulated by the brain (McDermott et al., 2017).

Exercise-associated hypernatremia. A serum, plasma, or blood sodium concentration greater than 145 mmol/L that occurs during or up to 24 hours after prolonged physical activity; this condition can present symptoms similar to exercise-associated hyponatremia. (Bennett et al., 2020).

Exercise-associated hyponatremia (EAH). A serum, plasma, or blood sodium serum concentration below the normal reference range of 135 mmol/L that occurs during or up to 24 hours after prolonged physical activity (Bennett et.al., 2020).

Hyperhydration. A state of elevated body water (excess) induced acutely before physical activity by means of excessive fluid (isotonic or hypotonic) ingestion (Bennett et al., 2020); the state of excessive total body water content with expanded intracellular and extracellular fluid volumes (McDermott et al., 2017).

Hypernatremia. An abnormally high plasma concentration of sodium ions (Dirckx, 2001).

Hypertonic. Having a greater osmotic pressure than a reference solution, which is ordinarily assumed to be blood plasma or interstitial fluid; more specifically, refers to a fluid in which cells shrink (Dirckx, 2001).

Hypohydration. Decrease in body water content. New steady-state condition of decreased water content (Dirckx, 2001); deficit of body water that is caused by acute or chronic dehydration (McDermott et al., 2017).

Hyponatremia. Abnormally low concentrations of sodium ions in the circulating blood (Dirckx, 2001).

Hypotonic. Having a lesser osmotic pressure than a reference solution, ordinarily plasma or interstitial fluid, refers to a fluid in which cells expand. (Dirckx, 2001).

Individualized hydration plan. Refers to a hydration plan that includes rehydration strategies that consider sweat rate, environment, acclimatization state, body size, exercise duration, exercise intensity, and individual fluid preferences and tolerance (McDermott et al., 2017).

Isotonic. Having equal tension; denoting solutions possessing the same effect on osmotic pressure; more specifically, limited to solutions in which cells neither swell nor shrink (Dirckx, 2001).

Marathon. A running event defined at 26.2 miles or 42 kilometers (Williams et al., 2012).

Milliequivalents (mEq). One thousandth equivalent; mole divided by valence (Dirckx, 2001).

Osmolality. The concentration of a solution expressed in osmoles of solute particles per kilogram of solvent (Dirckx, 2001).

Overhydration. Excessive oral intake of hypotonic fluids (e.g., water and sport electrolyte drinks) resulting in the amount and other electrolytes in the body becoming diluted (i.e. hyponatremia) (Bennett et al., 2020).

Personalized hydration plan. Refers to a hydration plan that optimizes the performance and safety of athletes during their sporting event, while considering the physiological, behavioral, logistical, and psychological needs of the athlete (Belval et al., 2019).

Programmed drinking. Drinking pre-determined amounts of fluids with the purpose of minimizing fluid losses (Kenefick, 2018).

Specific gravity. The weight of a body compared with that of another body of equal volume regarded as a unit; usually the weight of a liquid compared with that of distilled water (Dirckx, 2001).

Sweat. Especially sensible perspiration; to perspire (Dirckx, 2001).

Sweat loss. Body mass before exercise (kg) …Body mass after exercise (kg) + (Volume of fluid consumed during exercise [L]) – (Urine volume, if any [L]) (McDermott et al., 2017)

Sweat rate. Sweat loss (L) /exercise duration (hours); expressed in L/hour (McDermott et al., 2017).

Ultramarathon. Any running event over the marathon distance at 26.2 miles or 40 kilometers (Douglas, 2014).

CHAPTER 2. LITERATURE REVIEW

The goal of the literature review was to demonstrate the importance of exercise-associated hyponatremia (EAH). This review encompassed not only EAH, but also related topics of hydration during exercise, recommendations for hydration, carbohydrate intake during exercise, prevalence of EAH, additional studies in EAH, and beliefs on hydration and EAH. In addition, a comprehensive review and evaluation of the current literature on EAH was essential to understand the gaps and the need for additional research.

Data and Methodology

In completing the literature review for the topic of identification and comparison of hydration patterns among marathon runners, both context and content were included. Research was primarily from health-related publications and included international publications printed in English. In addition, in order to obtain specific information, a few non-peer reviewed sources were utilized.

Databases.

The primary electronic databases included PubMed (through NDSU library services) and Google Scholar. The literature review began in the fall of 2017 and continued through the fall of 2020 to create a comprehensive search of this topic.

Search terms.

This literature review focused on endurance athletes, specifically marathon runners, and the condition of EAH. Key search terms and phrases included "hyponatremia", "exercise-associated hyponatremia", "hydration", "marathon runners and hydration", "endurance athletes and hydration", "fluid intake", "fluid consumption", "endurance athletes and EAH", "etiology of EAH", "fluid ingestion", "rehydration", "hyperhydration", "hypohydration", "overdrinking", "prevalence of EAH", "hydration status and athletes", "hydration status", "ad libitum drinking", "prescribed drinking", "drinking according to thirst", and "exercise and hydration". Other related topics included additional search terms such as, "carbohydrates and hydration", "sports drinks", "sports drinks and EAH", "carbohydrates and exercise", "carbohydrate intake and endurance athletes", "sweat loss", "sweat loss and hydration", "hydration and beliefs", "beliefs and EAH", "sodium and beliefs", "marathoners and beliefs", and "ultra-marathoners". In addition, appropriate position papers were utilized in the research. Search criteria included "NATA", "ACSM", and the "Academy of Nutrition and Dietetics".

Inclusion criteria.

Literature associated with EAH and survey design is somewhat limited. The inclusion criteria were specific to EAH, and the related topics to EAH, such as hydration, carbohydrates, hydration beliefs, EAH beliefs, and marathon running, and ultra-endurance exercise. Studies included case studies, relevant position papers, review papers, descriptive studies, meta-analyses, and both qualitative and quantitative studies. There were no restrictions on sample sizes in the various research studies.

Exclusion criteria.

Few criteria were identified for exclusion due to the specificity of this topic. Generally, articles needed to include a least one of the identified key words.

Understanding EAH

In order to understand the complexity of EAH, it is important to review hydration and exercise and some of the related research in this area. Since EAH is caused by overhydration, the recommended hydration strategies during exercise will be discussed. Also, the role of carbohydrates and hydration, prevalence of EAH, and additional studies in EAH will be addressed. As a growing concern in the race medicine field, EAH may occur in approximately 10-20% of distance athletes during and after a long-distance event (McDermott et al., 2017). More recent sources report a lower rate of EAH in marathon runners of less than 1%, but higher in ultra-race runners (Bennett et al., 2020).

Hydration, dehydration, and exercise.

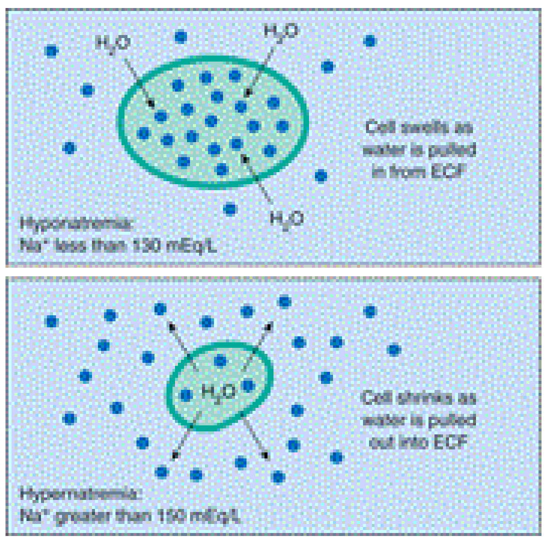
The importance of hydration has been a topic in exercise science for many years and has contributed to a growth in sports drink sales. Historically, marathon runners were not advised to drink at all while running an event (Sutehall, Muniz-Pardos, Bosch, Gianfrancesco & Pitsiladis, 2018). The relationship between hydration and endurance exercise had not been established in the early 1900's. As the cardiovascular and thermoregulation models were developed, the impact of dehydration on the body was explored. Dehydration may cause unnecessary stress on the heart, ultimately leading to heat stroke (Sutehall et al., 2018). Sweating during exercise and a reduction in plasma volume can lead to an increase in cardiac output. This may result in a reduced blood flow to the skin, and ultimately heat stroke (Sutehall et al., 2018). Thus, the attention on dehydration led to the attention on hydration. Over time, general recommendations to hydrate during exercise were taken to the extreme, including "drink as much as possible", resulting in overhydration (Hew-Butler et al., 2017).

Excessive liquid consumption may complicate the balance of sodium in the cell, especially when hydration exceeds sweat and fluid loss. As a result, the symptoms of EAH are caused by the osmotic shifts of water into the intracellular compartment (Hew-Butler et al., 2015). The shifts of water into a confined space, such as the cranium, and into the central nervous system tissues may cause complications such as cerebral edema or respiratory failure (McDermott et al., 2017; Urso, Brucculeri & Caimi, 2012).

Figure 2.1 below (upper and lower panels) shows the effect of extracellular sodium (Na+) level on cell size (Brainkart.com, n.d.). The upper panel displays hyponatremia in which the levels of sodium (Na+) are diluted (possibly due to overdrinking), and the cell pulls in more water (swelling). The lower panel shows the opposite, hypernatremia, in which the cell shrinks and more water moves to the extracellular fluid, causing the sodium (Na+) concentration to be higher in the extracellular fluid (ECF). The ECF is the fluid outside of the cell.

Figure 2.1

Effect of extracellular fluid (ECF) on sodium (Na+) level on cell size



In the figure, the amount of sodium (Na+) is expressed in milliequivalents/L(mEq/L). In most research, hyponatremia is expressed in mmols/L. In this case, mEq/L for sodium (Na+) is equal to the mmols/L for sodium (Na+). Thus, 130 mEq/L is equal to 130 mmol/L and 150 mEq/L is equal to 150 mmols/L. The National Association of Athletic Trainers' (NATA) define EAH as having a serum sodium (Na+) concentration of 135 mmol/L or less, and defines critical hyponatremia as having a serum sodium (Na+) concentration of 120 mmol/L or less (McDermott et al., 2017). On the other hand, exercise-associated hypernatremia is defined as having a serum sodium concentration of greater than 145mmols/L (Bennett et al., 2020).

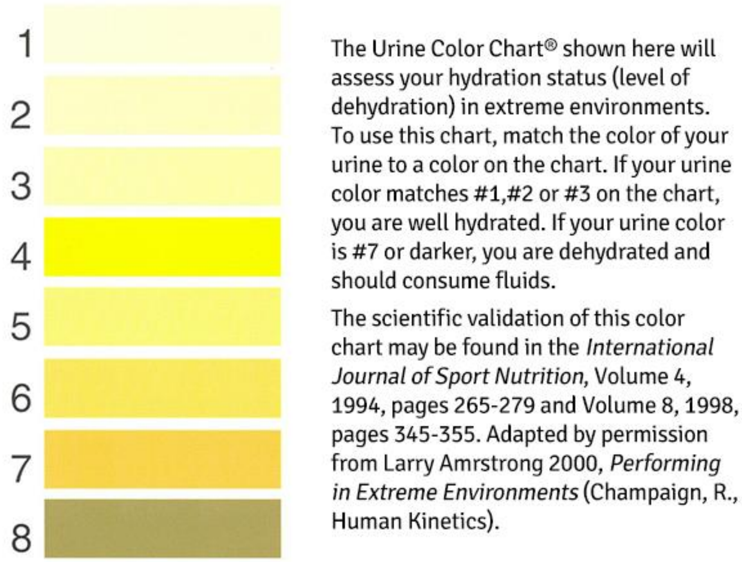
Fluid intake is a key concern during endurance exercise, particularly in events over one hour. According to a joint paper by the Academy of Nutrition and Dietetics, Dietitians of Canada and the American College of Sports Medicine and in NATA's position paper, a recommended hydration plan should be individualized (Thomas, Erdman, & Burke, 2016; McDermott et al., 2017). In a more recent review (Belval, Hosokawa, Casa, Adams, Armstrong, Baker, … Wingo, 2019), a personalized hydration plan is recommended for athletes and is sport specific. Although it is similar to an individualized hydration plan and the terms are sometimes used interchangeably, a personalized hydration plan slightly expands the definition. It includes not only optimizing the performance and safety of the athlete, but also considers the psychological, behavioral, logistical, and physiological needs of the athlete (Belval et al., 2019). In addition, the most recent position paper of ACSM on fluid intake provides general guidelines. It is recommended that athletes drink between 0.4 – 0.8 L/hr for most events (Thomas et al., 2016). The lower end of the range is for lighter individuals exercising in cooler environments and the upper end of the range is for heavier individuals exercising in warmer environments.

In the NATA's position statement on fluid replacement for the physically active, overall optimal hydration during exercise is between 1% hyperhydration and 3% hypohydration (McDermott et al., 2017). Hydration balance in the body is on average plus or minus 2% at any given time (Kenefick, 2018; McDermott et al., 2017). Maintaining these levels of hydration allows for optimal performance during exercise (Kenefick, 2018; McDermott et al., 2017). Body weight losses up to 2% take time to accumulate during exercise. Factors impacting body weight losses during exercise include heat, exercise intensity with higher sweat rates, and exercise duration of over 90 minutes (Kenefick, 2018). In that case, programmed drinking is recommended (Kenefick, 2018). On the other hand, Kenefick (2018) recommends drinking according to thirst only for lower intensity exercise in cooler environments for under 2 hours.

During marathon and ultra-marathon competition, optimal hydration without dehydration or hyperhydration can be a delicate balance that depends on many factors, such as age, sex, race time, environmental factors, and sweat loss rate (McDermott et al., 2017). Sweat rates for adults during exercise are highly variable and range from 0.5 to 4.0 L/hr for adults over age eighteen (McDermott et al., 2017). In comparison, an average individual consumes about 2.0 liters of fluid per day via endogenous fluids and foods (McDermott et al., 2017). Sweat loss can be determined from subtracting one's body mass after exercise from one's body mass at the start of exercise and sweat rate is the sweat loss divided by the exercise duration (Baker, 2016; McDermott et al., 2017). One goal of hydration during exercise is to replace as much of the sweat lost as possible. Water and electrolytes are lost through perspiration (sweat) during exercise. Another way to track hydration status in athletes is urine concentration. It may be used to screen for the level of hydration by observing the urine color first thing after rising in the morning (Kavouras, 2002; McDermott et al., 2017). Darker color urine would indicate a higher concentration of urine, and a potential sign of dehydration (Figure 2.2). The color of urine should be assessed in a clear cup, not in the toilet. The color is also impacted by physical activity, exercise, diet, fluid intake, medications, and illness (Armstrong, Herrera, Hacker, Casa, Kavouras, & Maresh, 1998; McDermott, et al., 2017). This method has been shown to be effective for athletes to assess their hydration status (Kavouras, 2002; McDermott et al., 2017).

Figure 2.2

Urine color chart for dehydration (Armstrong et al., 1994)



Therefore, urine color has been found to be an effective index of hydration status in healthy individuals (Kavouras, 2002; McDermott et al., 2017). However, this method may not be effective when used with critically ill patients with severe dehydration (Kavouras, 2002). Also, clear or very light-yellow urine may indicate overhydration, but may be mistaken for euhydration because the colors are similar for some.

In lieu of a personalized or individualized plan, drinking according to thirst as a hydration strategy is recommended (Bennett et al., 2020). Drinking beyond thirst during exercise may not only lead to EAH, but has been identified as a major cause of EAH (Bennett et al., 2020; Hew-Butler et al., 2017). This has led to specific recommendations around hydration during exercise. According to an EAH review update by Hew-Butler et al. (2017), several strategies were suggested to prevent overhydrating. These include drinking according to thirst; reducing the availability of fluids among the routes of exercise; and the monitoring of weight changes during exercise (Hew-Butler et al., 2017). Several papers concur that drinking when thirsty before, during, and after exercise is an appropriate strategy to avoid fluid imbalances during exercise (Beis et al., 2012; Hew-Butler, 2018; O'Neal et al., 2011).

Other hydration strategies include programmed or prescribed drinking, and ad libitum drinking, which is drinking at one's pleasure (McDermott et al., 2017). Programmed drinking, or drinking pre-determined amounts, can also be an effective hydration strategy, especially for exercising in the heat or at higher intensities (Kenefick, 2018). Programmed or prescribed drinking can be in the category of individualized hydration planning. There is some evidence supporting sport specific hydration plans, especially for cycling. For example, ad libitum drinking was recommended over drinking according to thirst for ultra-endurance nonelite cyclists (Armstrong, Johnson, Kunces, Ganio, Judelson, Kupchak…. Williamson, 2014). In another cycling study, the researchers found prescribed drinking lead to better performance than ad libitum drinking (Bardis, Kavouras, Adams, Geladas, Panagiotakos, and Sidossis, 2017).
In summary, the ultimate goal of hydration is to replace fluids lost during exercise without overhydrating. However, when drinking according to thirst, special consideration may be taken for middle-aged to older adults during physical exercise because adults over the age of 50 start to lose their thirst sensitivity and urine-concentrating ability (McDermott et al., 2017).

There is growing evidence that elite or well-trained athletes may lose more than 2-3% of the recommended body percent weight during exercise to achieve optimal performance (Beis et al., 2012; Goulet, 2012; McDermott et al., 2017; Rosner, 2015). In a study of elite male runners, losses up to 9.8% of their body weight were reported, which is over three times the recommended amount. One general conclusion was that elite runners may be able to tolerate dehydration more readily than the recreational runner (Beis et al., 2012). In addition, Goulet (2013) found that losses of up to 4% of body weight did not deter performance of trained cyclists in a time trial staged in a lab. In a meta-analysis, Goulet (2013) reviewed 15 research articles on exercise-induced dehydration and body weight. The work efforts of the athletes were measured by a same scale to assure a similar comparison. Goulet (2012) concluded that the loss of 2% body weight rule was not applicable to studies done out of the laboratory setting. In other words, athletes participating in events or races that are typically outdoors may be able to have body weight loss of greater than 2% without deterring performance or health (Goulet, 2013). Outdoor activities have other uncontrollable factors, such as the weather, that may impact study results. That being said, for the non-elite or recreational athlete, body weight changes due to partial dehydration of no more than 2% remain the recommended guideline (McDermott et al., 2017; Thomas et al., 2016).

McCartney, Desbrow, and Irvine (2017) conducted an extensive meta-analysis of 42 studies to examine differences in hydration needs among various types of exercise, primarily endurance exercise. The research criteria included: experimental design studies with adults aged 18 years or more with no comorbidities, performance outcomes that measured under both controlled and intervention conditions, a standardized mode of dehydration, a hydration status that was manipulated before the performance task began, a defined time limit to consume fluid, objective measurements of hydration levels, and research papers only accessible in English (McCartney et al., 2017). After the review of 42 publications, 64 trials were reviewed. The researchers found that dehydration decreased body weight on average by 1.3 to 4.2%. As suspected, fluid intake following dehydration may improve continuous exercise performance, especially in heat stress conditions and longer durations (McCartney et al., 2017). There were several limitations in this meta-analysis study. First, there may be other studies written in other languages that were not used in the analysis. Second, there were a few studies that used a placebo as a control. This could impact the perception of treatment and the results. Third, the placebo effect of using fluids could have biased results of some studies. Fourth, the control was either no fluid or some fluid. Some fluid is different than no fluid; therefore, it is hard to decipher this in comparison to the euhydrated subject. Fifth, the overall treatment effect was potentially influenced by the time of hydration that may have varied in the studies. The timing of fluid intake will impact dehydration. Finally, fluid intake of less than 200 ml was negligible on dehydration and was considered in some of the control groups. Fluid replacement strategies during exercise are highly personalized and are dependent on many factors, including sweat rate (McDermott et al., 2017). The researchers concluded that fluid intake improved performance for continuous exercise after dehydration under heat stress conditions (McCartney et al., 2017). In regard to dehydration with intermittent, balance, resistance, or sports specific exercises, more research is needed.

Although slight nuances exist in the current hydration position papers and the EAH consensus papers, the ultimate goal of avoiding under- or overhydration is the same (Kenefick, 2018). In the EAH review update by Hew-Butler et al. (2017), the hydration guidelines reflect the premise of drinking according to thirst to avoid EAH. Specifically, the overall hydration recommendations are to drink according to thirst, hydrate before exercise, and monitor hydration during events lasting longer than one-hour of high intensity exercise (Hew-Butler, 2018). In a more recent EAH update (Bennett et al., 2020), the overall recommendation was updated to recognize the importance of an individualized or personalized hydration strategy. In lieu of a personalized or individualized strategy, drinking according to thirst is recommended. Although sweat rate is important, it was not the focus of this EAH review. Thomas et al. (2016) recommends replacing fluid during exercise based on sweat loss, while preventing dehydration and not exceeding sweat rates. NATA's position paper suggests a similar hydration strategy during exercise that not only considers sweat rate, but also the environment, acclimatization state, body size, exercise duration, exercise intensity, and individual fluid preferences and tolerance (McDermott et al. 2017). Moreover, too much fluid intake may impede performance via gastrointestinal discomfort (McCartney et al. 2017; Thomas et al., 2016). Specifically, fluids with higher total calorie content per ounce or per dose will slow gastric emptying (McCartney et al., 2017; Thomas et al., 2016). During running, the movement of fluid caused by running may be a discomfort. Hew-Butler et al. (2017) suggested that a large amount of fluid ingested during the race may lead to a faster absorption at the end of race, which can lead to EAH. Thus, the amount of fluid to drink during a race at one time to avoid impeding performance remains unclear (McCartney et al., 2017). Specifically, training the gut ahead of an event, i.e. during training, may help to prevent any gastrointestinal disturbances (Thomas et al., 2016). However, it is clear that an individualized or personalized hydration plan is necessary for physically active individuals (Belval et al. 2019; Bennett et al., 2020; McDermott et al., 2017; Thomas et al., 2016).

Carbohydrates, sports drinks, and hydration.

Sports drinks are used in addition to or in place of water for hydration as well as for carbohydrate and electrolyte supplementation. For longer and more intense exercise, especially in extreme conditions, sports drinks are recommended as a rehydration strategy (McDermott et al., 2017). Also, the carbohydrates and electrolytes found in sports drinks may help maintain blood glucose, carbohydrate oxidation and electrolyte balance (McDermott et al., 2017).

The market is saturated with various types of sports drinks. Has the market driven the need for sports drinks? Do sports drinks enhance exercise performance? The increase in sports drinks resulted in part from the “drink as much as possible” hydration strategy that followed the “no drinking during exercise” advise given prior to 1981 (Knechtle, 2019). In a review of the history of sports drinks, Cohen (2012) suggested that the attention given to the sports drinks topic was driven from industry and academia. According to the review, the attention to the importance of hydration during exercise somewhat aligns with the rise of sports drinks. Cohen (2012) also suggested that the large corporations, such as PepsiCo, Coca-Cola, and GlaxoSmithKline have played a part in the growth of this industry with their money and sponsorships of key athletic events. Cohen (2012) suggested that companies claim that sports drinks stimulate thirst, thus suggesting an increased consumption of fluid, but the research does not back this claim. On the other hand, Jeukendrup (2014) asserted that increasing fluid intake with sports drinks is a good way to avoid using the thirst mechanism as a sole way to trigger thirst. Also, Knechtle et al. (2019) support the notion that water alone is absorbed slower that carbohydrate and electrolyte-based drinks which could be partially due to the mechanism that has electrolytes following water in and out the cell (Figure 2.1).

What is the best type of sports drink to consume during competition to improve endurance performance? The research showed a consensus in the range of 5-8% carbohydrate concentration. According to McDermott et al. (2017), the recommended carbohydrate solution in a sports drink for absorption is between 3-8%, but the higher concentration of 5-8% may decrease the rate of gastric emptying. Urdampilleta and Gomez-Zorita (2014) recommended that carbohydrate concentration does not exceed 6-9%. Others suggest that the recommended concentration amount to improve performance is 6-7% (Thomas et al., 2016), 5–6.9% (Sutehall et al. 2018) and 5-8% (Wilson, 2016). Overall, recommended carbohydrate intake is 30-60 grams/hour for events between one to two and a half hours, and up to 90 grams/hour for events over three hours, if tolerated (Cermak & Loon, 2013; Rollo, James, Croft, & Williams, 2012; Thomas et al., 2016).

In addition to fluids and carbohydrates, another goal of sports drinks is to provide electrolytes. The primary electrolytes lost during exercise and sweating include sodium and chloride. Urdampilleta and Gomez-Zorita (2014) have recommended consumption of 0.7-1.1 L/h of an isotonic drink, with .0.5-.0.7 grams of Na/L during activities between 2-3 hours and .7-1.2 g of Na/L in ultra-endurance activities. Isotonic drinks contain sodium in the range of 200-320 mOsm/kg of water (Urdampilleta & Gomez-Zorita, 2014). An example of an isotonic sports drink may include 500 ml of water, 32 g of carbohydrate, 120 mg calcium, 248 mg of chloride, and 230 mg sodium (Colakoglu et al., 2016). Most sports drinks are either isotonic or hypotonic (see Table 2.1), which would have a lower carbohydrate percentage than a hypertonic drink.

Below is a table listing the contents of common beverages (Shirreffs, 2009).

Table 2.1

Carbohydrate and electrolyte content, and osmolality of common beverages (based on laboratory samples)

BEVERAGE	Carbohydrate (%)	Sodium (mmol/L)	Potassium (mmol/L)	Osmolality (mosmol/kg)
Gatorade	6	20	3	280
Isotar	7	30	*	289
Powerade	6	23	2	280
Orange juice	10	4	45	660
Apple juice	13	1	26	*
Tomato juice	3	10	7	*
Cola	11	3	1	700
Oral rehydration solution	2	45	20	250
Bottled water	0	0	0	9
Milk (white)	5	26	37	288

Note: *means not measured
Shirreffs, 2009

In the table above, most of these drinks are isotonic, except for bottled water, juice, and cola. The fluids with the higher osmolality, including juice and cola, are hypertonic. Water is hypotonic and has no carbohydrate content. Although hydration and potential carbohydrate intake amounts during exercise is individual, isotonic and hypotonic drinks are generally best for endurance exercise over 90 minutes due to the moderate carbohydrate content of 5-6% (McDermott et al., 2017; Shirreffs, 2009). A hypertonic drink (such as cola or fruit juice) has a higher osmolality and higher sugar content, which may result in gastrointestinal disturbances during exercise (Shirreffs, 2009). In addition, the presence of carbohydrates in a 5-6% solution can increase the uptake of water and sodium absorption (Shirreffs, 2009). In a randomized double-blind study, Colakoglu, Cayci, Yaman, Karacan, Gonulates, Ipekoglu, and Er (2016) explored the effect of consuming isotonic sports drinks on skeletal muscle damage with 21 elite male orienteering athletes. Overall, the researchers found that the intake of an isotonic drink before exercise may prevent skeletal muscle damage. This research should be explored with other types of athletes.

Another interesting study, a crossover randomized design, examined the influence of ingesting a carbohydrate-electrolyte drink based on ad libitum drinking, prescribed drinking, or no drinking within one hour of running as hydration strategies. The researchers measured both performance and gastrointestinal discomfort (Rollo, James, Croft, & Williams, 2012). The nine participants were male recreational runners who completed a 10-mile road run on three different occasions, with one week between each run. The course was a relatively flat one-mile circuit, and the runners were required to complete 10 circuits. Each runner completed three trials: no drinking group, prescribed drinking, and ad libitum drinking group. The beverage used was commercially available Gatorade, 60g/L carbohydrate electrolyte beverage (carbohydrate – 2%

sucrose, 4% maltodextrin; electrolytes – sodium 500mg/L, potassium 120mg/L, chloride 470 mg/L) (Rollo et al., 2012). In the no drinking group, the runners did not ingest any beverage (0 ml, 0 g carbohydrate). In the ad libitum drinking group, the runners could drink as they wished which averaged 315 ± 123 ml, 19 ±7 g carbohydrates. In the prescribed drinking group, the runners drank a prescribed volume pre-measured at 60g/hour carbohydrate. The beverages were in bottles of 500-ml and were provided at miles 2, 4, 6, and 8. The bottles were labeled for each runner and weighed to track the amount ingested. For the ad libitum drinking group, there were more beverages provided if desired to those runners. The researchers reported that there was a significant difference ($p<0.10$) in performance time in those runners who drank ad libitum, vs. prescribed or no drinking. Moreover, the runners in the prescribed trial reported less gastrointestinal discomfort (self-reported) than the no drinking or ad libitum group. Overall, the results indicated that drinking the carbohydrate-electrolyte beverages during endurance exercise for about one-hour ad libitum can be beneficial, particularly for those who do not drink carbohydrate-electrolyte beverages habitually. Although there were no limitations identified in this study, the statistical testing ($p<0.10$) and small sample size ($n=9$) are considered limitations.

After an extensive literature review on carbohydrate intake during endurance running, Wilson (2016) reviewed over 8000 articles and selected studies that were categorized in three ways. These included comparing a carbohydrate drink to plain water, comparing a carbohydrate drink to a placebo (volume the same), and evaluating carbohydrate feeding strategies during exercise. Wilson (2016) concluded that ingesting of carbohydrates during running has key practical applications. One, carbohydrate drinks (5-8% concentration) consumed at about 100-200 ml every 15-20 minutes will likely improve performance (Wilson, 2016). The NATA position paper states the same: consuming 200 ml every 20 minutes is ideal, with the exception of sports with extended breaks between playing time (McDermott et. al., 2017). Second, beneficial effects will most likely occur during events lasting over two hours. Third, there is question of whether carbohydrate consumption benefits exercise performance for events under 90 minutes. Finally, Wilson (2016) found that consuming carbohydrate beverages substantially above ad libitum levels does not increase performance levels and may increase GI distress. In other words, more is not better.

In a review of the use of carbohydrates during exercise, Cermak and Loon (2013) had similar conclusions to Wilson's review (2016). Theoretically, carbohydrate ingestion during exercise may act as an ergogenic aid by replenishing muscle and liver glycogen, preventing hypoglycemia, and maintaining high rates of carbohydrate oxidation (Cermak & Loon, 2013). First, carbohydrate intake is recommended for over 2 hours of moderate to high intensity endurance exercise to have this beneficial effect for endurance exercise (Cermak & Loon, 2013). Second, the research seems to be in sync with the recommendations of carbohydrate intake of 60g/hour, for events up to 2 hours, and 90g/hour for events lasting over 2.5 to 3 hours (Cermak & Loon, 2013; Jeukendrup, 2014; Rollo et al., 2012). Cermak and Loon (2013) also suggested that 90g/hour of carbohydrate for exercise over 4 hours. Finally, multiple transportable carbohydrates (MTC) are now generally recommended for ultra-endurance events (Jeukendrup, 2014). The MTC carbohydrate mix is generally a 2:1 ratio of glucose to fructose (Rowlands & Houltham, 2017).

In a more recent study, Schleh and Dumke (2018) confirmed that there was no difference between ingesting an oral hydration solution or a sports drink when exercising in the heat. Noteworthy is that the sodium content of the oral hydration solution was 1330 mg/L compared to 458 mg/L in the sports drink. In an experimental design, ten trained cyclists were tested in the heat while wearing firefighter protective clothing while exercising. They compared two commercially available drinks in a double blind, random cross-over study. The sports drink was Gatorade Thirst Quencher™ and the oral hydration solution was DripDrop™. The cyclists completed two 45-minute exercise bouts of walking, with 30 minutes of rest in between each bout. The subjects consumed fluid replacement at 150% of sweat loss of either the oral hydration solution or the sports drink. Although there were differences in content of each drink, the key parameters measured, such as sweat rate, dehydration, blood glucose (mg/dl) and plasma volume (%) did not differ between the two groups. Regardless, the researchers concluded that the volume of fluid, not the drink contents was what mattered most for hydration in the heat (Schleh & Dumke, 2018). Moreover, the findings found it essential to drink above sweat rate loss when exercising in the heat. In this case, it was 150% of sweat loss.

Some research suggests the optimum mix of carbohydrate supplementation is a maltodextrin and fructose mix at a 1:1 ratio (Sutehall et al., 2018). This mix has a lower osmolality, due to the type of sugar (maltodextrin vs. glucose), and does not inhibit gastric emptying (Sutehall et al., 2018). This combination has been shown to increase exogenous carbohydrate oxidation when compared to glucose only (Sutehall et al., 2018). Cermak and Loon (2013) mentioned in their review that this type of carbohydrate mix may not be tolerable by all individuals and that the carbohydrate ingestion plan needs to be personalized.

Wilson (2015) reviewed 27 research articles on the ingestion of MTC during exercise. Although the review indicated that MTC does lead to increased exogenous carbohydrate oxidation, reduced GI distress, and improved performance, it was limited to cycling activity over 2.5 hours. Wilson (2015) suggested the need for further research applicable to other activities, such as running, and/or other populations, such as women and adolescents. Similarly, Rowlands et al. (2015) completed a review of 14 MTC research studies which found the same results. Again, male cyclists made small performance improvements when ingesting MTC for exercise between 2.5 to 3 hours.

What is exercise-associated hyponatremia?

The NATA Position Statement: Fluid replacement for the Physically Active reported that EAH is caused by excessive consumption of hypotonic beverages (including sports drinks), often combined with reduced renal water clearance, resulting in maintained or increased body weight during exercise lasting one hour or more (McDermott et al., 2017). More often, EAH occurs during exercise over 4 hours (Bennett et al., 2020; Hew Butler et al., 2017) or even over 4-6 hours (Knechtle et al., 2019) and 24 hours after exercise. Specifically, EAH is clinically defined as a serum sodium concentration of less than 135 mmol/L during or up to 24 hours after prolonged physical activity (Bennett et al., 2020; Hew-Butler et al., 2017; McDermott et al., 2017). Hypernatremia is defined at a serum sodium > 145 mmol/L (Krabak, 2017; McDermott et al., 2017). Exercise-associated hyponatremia is primarily associated with overhydrating of hypotonic fluids and weight gain during exercise (Bennett et al., 2020; Hew-Butler et. al., 2017; McDermott et. al., 2017; Murray & Eichner, 2004). This can be due to increased water or sports drink consumption before and/or during an event. In addition to an overconsumption of fluids, water retention may be caused by the suppression of arginine vasopressin (AVP), which is the hormone that regulates water excretion (Bennett et al., 2020; Hew-Butler et al., 2017). If this hormone is suppressed, water retention can occur. When coupled with excess fluid consumption, EAH can occur. Thus, overdrinking combined with the suppression of AVP results in an inability of the kidney to excrete the excess water load (Hew-Butler et al., 2015). The AVP hormone suppression may be impacted by intake of non-steroidal anti-inflammatory drugs and selective serotonin reuptake inhibitors, as well as other non-specific stresses such as pain, emotion, and nausea/vomiting, hypoglycemia, and exposure to heat (Hew-Butler et al., 2017). Although the use of nonsteroidal anti-inflammatory drugs (NSAIDs) may impact the suppression of AVP, which can lead to water retention, there is not enough evidence to conclude it as a risk factor for EAH (Bennett et al., 2020; Hew-Butler et al., 2015).

Although the primary cause of EAH is excessive drinking of hypotonic fluids beyond the capacity for renal water excretion (Bennett et al., 2020), there are other risk factors that have been identified. Long exercise duration, i.e. exercise over 4 hours, high ambient temperatures, and nausea (Bennett et al., 2020). Additional potential risk factors include race or event inexperience, slow running or performance pace, and the high availability of drinking fluids (Hew-Butler et al., 2015; Hew-Butler et al., 2017, & McDermott et al., 2017). Females were thought be more at risk, but when adjusted for BMI and race times, the sex factor is not significant (Bennett et al., 2020). Finally, those with high sweat sodium concentrations may be more at risk (Bennett et al., 2020).

Exercise-associated hyponatremia may be asymptomatic or symptomatic. In some cases of asymptomatic EAH, performance is not impaired (Knechtle, 2019) and often these cases are unrecognized. Symptoms of EAH may include headaches, nausea, vomiting, weight gain, bloating, confusion, and muscle cramping (Hew-Butler, 2018; Krabuk, et al., 2016; Thomas et al., 2016). A further distinction of symptoms recognizes the fast and slow development of EAH. Fast developing EAH may include additional symptoms such as dizziness, weakness, adynamia, tremor, fatigue, swelling of hands and feet, somnolence, and coma (Knechtle, 2019). In the slow to chronic development of EAH, other symptoms may include disorientation, lethargy, confusion, inappetence, change of personality, gait disturbance, and attention deficit disorder

(Knechtle, 2019). Because these symptoms are nonspecific and may be similar to dehydration, altitude sickness, heat stroke, hypoglycemia, or exercise-induced collapse, treatment of EAH can be tricky. At the Boston Marathon and many other large marathons, an extensive medical system is in place for treating athletes for various conditions and illnesses. If a runner has some typical symptoms, such as headaches, nausea, and confusion, their blood may be checked immediately with a portable machine (Abbott i-STAT System Critical Blood Analyzer, Chicago, IL). This measures the amount of sodium in the blood. If serum sodium is under 135mmol/L, then appropriate treatment is taken. In many cases, the runner is given bouillon cubes (900 mg of sodium per cube) or Top Ramen noodles in four ounces of water. This raises the sodium levels quickly and generally the runner will recover (Hew-Butler, et al., 2017; K. Ackerman, personal communication, April 20, 2019). Also, 100 mL of 3% saline flavored with Crystal Light (Chicago, IL) or salty snacks can be used for patients with mild or moderate EAH (Bennett et al., 2020; Hew-Butler et al., 2017). In other cases, a hypertonic IV may be administered (McDermott et al., 2017). It is important to observe the runner for at least 60 minutes to give the gut a chance to complete digestion of fluids consumed that may have been in excess, and the body a chance to go back to homeostasis. The blood analyzer machines are reportedly unreliable in temperatures outside of 60 to 80 degrees F such as during a hot or cold day associated with both ultra-endurance and challenging trail running events (Bennett et al., 2020).

Another concern with EAH-related illness include rhabdomyolysis. Chlibkova et al. (2015) had expanded the definition of EAH to include external rhabdomyolysis, which is the muscle breakdown with release of toxic chemicals into plasma and urine. Rhabdomyolysis can lead to kidney failure. There was some growing evidence that hyponatremic individuals are more prone to experience rhabdomyolysis (Chlibkova et al., 2017; Chlibkova et al., 2015; Hew-Butler et al., 2017). In one unique study, Chlibkova et al. (2015) compared ultra-mountain bikers and ultra-runners from five different ultra-running and ultra-cycling events in 2012-2013. The goal of this study was to explore the occurrence of both EAH and rhabdomyolysis in ultra-endurance athletes, and to compare ultra-mountain-bikers with ultra-runners. All events were at least 24 hours in duration. Clinical data, including blood and urine samples, were drawn both pre- and post-race for all participants. Blood creatine kinase was measured to test for rhabdomyolysis. Blood creatine kinase levels over 10,000 U/L of blood indicate rhabdomyolysis (Chlibkova et al., 2015). The overall results supported the hypothesis that rhabdomyolysis was more common among those who had experienced EAH. Also, based on this study, ultra-runners tended to develop rhabdomyolysis more frequently than ultra-mountain-bikers ($p < 0.01$). Based on these results, one may infer that different types of endurance athletes could have different hydration practices that would impact the risk of EAH. Further research has shown a limited relationship between rhabdomyolysis and EAH (M. Rosner, personal communication, July 26, 2020).

Occurrence of EAH.

Exercise-associated hyponatremia is a concern across multiple endurance and ultra-endurance sports. However, the reported number of EAH cases vary (Bennett et al., 2020). Because blood sampling is required for diagnosis, many cases go undetected. According to the NATA Position Statement, EAH occurs in approximately 10% to 20% of distance athletes after events (McDermott et al., 2017). Specifically, EAH inmarathon running has a mean prevalence of 8%, but can range from 5 to 20% depending on how or if it is reported or measured (Knechtle et al., 2019). In a more recent paper, symptomatic EAH incidence is less than 1% in marathon runners (Bennett et al., 2020). As mentioned previously, the number of people participating in ultra-endurance events continues to increase (Douglas, 2014). The prevalence of EAH has been reported higher in ultra-endurance athletes from 23-38% (Bennett et al., 2020; Knechtle et al., 2019). but is dependent on the sport. Higher prevalence of EAH has been reported in ultra-marathon runners and triathletes, while lower in cycling (Bennett et al., 2020; Knechtle et al., 2019).

Several studies have been reviewed to discuss this topic across multiple endurance sports. Although this topic stemmed from marathon running, the prevalence of EAH has been explored in other endurance athletes including cyclists, swimmers, triathletes, trail runners and mountain-bikers. In addition to endurance athletes, there is evidence that EAH has occurred in other sports or activities such as yoga, bowling, tennis, rugby, football, spinning, river rafting, and rowing (Hew-Butler et al., 2017; Knechtle et al., 2019) and among military personnel, first responders, park rangers, and park visitors (Bennett et al., 2020).The focus in this literature review is endurance athletes.

How common is EAH in marathon running? In a cross-sectional observational study, Mohseni et al. (2011) compared half and full marathoners both pre-race and post-race to determine hyponatremia, renal dysfunction, and electrolyte abnormalities. The 200 volunteer participants completed a survey (Appendices A and B) and had blood samples tested via a capillary finger stick pre-race and post-race. All registrants were eligible to participate, except those under the age of 18. Of the participants, about 50% were half marathoner racers, and the other half were full marathon racers. Medical history or running experience was not considered as a factor in the selection process, but race history was collected in the participant survey/questionnaire. Thus, there was a range of experience; from 1 to 57 prior races completed for the half marathon group, and 1 to 187 prior races were completed for the full marathon racing participants. Hyponatremia was determined from examining the blood samples of the participants that specifically measured serum sodium pre-race and post-race. Mohseni et al. (2011) found that pre-race hyponatremia was 5.0% and post-race was 8.2% in both half and full marathoners in a sample size of 161 pre-race participants and 195 post-race participants respectively. However, the incidence of hyponatremia was higher pre-race in the half marathoners at 6% (5 of 84) compared to the marathoners at 3.9% (3 of 77). On the other hand, the marathoners had higher rates at 13.5% (12 of 89) of hyponatremia post-race than the half marathoners at 3.8% (4 of 106). The estimated number of hyponatremic marathoners is in line with typical EAH estimates between 10-20% (McDermott et al., 2017). Also, the average time of the sample of marathon finishers was 5.6 hours, vs. 2.7 hours for the half. Exercise over 4 hours is a risk factor for EAH (Hew-Butler et al, 2017).

The researchers speculated the number of hyponatremia cases may be related to the significant number (one every mile) of hydration stations throughout the race course (Mohseni et al., 2011). The authors suggested that finishing times over four hours increased the risk for EAH and it appeared the runners were drinking too much (Mohseni et al., 2011). There were several limitations of this study. One, the study design included self-selected participants, not random. This introduces selection-bias. Second, there were some incomplete data sets from participants. Not all individuals completed pre-race and post-race blood tests. Third, the race pace was not considered in this study and about 15 subjects actually were considered walkers (Mohseni et al., 2011). Finally, the authors concluded the clinical significance of the study is unknown.

In a prospective observational cohort study, Krabak et al. (2017) assessed the incidence and prevalence of EAH, hyponatremia, hypernatremia, and hydration status in ultra-marathoners during a stage race. Prior research was limited when focusing on ultra-marathoners, defined as athletes completing an event over 42K. This study was unique in that it included four ultra-stage marathons and a 50-mile race in the fifth stage over a five-day period. In this study, 128 subjects volunteered. A stage is considered part of a multi-part race, usually covering a day of a multi-day race. A venous blood sample was obtained from each participant in a seated position. Krabak et al. (2017) concluded that the incidence of EAH in a stage race was similar to that of marathon events. Also, EAH was associated with weight gain in early stage non-finishers and postrace finishers. However, the total incidence of hypernatremia was three times greater than the incidence of EAH. There were a few limitations of this study. Selection bias was also a limitation. Also, blood samples were not collected at the beginning of each race, just at the finish of each race. In a prior pilot study, the authors noted the impracticality of collecting blood samples prior to the race and possibility of increased dropout rates of up to 75 percent (Krabuk et al., 2017). Of note, the runners did not want to be bothered with a blood test when getting prepared for the race and did not have the time. Other studies (Mohseni et al., 2011) had collected blood samples both before and after the race. Finally, due to the nature of a multi-stage race, participants had to eat and hydrate both during and between stages. This caloric (and food water) intake was not factored into the results. Measuring the number of calories consumed during the race in addition to measuring blood samples is a possibility for a future study of EAH. Knowing individual food intake would give a better understanding of its impact on sodium balance, hydration status, and ultimately EAH.

In another related study, Wagner, Knechtle, Knechtle, Rust, and Rosemann (2012) assessed EAH in both male and female marathon swimmers. Are the patterns and characteristics of EAH in long-distance swimmers the same as other events? Due to the nature of swimming, hydration and feeding during long-distance events can be complex. Support boats are provided for the athletes to utilize, but this requires them stopping to fuel or hydrate. Some athletes do not want to stop swimming to hydrate at a support boat. Whereas in cycling and/or running, athletes may carry their own water and fuel for most events. This may reduce or eliminate the need for stopping to refuel. In longer endurance events on land, such as marathon or ultramarathon running, most have hydration or feeding stops incorporated in the route. Wagner et al. (2012) hypothesized that female ultra-endurance swimmers would be younger, have a lower pre-race body mass index, a slower training pace, compete more slowly, drink more while racing and show a higher prevalence of EAH when compared with male ultra-endurance swimmers. Participants were recruited prior to the event by a newsletter sent six months prior to the event. Twenty-five male and 11 females volunteered over a two-year event period, including both 2009 and 2010. The mean age was 40 for both men and women participants. Subjects conveyed their swimming experience and history. This event, the Marathon Swim in Lake Zurich, recruits only elite athletes from all over the world. It is used as preparation event for the swim across the English Channel. In addition, anthropometric measures, capillary blood and urine samples were taken. Intake of food and fluid during the race was recorded by the support crews for each athlete. Although the sample size was small, the researchers found that 8% of males (n = 2) and 36% of females (n = 4) developed EAH during this event (Wagner et al., 2012). The higher percent of females that developed EAH in swimming is similar to other endurance events. These results support the hypothesis that metabolic abnormalities, such as hyponatremia and EAH, are common across endurance events, and are more common in females, as well as support prior research (Mohseni et al., 2011). Although females have been said to be more at risk for EAH than males, more recent experts have concluded this is not the case when adjusted for body mass index and race time (Bennett et al., 2020). Some limitations of this study include the small sample size as well as selection bias. The authors concluded that further research in swimming and EAH is necessary. Recently, EAH has been identified more frequently in swimmers (Knechtle et al., 2019).

In an earlier cross-sectional study, Chlibkova et al. (2014) assessed the prevalence of EAH across seven different ultra-endurance events in either running or mountain biking. The events included two 24-hour mountain-bike races, one 24 hour running event, and one multi-stage mountain bike race in the Czech Republic. There were 58 volunteer participants across the events and 53 finishers. Blood and urine samples, as well as body mass were measured before and after each race. The athletes were able to consume food and fluids during the event. Fluid consumption was recorded by the athlete or the support team and then estimated for each event. Food intake was not recorded. Hydration status was determined by change in body mass. This included overhydration as greater than zero % change, euhydration was less than zero to a decrease in 3% change, and dehydration was considered more than a 3% decrease in body mass (Chlibkova et al., 2014). Of the 53 finishers, 5.7%, one in each event category (three individuals), developed post-race EAH, except for the 24-hour ultra-mountain-bikers (Chlibkova et al., 2014). Exercise-associated hyponatremia was determined by measuring the blood samples pre- and post-race. The results did also support the fact that small changes in body mass (up to a 6.6 % loss and up to a 3.6% gain) do not impair performance and that the occurrence of EAH was similar to prior research (Chlibkova et al., 2014). Performance in an ultra-endurance event is primarily determined from distance achieved and/or speed. Finally, the primary limitation mentioned in the study was the inability to collect urinary excretion with the nature of these longer events. As a follow-up, Chlibkova, Rosemann, Posch, Matousek, and Knechtle (2016), further investigated the data from the prior study (Chlibkova et al., 2014). The researchers determined that previously reported EAH was actually higher in ultra-endurance athletes in this study. Post-exercise EAH was reported in 11.5% vs. 5.7% of the finishers (Chlibkova et al., 2016).

In a more recent study, Nolte, Nolte, and Hew-Butler (2018) examined ad libitum water consumption in soldiers during a 40 km march. Ad libitum and drinking according to thirst are sometimes considered the same in the literature, but they are actually slightly different. Drinking ad libitum is drink at one's pleasure, whereas drinking according to thirst is determined by the thirst mechanism (McDermott et al., 2017). Although ad libitum drinking during exercise is often recommended as a hydration strategy, it is unclear if it is effective in preventing EAH. Twenty-eight healthy male South African soldiers marched a 40 km route over a 9.11 ± 00.43 (hours: minutes) time period and were instructed to drink ad libitum. They each carried their own water, with no food or sodium. Extensive blood work was completed before and after the march. Particular attention was paid to blood sodium levels, urine output, and body mass changes. As a result, the researchers found that the ad libitum hydration method resulted in a 4% body mass loss and only one soldier tested positive for EAH (at 134 mmol/L), just slightly below the required detection level of 135 mmol/L (Nolte et al., 2018). They concluded that EAH was not prevalent despite a 4% loss of body mass and with drinking ad libitum as the hydration strategy.

Additional Studies in EAH

Sodium, sweat loss and EAH.

Individual sweat rates during exercise are highly individual and depend on body size, environmental conditions, exercise intensity, and other factors (McDermott et al., 2017). According to Hew-Butler et al. (2017), EAH develops from the ingestion of hypotonic fluids (water and sports drinks) that exceed sweat, urine, and insensible (mainly respiratory and gastrointestinal) losses. Prior thinking suggested taking sodium supplements to prevent hyponatremia during or after an endurance event was beneficial. There is not enough evidence to support this view for all participants (Hew-Butler et al., 2017; McCubbin et al., 2019). However, the ingestion of sodium is recommended for heavy sweaters, i.e. those with sweat rates are greater than 1.2 L/hour for events over two hours of duration (Thomas et al., 2016).

In an ecological experimental design, Lara et al. (2016) found great individual variability in sweat electrolyte concentration and performance during a marathon run. In other words, the sodium needs vary greatly due to different rates and concentrations in which people sweat. Depending on multiple factors, including the sport, the sweat rate ranged from 13 – 105 mmol/L among various types of athletes (Lara et al., 2016). Sweat rate variables include body size, sex, environmental conditions, exercise intensity, and acclimatization factors (McDermott et al., 2017). Additional sources of sweat rate variability during exercise include aerobic capacity, genetic predisposition, body composition, diet and hydration status (Baker, 2016). Thus, the purpose of this study was to determine sweat electrolyte concentration in a large group of marathon runners. During this study (Lara et al., 2016), sweat loss was measured (via two sweat patches) among 157 experienced and healthy marathon runners during a race. The subjects, 141 men and 16 women, volunteered to take part in the research. They completed a pre-race survey to determine self-reported BMI, race experience, best marathon time, and medical history. Subjects were excluded from the study if they had history of any muscular disorders, kidney or cardiac disease, or if they were taking any type of medication. The participants were allowed to drink at their discretion (ad libitum) during the race. After the race, they completed a questionnaire to record the amount they consumed during the race and the number of stops in which they needed to urinate or defecate. In the data analysis, the subjects were divided into three groups based on their sweat rate including low (26.0%), medium (53.0%), and high salt sweaters (19.7%). Sweat rate categories were defined by low-salt sweaters (sweat sodium concentration under 30 mmol/L), the medium sweaters (sweat sodium concentration between 30-60 mmol/L), and heavy or salty sweaters (sweat sodium concentrations greater than 60 mmol/L). ANOVA and Chi squared tests were used to compare the groups. In comparing the groups, the fluid intake and electrolyte intake via food and drink were similar between the groups. The women had lower sweat rates and slower race pace than the men. Lara et al. (2016) concluded that the individual variability in sweat loss was only explained by running pace and sex. Women also presented a lower sweat rate than men (0.5±0.2 vs 1.0±0.3 l/h; p=0.01) and a lower running pace during the race (2.8±0.4 vs 3.1±0.5m/s; p=0.04). This is slightly different from the hypothesis that predicted the running pace and body type would be the main predictors of sweat concentration. Although body types are different between sexes, and body type is associated with sex, sex itself was a stronger factor than body type. This is perhaps due to other factors, including the differences in lower body mass and exercise thermoregulation. Understanding the concentration of sweat loss may aid in our overall understanding of the development of EAH. The researchers identified several limitations of this study. One, blood samples were not taken post-race due to the impracticality and sample size. Another limitation was that the sample size of women was about 10% and these results should be interpreted with caution (Lara et al., 2016). Finally, the method of sweat collection with use of regional patches on the forearm may not be as accurate as other methods. This method may overestimate the amount of sweat concentration measured and therefore, it may have impacted the results (Baker, 2016; Lara et al., 2016). Although there are some disadvantages to using local sweat patches to measure total sweat loss, such as variation in sweat in the body area chosen, research has shown a high correlation between local sweat and whole-body sweat (Baker, 2016).

Similarly, Hoffman and Stuemplfe (2015) conducted a study to determine whether sodium supplementation is important in the prevention of EAH during exercise up to 30 hours, in this case a 161-km ultramarathon. All race participants were potential subjects. Of 376 possible subjects, 78.7% completed the race, and 181 participants completed the study-related testing, which included a pre-race and post-race body weight and post-race blood samples from those who were willing to provide a sample, and a post-race questionnaire. The web based post-race questionnaire was sent electronically during the event. Reminder emails were sent to participants at 7 days and 12 days after the event. The survey was closed 15 days after the event. The questionnaire targeted running background, hydration habits, use of sodium supplements, training regime, factors that determined fluid intake, and if they experienced nausea or vomiting during the race. This questionnaire had a 74.5% completion rate. Body weight was measured with calibrated scales (Sunbeam Products, Inc., Health O Meter, model 349KLX; Boca Raton, FL) one day before the race, 1.5 hour before the race, three times during the race at 47.8, 89.6, and 125.5 km, and at the end of the race. In addition, 61% of the finishers (n=276) did the post-race blood test and 53% of the finishers did both the blood test and the post-race survey. Results indicated that 6.6% of the finishers were hyponatremic and 93.3% of the runners used sodium supplements (Hoffman & Stuempfle, 2015). Thus, the researchers found that the sodium supplementation had little impact on developing EAH during this event. There were no differences in sodium supplementation for hyponatremic and normonatremic finishers (Hoffman & Stuempfle, 2015). There a few limitations of this study. One, self-reported data was used for food and drinks consumption during and post-race. A full pre-race dietary analysis to review sodium intake was not part of this study. Two, blood samples during the race would have been helpful for the final analysis, but this is not very practical. Three, the researchers did not report the amount of sodium supplementation. In summary, the authors concluded that avoiding overhydrating, and not sodium supplementation, is the primary means of preventing EAH in endurance events over 90 minutes, and in this case 30 hours.

In efforts to address sodium intake beliefs, information sources, and practices, McCubbin, Cox, and Costa (2019) surveyed endurance athletes in six English-speaking countries using an online questionnaire (Appendix C). Qualtrics (Provo, UT) was the online platform utilized. The four sections of questions included information about sodium sources, sodium beliefs, intended practices, and sweat composition testing. The survey was distributed via email and social media (Facebook). The participants included endurance athletes greater than or equal to 18 years of age, of any competitive level, and they must have been planning to participate in an event greater than or equal to two hours in the next six months. The 344 athletes (199 males and 145 females) were from Australia and New Zealand (60%), North America (26%), and the United Kingdom and Ireland (7.7%). To allow for regional comparisons, the remaining participants (n=22) were excluded because they lived outside of these areas. A variety of endurance sports, such as long-distance running, cycling, and open water swimming, were included. The results supported the authors' hypothesis that endurance athletes may have misconceptions about the use of sodium supplementation during exercise. Moreover, many athletes generally base their perceptions only after consulting non-scientific or non-peer reviewed resources of information. First of all, specific information sources ranked high to low were social support groups (63%), self-experimentation (56%), media (48%), health professionals (38%), and sport-specific support groups (35%). This finding supports other research in that endurance athletes are not using scientific research to make decisions regarding their activity. Second, common beliefs by participants on sodium intake during exercise included that improved performance, prevented or managed cramps and/or EAH. However, the research is scarce to support these common beliefs (McCubbin et al., 2019). In conclusion, the authors suggest there is a need for specific sodium intake guidelines to optimize performance for endurance athletes.

Carbohydrate intake and EAH.

Hubing, Bassett, Quigg, Phillips, Barbee, and Mitchell (2011) assessed EAH by observing different pre-exercise statuses of 10 elite male cyclists. In an experimental design with four trials, the researchers combined carbohydrate and hydration status to create four test groups among the ten participants with two to three subjects in each group. These included low carbohydrate/euhydrated, low carbohydrate/no fluid, high carbohydrate/euhydrated, and high carbohydrate/no fluid. The purpose of this study was to evaluate the effect of carbohydrate and hydration status on plasma sodium concentrations and fluid balance during and after prolonged exercise in the heat. The tests were done in a controlled environment in which the four test groups performed a depletion ride (to deplete carbohydrate stores) followed by rest two days before the test. Each group was provided one of the four protocols and the participants did a specific 90-minute ride at 60% VO2 max on a cycle ergometer. There was a three-hour rehydration period of only water after the completion of the test ride. The researchers also observed the potential for post-exercise EAH. They collected respiratory exchange rates periodically during exercise to measure carbohydrate oxidation. In addition, blood samples were drawn pre-exercise, 45-minutes into the exercise bout, and post-exercise. Sweat samples were collected via the arm-bag method after 45 minutes and 5 minutes before the end of exercise. Core temperature and heart rate were measured throughout the exercise bout. One of the limitations of this study included the use of a small sample size (n=10). Also, the arm-bag method of collecting sweat may not accurately represent overall body sweat. The sweat produced by the arm-bag method is much more concentrated and may over estimate sweat rates (Heyningen, & Weiner, 1952). The main conclusion of the study was that a high carbohydrate status (pre-event) and an euhydrated state may provide the most protection against EAH. Plasma sodium was greatest in both the dehydrated states, regardless of the carbohydrate consumption. Further research with a larger sample size including females, longer duration of exercise (greater than 90-minutes), perhaps the use of a different test for sweat rate, and outdoor or non-lab conditions would be helpful in confirming these results.

Hydration beliefs and EAH.

Hydration beliefs and EAH knowledge may not necessarily lead to behavior change in participants during an event. Chlibkova et al. (2017) compared the hydration beliefs and behaviors in endurance recreational athletes. The athletes included both runners and mountain-bikers, who were screened for their knowledge of EAH. In this unique study, 138 recreational athletes from seven different endurance and ultra-endurance events were surveyed pre-and post-race to determine their perceptions of hydration and EAH (Appendix D). Prior to the study, a pilot survey was completed with ten runners and fifteen mountain bikers to determine if any questions were unclear. Any unclear questions were not used. A web-based questionnaire was available to all participants prior to the race. A post-race questionnaire was distributed immediately after the race. The experience of the athletes was determined from the years active at the sport, the number of similar completed events, and the total training hours per week. There were several key findings. One, the subjects who were more experienced athletes showed a stronger knowledge of EAH, but this did not influence their hydration patterns. Second, hydration knowledge was positively associated with hydration planning ($n = 138$, $p = 0.003$).

Third, 59% of the participants had a pre-race drinking plan, 58% had a mid-race drinking plan, and 55% had a post-race hydration plan. However, this did not impact their planned hydration, reported fluid intake, or post-race plasma solution. Fourth, 12% of hyponatremic participants as determined at the end of race did not have different hydration beliefs, race behaviors, or reported fluid intake than those who did not have hyponatremia. The limitations of this study include selection bias, because participants volunteered. Also, in general, self-reported data has limitations. Individuals may tend to over- or underestimate their fluid intake (Chlibkova et al., 2017). Due to the nature of the races, both sexes may have not been fully represented (88 men and 25 women). Overall, the knowledge or belief system about hydration patterns did not impact the development of EAH (Chlibkova et al., 2017). This study can impact and direct further education on hydration and EAH for endurance athletes.

In a more recent study, Yates et al. (2018) measured hydration status and behavior in middle-aged cyclists during a century event (100 miles) in Texas, the “Hotter n’ Hell 100”. Because aging adults lose their thirst mechanism, they may be at increased risk for dehydration, hyponatremia, or EAH (McDermott et al., 2017). Further understanding the drinking behavior of middle-age adults, may contribute to the prevention of hyponatremia and/or EAH. Participants were recruited via email and paper flyers sent out prior to the event. Thirty-six male cyclists, ages 53±9 years old, were divided into three groups of 12 based on hydration status. All participants completed a medical history questionnaire and a 90-day exercise history. Based on the specific gravity of their urine two days before, the cyclists were grouped by hydration status of being slightly hydrated, euhydrated, and slightly dehydrated. The specific gravity test was based on recent hydration indices and position papers (Baker, 2016; Thomas et al., 2016). All groups had similar characteristics, such as experience riding, exercise history, and the completion of long-distance events (100 miles). There were no significant differences in age, BMI, height, body mass, or body fat percentage among the groups. Two surveys were administered prior to the event to determine hydration patterns and beliefs. The first survey asked the cyclists about drinking behaviors during their training and the second survey focused on the factors that influence their drinking patterns during this event. In the first survey, Yates et al. (2018) found more than 65% of cyclists were influenced by to drink according to thirst or personal experience. Also, the participants felt that dehydration would impact their performance negatively. On the contrary, the majority of the euhydrated group (83%) drank according to a hydration plan. This makes sense that those who have optimal hydration (euhydrated) are following a hydration plan. In the second survey, the researchers assessed the factors that influenced personal drinking behaviors. The participants were least influenced, not influenced or informed by scientific exercise hydration recommendations, such as ACSM or NATA. Similarly, their drinking behaviors were not impacted by advertisements from sports drink manufacturers. Finally, the results suggest that the drinking patterns of middle-aged cyclists were primarily impacted by their own experiences, and trial and error. The authors suggest that an individualized hydration plan, based on field and training experience, should be created for the middle-age cyclists (Yates et al., 2018). Thus, training plays a role when developing an individualized hydration plan for long-distance cyclists and also for other endurance athletes.

Another similar study assessed hydration patterns and perceptions of half-marathon and marathon runners (O'Neal et al., 2011). These researchers targeted non-elite runners, or those who did not need a qualifying time to participate in the Little Rock Half Marathon and Marathon in 2010. There were 2,908 runners completing the half marathon, and 1,550 runners completing the marathon. During the exposition two days before the race, researchers recruited 300 participants to complete the survey onsite at a table in the exposition hall. Of the 300 participants, 276 (146 men and 130 women) had completed the 23-item survey at the time of picking up their bib and race packet (92% response rate). The other 24 surveys were discarded for being incomplete. For the analysis, the researchers divided the participants into three groups of low, medium, and high based on their volume of running, expected race completion times, and running experience. A weighted score was determined based on these parameters. For example, the participants in the "high" group had more experience running, better times, and more frequent training sessions in comparison to the medium and low groups. Volume of running was weighted at 35%, while expected finishing time (performance) was weighted at 35%. Running experience was divided into three areas, each weighted at 10%. These included organized running over 24 months, years of running half or full marathons, and aerobic sessions per week. The final survey was 23 questions that asked about sport drink consumption patterns, influences on hydration patterns and strategies, and various viewpoints on hydration patterns. First, the vast majority (almost 70%) believed they experienced a decrease in performance due to dehydration. These results were similar to the other study (Yates et al., 2018). Second, 64% of participants received the most hydration advice from other runners. Third, 22% of the runners monitored their hydration status by reporting urine color or frequency of urinating on a run. Fourth, 42% of runners reported always hydrating during outdoor runs, but only 6% reported never drinking during an outdoor run. Fifth, the full marathon runners reported greater regular consumption of sport drinks in comparison to the half marathon runners. Limitations of this study included the fact that most of the participants (70%) were used to running in hot and humid environments and may have certain established hydration beliefs in comparison to those who run in cooler weather. Also, the target audience, recreational or non-elite runners, generally does not have the guidance of a trainer or coach. In comparison, one would assume an elite runner has professional guidance. In summary, the authors (O'Neal et al., 2011) concluded that non-elite runners should be more informed on hydration techniques and in developing individualized hydration strategies. Also, they identified a future need for investigators to explore ways to disseminate scientific findings to the public.

Similar research assessed the hydration patterns of runners in the London Marathon. Williams et al., (2012) wanted to further assess the risk for EAH in marathon runners by understanding their knowledge of EAH and hydration in general. A pilot study was done with 20 runners of variable experience prior to the event. Participants for this study were recruited at different intervals during each of the four registration days prior to the event. One in every nine runners was approached by the researchers, given information about the study, and then asked to participate. If the runner agreed, they were asked to complete a questionnaire at the research table. Overall, 217 runners completed the questionnaire, including 66 females and 151 males. The questionnaire was comprised of 11 demographic related questions and 28 drinking strategy related questions (Appendix E). The drinking strategy questions were related to fluid intake sources, knowledge of fluid intake and risk, knowledge of terms and concepts (i.e. EAH, low sodium levels), and open-ended questions on EAH. Interestingly, the results indicated that 95.8% of the participants had a drinking plan for the race and 21.6% planned to drink from every station (Williams et al., 2012). This was despite the fact that the race organizers recommended not drinking at every station and to not drink excessively. The London Marathon had 24 water stops – one at every mile between mile 3 and mile 25. Sports drinks were available at 5-mile intervals (5, 10, 15, and 20) and again at the 23-mile station. Similar to a prior study (O'Neal et al., 2011), the majority (93.1 %) of study participants received their hydration information from running friends and magazines, vs. scientific position papers or research reviews. In addition, only 25% of the runners identified "drinking according to thirst" as a hydration strategy. Finally, the knowledge of safe drinking strategies and EAH was also poor. The authors estimated that 12% of those sampled would be at risk for EAH. This is in alignment with the 13% of those runners with EAH in the Almond et al. (2005) study and is consistent with other literature (McDermott et al., 2017). However, one limitation of the study is that the participants, who were volunteers, may not be representative of the racing population. Also, there are inherent limitations of self-reported data. Future studies should continue to emphasize the need for education on hydration and EAH for marathon runners and endurance athletes.

Two of the original authors and three additional researchers administered the exact same survey to the London Marathon runners in 2014 (Appendix E). Their goals were to assess this sample of London Marathon runners and to compare the results to the initial study in 2010 (Leggett, Williams, Daly, Kipps, & Twycross-Lewis, 2018). The methods were repeated and 298 participants, 148 males and 150 females, completed the survey. The researchers explored the runners intended hydration strategies during the marathon, sources of hydration information, and knowledge of EAH. They found that the intended hydration strategy of drinking according to thirst had increased from 25.3% of runners in 2010 to 48.7% of runners in 2014. This is most likely a result of increased and continued education on hydration practices and EAH that was provided by the London Marathon administration. However, this also leaves an approximate 50% of runners with different hydration strategies, including those that may lead to drinking too much. In addition to these findings, 5% of the 2014 participants had estimated to drink more than 3.5 L during the race (Leggett et al., 2018). This is a decrease from the 2010 survey in which 12% of the participants reported that intended to drink over 3.5 L during the race. Consuming over 3.5 L of liquid has been shown as a risk factor in the development of EAH (Almond et al., 2005; Leggett et al., 2018; Williams et al., 2012). In summary, continued education for marathon runners on both hydration practices and EAH are essential to further reduce the risk of EAH (Leggett et al., 2018).

Summary

The prevalence of EAH in endurance athletes has been well-established throughout the research. Although any type endurance athletes may experience EAH, it occurs more frequently in ultra-endurance athletes. It has been well-documented that overhydration is the primary cause of EAH and it is likely combined with AVP suppression (Bennett et al., 2020; Hew-Butler et al., 2017; Hew-Butler et al., 2015; McDermott et al., 2017). Hydration is essential for optimal performance and health. Although individualized or personalized hydration plans are preferred, drinking according to thirst is a general hydration strategy that is recommended for most athletes in lieu of a personalized or individualized plan (Bennett et al., 2020).

Several areas of future research have been identified throughout this review. First, although the focus of this research is long-distance running, there have been very few studies on endurance swimmers and potentially rowing crews (Wagner et al., 2012). Second, although there have been some comparisons between running and cycling and/or mountain biking, there could be further exploration to compare these sports. Hydration and EAH studies have been limited in trail running as well. Third, Chlibkova et al. (2014) suggested that further research was needed to investigate the changes in body composition to determine the impact on EAH and performance. Fourth, Bennett et al. (2020) discussed the fact that EAH has been documented in individuals that do long back country activities, such as hiking and climbing. Because cases often go unrecognized, this is another area that may need EAH research. Fifth, Chlibkova et al. (2017)

suggested that more research should be done regarding hydration beliefs and patterns. Although there have been several studies assessing hydration beliefs (Leggett et al., 2018; Williams et. al., 2014). There appears to be a need to assess the hydration practices in training when compared to an actual event (Yates et al., 2018). Even though training hydration needs may be different due to weather or exercise intensity, behaviors should be replicated in an event. Inexperienced and even experienced runners may be impacted by the availability of drinks throughout the course, and thus tend to overdrink during an event. Sixth, the impact of food consumption during races on the prevalence of EAH in both marathon and ultra-endurance athletes across different sports has yet to be explored (Chlibkova, Nikolaidis, Rosemann, Knechtle, & Bednar, 2019). The hydration from food ingested during a race typically is not measured (Mohseni et al., 2011). Food intake is essential for ultra-endurance athletes. Finally, with EAH still a risk and concern for the race medicine field, continued education on EAH is still a priority for race event officiates, participants and the running community overall (Bennett et al., 2020; Chlibkova et al., 2017; Leggett et al., 2018; O’Neal et al., 2011; Williams et al., 2012).

Purpose

The purpose of this research is to assess and compare the hydration practices of marathon runners during an intended long training run, an intended marathon event, and on the actual race day. The primary hypothesis is three-fold. One, hydration practices are generally different for most runners during training than during an event. Two, intended hydration practices for the event are different than actual hydration practices for some runners. Third, there are some runners who drink more during the event than necessary or intended. Thus, there may be increased risk for some runners of EAH during an event. Although there are several risk factors for EAH, overhydration is a main contributor.

With an ongoing concern and attention to this topic, the survey results and analysis will benefit the running and academic community. The research will provide information specific to the runners in this study, including an understanding of the knowledge of hydration and EAH, hydration practices, and an estimated volume of fluids consumed by each runner during an event. The data analysis will also help us to understand the hydration practices in marathon/ultramarathon running and will attempt to answer the key research questions.

Key Research Questions

1. What are the hydration practices of marathon runners during an intended long training run, an intended event, and an actual event?
2. What are the similarities and differences in hydration practices between an intended long training run, an intended event, and an actual event?
3. Do runners drink more on event day than they intend to drink?
4. What are the key influencing factors in determining hydration practices during the event?
5. What is the general awareness of EAH and preventive techniques in running community surveyed?

This study was approved by the Institutional Review Board at North Dakota State University.

CHAPTER 3. METHODS

Introduction

These studies assessed and compared self-reported, intended hydration practices of marathon runners *during training, during an intended marathon event, and during a marathon*. Similar research studies to date (Leggett, Williams, Daly, Kipps, & Twycross-Lewis, 2018; Williams, Tzortziou-Brown, Malliaras, Perry, & Kipps, 2012) have yet to compare these three scenarios. Also, a pre- and post-race survey is unique to these studies and allows for comparison between intentional and actual hydration practices. In addition, sources of hydration information, knowledge of EAH and hydration, and EAH prevention techniques were evaluated as part of these studies. More detailed questions regarding EAH was unique to these studies.

The original intent of this research was to survey marathon runners associated with a marathon event. The pilot study (Chapter 4) was conducted with the Hyannis Marathon event (Hyannis, MA). The Fargo, ND Marathon had agreed to administer the survey (January 2020). The race was scheduled for May 9, 2020 and then rescheduled for August 29, 2020 due to COVID19. It was then cancelled again on July 27, 2020. There were a few other marathons that were possibilities, including the Bismarck, ND Marathon, and the Boston Marathon but they were also cancelled. The researcher asked a contact associated with the London Marathon which was supposed to take place in the fall of 2020. However, the race was administered with elite runners only and the course was changed as well. In order to continue this study, the researcher found trail race events that occurred during COVID-19 (Chapter 5). To add to this body of research, an additional hydration survey was created that was not race specific. A general hydration survey study that targeted long-distance runners was implemented (Chapter 6).

Study design.

A pilot study was planned for the Hyannis Marathon and was conducted during February, 2020 (Chapter 4). The intention of the pilot was to test the questions with an actual race and to complete a statistical analysis in order to inform methods for the larger study. Any questions that were unclear were re-written or eliminated. A post-race survey was also included in the pilot, and pre- and post-race questions were used as part of the analysis.

Prior to the Hyannis Marathon pilot study, the survey was sent to about 20 runners and/or fitness enthusiasts known by the researcher. The purpose was to test the survey for consistency, understanding, and to suggest possible improvements. Minor changes were made to improve the survey including revision of three questions. For example, the definition of a long training run was changed from 10 to 15 miles in the pilot based on feedback. The same approach was taken with the pilot research. A few questions were revised.

Participants and recruitment.

Information describing the research was sent via email to the Hyannis (MA) Marathon race director. The researcher worked with the Hyannis race team to administer the survey. In order to promote participation in the research, a description was posted on the Hyannis Race website on the home page and on their Facebook page (Appendix H). All participants were volunteers and no financial incentives were provided.

Nine days before the race, a link to the survey was sent to the Hyannis race contact. This survey link was sent out by the race contact in an email with a suggested note to the runners. Specifically, the link in the email went directly to the survey which was administered via Qualtrics (Provo, UT). Prior to actually starting the survey, a letter was provided to further explain the research and to gain online consent (Appendix L) to participate in the survey research. Once a runner volunteer participant clicked the consent button, the survey was started. Each participant had to complete each question before moving forward in the survey. In addition, the pre-race survey had a question at the end of the survey to ask those who completed it, to volunteer to complete an optional follow-up post-race survey. The post-race survey was sent immediately after the race. In order to prevent any memory lapse, the participants were asked to complete it within 60 hours of the event. Two reminder notices were sent via email after the race.

Survey design.

After a review of several related hydration surveys in the literature (Chibkova et al. 2017; Leggett et al. 2018, McCubbin et al., 2018; Mohseni et al., 2011; O'Neal et al., 2011; Williams et al., 2012; Yates et al., 2018), the surveys were designed to address the research questions. The questionnaire was conducted using Qualtrics (Provo, UT). The pre-race survey (Appendix F) assessed the intended hydration practices and volumes during a long-training run (LTR) and the event of their choice. The post-race survey (Appendix G) was designed to collect self-reported volumes before and during the marathon, as well as the hydration strategies during the actual event.

The information from both the pre- and post-race surveys allowed for comparison of intended hydration practices with actual practices during their chosen event. The pre-race survey included 52 questions divided into seven areas. These included demographic information, running experience, sources of information on hydration, intended hydration practices before and during a long training run, intended hydration practices before and during a potential marathon event day, the actual hydration practices before and during the marathon, and the knowledge/prevention methods of EAH. Questions regarding the amount of fluid consumed was accompanied by a visual diagram of the amount of fluid contained in a typical cup used during the race course. Running experience was assessed from a multiple-choice question adopted from McCubbin, Cox, and Costa (2018). Experience in at least one race competition, or one long-distance run was deemed, “Experienced”; less than one race or long-distance run, “Inexperienced.” The four questions related to knowledge of EAH were expanded from other studies (Leggett et al., 2018, Williams et al., 2012). A binary question similar to previous studies asked if runners “are familiar with EAH” and if they “had a solid understanding of hydration for a marathon” (Leggett et al., 2018, Williams et al., 2012). In order to assess the knowledge of the runners and EAH, one question asked them to select “contributing factors” and another asked them to “select ways to prevent EAH” to ascertain criterion validity.

The post-race survey (Appendix G) was emailed to those who volunteered in the pre-race survey immediately after the race. It probed for estimates of actual hydration consumption before and during the event and overall hydration practices. There were 21 multiple choice questions and one open-ended question to close the survey. In this section, there were also three questions relating to hydration stops and three questions related to carrying or wearing hydration packs. The majority of questions replicated the pre-race survey with the exception of three questions: one question regarding weight change, another probed for physiological symptoms during or after the run, and the last was an open-ended question asking for final comments.

Statistical Analysis

All statistical analyses were performed using SAS version 9.4 (Cary, NC). The runners' demographic data, total and subcategory mean scores and standard deviations were calculated using descriptive statistics in Qualtrics (Provo, UT). A subcategory refers to a breakdown of a main category, such as sex, age, or experience. Correlation tests were used to compare volumes consumed between the three scenarios, including an intended long training run, an intended marathon, and during the marathon event. A one-sided paired t-test was used to test if there was a significant difference between volumes consumed before and during the three scenarios. A Kappa agreement test was performed to evaluate the significance of agreement in the selection of hydration strategies in all the scenarios for all runners, both experienced and inexperienced runners. Alpha was set at <0.05.

CHAPTER 4. COMPARING RUNNERS' HYDRATION PRACTICES DURING AN INTENDED TRAINING RUN, AN INTENDED MARATHON, AND THE HYANNIS MARATHON (MANUSCRIPT ONE)

Abstract

Title**:** Comparing runners' hydration practices during an intended training run, an intended marathon, and the Hyannis Marathon.

Context**:** Prior studies on marathon runners have yet to assess hydration practices in training and during an event in order to prevent EAH. Training should mimic an event to optimize performance. Optimal hydration practices in training are ideally replicated during competition. Hydration strategies, such as drinking according to thirst, have been identified as key to prevent EAH. Familiarity and knowledge of EAH was assessed.

Objective: The purpose of this research was to assess and compare the self-reported hydration practices of marathon runners during an intended training run, an intended marathon event, and during an actual marathon.

Design: Cross-sectional pre- and post-survey design

Setting: The 2020 Hyannis, Massachusetts Marathon; race time temperature was between 45-53 degrees F. Conditions were mild and partly cloudy. Race start time was 9:30 am EST.

Participants*:* There were 214 of 250 eligible participants that opted for email correspondence. A total of 50 runners volunteered to be participants and 46 completed the-race survey.

Main outcome Measure(s): Survey questions addressed hydration practices, including hydration strategies, and volumes consumed before and during a marathon in three scenarios: an intended training run, an intended event and the actual event. Additional data included demographics, training experience, sources of hydration information, and knowledge of EAH.

Results: When comparing intended volumes consumed in training, both before and during, to the intended marathon, there was a moderate correlation ($R = 0.61$). However, there was a weak correlation ($R = 0.13$) when comparing volumes intended during training to the actual volumes during the marathon. The percentage of agreement in hydration strategies, ranging from 52-69%, was reported across the three scenarios. There was significance of agreement in all but one scenario (in inexperienced runners) measured by the Kappa statistic ($p<0.05$). Generally, experienced runners reported a higher level of agreement among the three scenarios. Runners consumed statistically ($p<0.05$) more than they intended during the marathon when compared to intended volumes during training and an event ($t = 4.49$, $t =3.68$). Runners reported “drinking according to thirst” 20% of the time during the actual marathon event. Finally, this study found that 54% reported awareness of EAH and a mixed knowledge of preventive factors.

Conclusion: There are differences in hydration practices when comparing an intended long training run, an intended marathon event, and an actual marathon event. This indicates a need for ongoing education on hydration practices and EAH. If runners mimic appropriate hydration practices during training and when running an event, the risk of EAH may be decreased. The primary limitations of this study are the self-reported nature of historical data and small sample size.

Key Words: overhydration, exercise-associated hyponatremia (EAH), thirst, marathon training, long-distance running.

Key Points

- Moderate to strong agreement was found to be significant when comparing hydration strategies between an intended long training run, and intended event, and the actual marathon.
- Self-reported volumes consumed during the marathon were significantly greater than the intended volumes during an event and a long training run. This practice likely increases risk for EAH.
- During the marathon, only 20% of the runners selected drinking according to thirst as their hydration strategy, which is identified as an important strategy to prevent EAH.
- Although about half of the runners in this study were familiar EAH, the majority did not identify the contributing factors or prevention methods.

Exercise-associated hyponatremia (EAH) is defined as serum sodium levels less than 135 mmol/L both during and 24 hours after exercise (McDermott et al., 2017). It occurs among various endurance and ultra-endurance athletes both during and 24 hours after exercise. It is estimated 10-20% of marathon runners experience EAH during and/or after their run (McDermott et al., 2017). More recent estimates suggest EAH occurs less than one percent in marathon runners, but is more common in ultra-endurance athletes at 23-28% (Bennett et al., 2020). Overhydration is the primary contributing factor to EAH (Bennett et al., 2020). Many have suggested that drinking according to thirst or consuming fluids as thirst dictates is the recommended hydration strategy to prevent EAH (Hew-Butler, Loi, Pani, & Rosner, 2017; Hoffman, 2019; Kipps, Sharma & Pedoe, 2011; Leggatt, Williams, Daly, Kipps & Twycross-Lewis, 2018). Others have suggested that having an individualized or personalized plan (Belval, Hosokawa, Casa, Adams, Armstrong, Baker…. Wingo, 2019, McDermott et al., 2017) is the optimal hydration strategy. Specifically, individualized hydration plans may consider sweat-rate, environment, acclimatization state, body size, exercise duration, exercise intensity, and individual fluid preferences and tolerance (McDermott et al., 2017). Similarly, a personalized hydration plan is one that optimizes the performance and safety of athletes during their sporting event, while considering the physiological, behavioral, logistical, and psychological needs of the athlete (Belval et al., 2019). If an individualized or personalized plan is not available, then "drinking according to thirst" should be considered as the appropriate hydration strategy to avoid overdrinking and EAH (Bennett et al., 2020; McDermott et al., 2017). Additional hydration strategies include ad libitum drinking, which is to drink at one's pleasure (McDermott et al., 2017), and programmed or prescribed drinking, which is drinking pre-determined amounts of fluid with the purpose of minimizing fluid losses (Kenefick, 2018).

Understanding overall hydration practices of marathon runners may help to assess their potential risk for EAH. Hydration practices not only include hydration strategies during training and competition, but also include the carrying of hydration packs, whether or not the runner stops to hydrate during a run, and hydration before and after the run. If runners figure out what works in training to optimize performance, then these practices can be mimicked during an event. If ideal hydration practices are replicated in a race, then overhydration may be avoided. Training is an appropriate way to practice for the actual event to determine what hydration or fuel optimizes performance (Thomas et al., 2016). If individual hydration practices are influenced by factors in an event, such as availability of fluids, the event excitement, time of race, or influences of other runners, then occurrences of overhydration may be increased. Also, social and emotional state pre-race may impact behavior and performance, especially in recreational marathon runners (Boullosa et al., 2020).

Determining exactly how much runners consume during a marathon event or during training is very difficult to measure. Unless a runner's hydration is carefully monitored, or if the runner carries what is necessary for hydration and drinks accordingly, it is challenging to practically measure the volume of fluid consumed. In addition, events provide hydration or aide stations during the race. Not only does the race cup size vary (generally 5-8 ounces), but the amount of fluid in the cup varies as well. Also, the amount of liquid consumed by the athlete will differ. Some liquid may be spilled, consumed, and some thrown on the ground or in waste baskets.

The purpose of this pilot research was to assess and compare self-reported, hydration practices of marathon runners during an intended long training run (LTR), an intended marathon event, and a marathon event. Similar research studies to date (Leggett et al., 2018; Williams et al., 2012) have yet to compare these three scenarios. Also, the pre- and post-race survey is unique to this study and allows for comparison between intentional and actual hydration practices. In addition, sources of hydration information, knowledge of EAH and hydration, and EAH prevention techniques were evaluated as part of this study.

Methods

Study design.

This was a cross-sectional pre- and post-questionnaire pilot study that included men and women signed up to compete in the Hyannis, Massachusetts Marathon in 2020. Approval was obtained from the Institutional Review Board at North Dakota State University. Each participant provided assumed consent. Pre- and post-race surveys were designed to assess the hydration practices among individuals registered to compete in the marathon.

Setting.

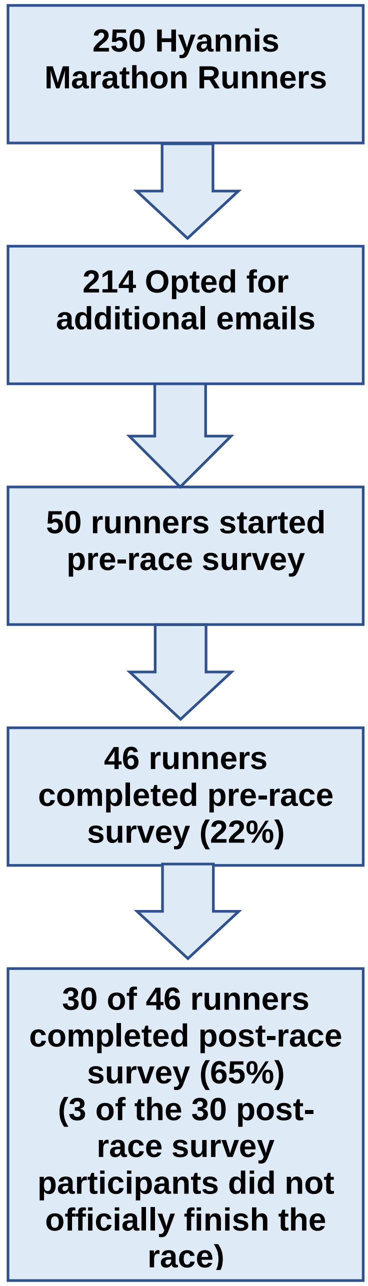
The 2020 Hyannis, Massachusetts Marathon; race time temperature was between 45-53 degrees Fahrenheit. Conditions were mild and partly cloudy. Race start time was 9:30 am EST.

Participants.

Hyannis Marathon runners that opted for email communication were eligible to participate in the survey(s) as illustrated in Figure 4.1. Similar to other studies (Williams et al., 2012; Leggett et al., 2018), experienced (EXP) marathon runners were defined as those who had completed at least one marathon. Inexperienced (INEXP) marathon runners were defined as those who had yet to complete a marathon.

Figure 4.1

Pre- and post-race research participants from the Hyannis, Massachusetts. Marathon, 2020



Instruments.

Online surveys were administered with Qualtrics (Provo, UT). The pre-race survey was sent ten days before the race. It assessed the intended hydration practices during a long-training run (LTR) and a marathon event. The post-race survey was sent immediately after the race and runners were allowed two days to complete it. It evaluated the self-reported volumes before and during the marathon, as well as the hydration strategies during the actual event. Prior to this study launch, the survey was tested among 20 runners and/or fitness enthusiasts known by the researcher. The purpose was to test the survey for consistency, face validity, understanding, and to suggest possible improvements. Minor changes were made to improve the survey including revision of three questions. For example, the LTR was initially defined as over ten miles then changed to 15 miles. Although there are a variety of marathon training programs for different types of running groups, most programs have the runner moderate lengths for portions of training, such as 10-15 miles, and up to 20 miles closer to the competition (HalHigdon.com, n.d.). Thus, runners would typically run at least one run over 15 miles in preparation for a marathon, and therefore, it was determined to be the LTR distance.

The information from both surveys allowed for comparison of intended hydration practices with actual practices during the marathon. The pre-race survey included 52 questions divided into six areas. These included demographic information, running experience, sources of information on hydration, intended hydration practices both before and during a LTR, intended hydration practices before and during marathon event day, and knowledge of EAH. Questions regarding the amount of fluid consumed was accompanied by a visual diagram of the amount of fluid contained in a typical cup used during the race course. Running experience was assessed from a multiple-choice question adopted from McCubbin, Cox, and Costa (2018). The four questions related to knowledge of EAH were expanded from other studies (Leggett et al., 2018, Williams et al., 2012). A binary question similar to previous studies asked if runners "are familiar with EAH" and if they "had a solid understanding of hydration for a marathon" (Leggett et al. 2018, Williams et al., 2012). In order to further assess the knowledge of the runners and

EAH, one question asked them to select "contributing factors" and another asked them to "select ways to prevent EAH" to ascertain criterion validity.

The post-race survey was emailed to those who volunteered in the pre-race survey (see Figure 4.1). It probed for estimates of actual hydration consumption before and during the event and hydration practices. There were 21 multiple choice questions and one open-ended question to close the survey. In this section, there were also three questions relating to hydration stops and three questions related to carrying or wearing hydration packs. The majority of questions replicated the pre-race survey with the exception of three questions: one question regarding weight change, another probed for physiological symptoms during or after the run, and the last was an open-ended question asking for final comments.

Procedures.

Information describing this multi-stage research was sent to registered race participants via email to the Hyannis Marathon race director. In order to promote participation in the research, a description was posted on the Hyannis Race website on the home page and on their Facebook page (Appendix H). All participants were volunteers and no financial incentives were provided. In the pre-race survey, the participants were asked to provide their email address to elect to receive the post-race survey. Those who provided their email address received the post-race survey immediately after the race. In order to prevent any memory lapse, the participants were asked to complete it within 60 hours of the event. Two reminder notices were sent one and day and two days after the race via email.

Statistical analysis.

All statistical analyses were performed using SAS version 9.4 (Cary, NC). The runners' demographic data, total and subcategory mean scores and standard deviations were calculated using descriptive statistics in Qualtrics (Provo, UT). A subcategory refers to a breakdown of a main category, such as sex, age, or experience. Correlation tests were used to compare volumes consumed among three scenarios, including an intended long training run, an intended marathon event, and during the actual marathon event. A one-sided paired t-test was used to test if there was a significant difference between combined volumes consumed before and during the three scenarios. A Kappa agreement test was used to evaluate the significance of agreement in the selection of hydration strategies in the scenarios for all runners, both experienced and inexperienced. Alpha was set at <0.05.

Results.

The descriptive statistics for participants are in Table 4.1. Some of the data was aggregated due to lack of heterogeneity (e.g. income, education, racial or ethnic category).

Table 4.1

Descriptive characteristics of the Hyannis Massachusetts hydration survey participants

CHARACTERISTIC (n=46)	NUMBER OF PARTICIPANTS (%)	Mean, +/- SD	Range
Age			
18-24 years	6 (13.04)	n/a	n/a
25-39 years	22 (47.83)	n/a	n/a
40-64 years	18 (39.13)	n/a	n/a
Sex			
Male	27 (58.70)	n/a	n/a
Female	19 (41.30)	n/a	n/a
Highest education completed			
Some college	4 (8.70)	n/a	n/a
Graduated college	13 (28.26)	n/a	n/a
Graduate school	29 (63.04)	n/a	n/a
Marital status			
Single	14 (30.43)	n/a	n/a
Married	29 (63.04)	n/a	n/a
Domestic partnership	3 (6.52)	n/a	n/a
Level of income			
$25,000 - $74,999	13 (28.26)	n/a	n/a
>$75,000	30 (65.22)	n/a	n/a
Prefer not to answer	3 (6.52)	n/a	n/a
Racial or ethnic category			
White	42 (91.30)	n/a	n/a
Other	4 (8.70)	n/a	n/a
BMI			
All	46 (100)	23.87, 3.67	20.02 - 38.57
Male (n=27)	27 (58.7)	24.01, 2.84	20.45 - 33.64
Female (n=19)	19 (41.3)	23.67, 4.69	20.02 - 38.57
Prior marathons			
<1	13 (28.26)	n/a	n/a
1-4	14 (30.43)	n/a	n/a
5-9	12 (36.36)	n/a	n/a
10 or more	7 (21.21)	n/a	n/a
Fastest time		*Hours: minutes*	*Hours: minutes*
All	33	3:45, 0.43	2:31 – 6:38
Males	19	3:29, 0.31	2:31 – 4:30
Females	14	4:06, 0.49	3:21 – 6:38
Expected time		*Hours: minutes*	*Hours: minutes*
All	45*	3:59, 0.51	2:45 – 6:30
Males	27	3:46, 0.45	2:45 – 6:00
Females	18	4:19, 0.54	3:25 – 6:30
Running Club			
Yes	11 (23.91)	n/a	n/a
No	35 (76.09)	n/a	n/a
Total weekly training hours			
Under 5 hours	4 (8.70)	n/a	n/a
5-8 hours	13 (28.26)	n/a	n/a
8-10 hours	15 (32.16)	n/a	n/a
Greater than 10 hours	14 (30.43)	n/a	n/a

**Note*: one runner did not answer both hours and minutes for this question and was excluded

Runners were asked to define their hydration strategy under all three scenarios - intended during training, intended during a marathon event, and the actual marathon event as part of a multiple-choice question (Table 4.2).

Table 4.2

Frequency of the hydration strategies in experienced (EXP) vs. inexperienced runners (INEXP)

Frequency of the hydration strategies in EXP vs. INEXP runners	Intended Long Training Run (LTR) n = 36 Frequency (%)		Intended Marathon n = 45 Frequency **(%)**		Actual Marathon n = 30 Frequency (%)	
Hydration Strategy	EXP (n = 26)	INEXP (n = 10)	EXP (n = 32)	INEXP (n = 13)	EXP (n = 20)	INEXP (n = 10)
I do not have one	1 (3.85)	2 (20.00)	1 (3.13)	1 (7.69)	0	2 (20.00)
According to thirst	4 (15.38)	2 (20.00)	3 (12.50)	3 (23.08)	2 (15.00)	3 (30.00)
Ad libitum	9 (34.62	1 (10.00)	8 (25.00)	2 (15.38)	7 (35.00)	1 (10.00)
Programmed	7 (26.92)	4 (40.00)	10 (31.25)	5 (38.46)	2 (10.00)	2 (20.00)
Personalized plan	0	0	0	0	0	0
Trial & error	4 (15.38)	1 (10.00)	6 (18.75)	1 (7.69)	5 (25.00)	1 (10.00)
Other	1 (3.85)	0	3 (9.38)	1 (7.69)	3 (15.00)	1 (10.00)

Note: Sample sizes may vary due to those who intended to drink during the LTR or intended marathon

The agreement of selection in the various hydration strategies in all participants were assessed for the different scenarios (Table 4.3).

Table 4.3

Agreement between various hydration strategies in all, experienced (EXP), and inexperienced (INEXP) runners

Hydration Strategy	Hydration Strategy	Agreement % Kappa (K) ALL	EXP	INEXP
Intended during LTR	Intended during marathon	69% K =0.604 p<.0001* n=36	65% K = 0.549 p<.0001* n=26	80% K = 0.740 p<.0001* n=10
Intended during marathon	Actual during marathon	52% K = 0.406 p<.0001* n=29	58% K = 0.456 p<.0001* n=19	40% K = 0.268 p<.0596 n=10
Intended during LTR	Actual during marathon	65% K = 0.619 p <.0001* n=23	73% K = 0.641 p<.0001* n=15n	63% K = 0.539 p<.0007* n=8

***** *Indicates statistical significance*

The percentage represents the agreement in runners' selection of the hydration strategy when comparing two scenarios. The Kappa test of agreement indicates statistical significance when comparing the hydration strategies in each of the scenarios.

Runners assessed what and how much they intended to drink during a LTR, an intended marathon event, and the actual marathon event (Table 4.4).

Table 4.4

Drink type and total volume intake during an intended long-training run (LTR), an intended marathon, and the actual marathon

	Intended LTR Frequency (%)	Intended Marathon Frequency (%)	Actual Marathon Frequency (%)
BEFORE:			
Water	36 (50.70)	35 (47.30)	20 (47.55)
Sports Drinks	13 (18.71)	18 (24.32)	8 (17.02)
Coffee	15(21.13)	14 (18.92)	12 (25.53)
Other	7 (9.86)	7 (9.96)	7 (14.89)
Amount: (in cups)			
None	0	1 (2.27)	0
1-2	33 (76.74)	22 (50.00)	11 (39.29)
3-5	7 (16.28)	16 (36.36)	13 (46.43)
>5	3 (6.98)	5 (11.36)	4 (14.29)
DURING:			
Water	11 (30.56)	11 (22.92)	6 (17.14)
Sports Drinks	2 (5.56)	5 (10.42)	6 (17.14)
Both	21 (58.33)	30 (62.50)	22 (62.85)
Other	2 (5.56)	2 (4.17)	1 (2.86)
Amount: (cups)			
1-3	18 (50.00)	16 (35.56)	5 (16.67)
4-6	11 (27.78)	14 (31.11)	10 (33.33)
7-9	7 (19.44)	9 (20.00)	9 (30)
10-12	0	2 (4.44)	4 (13.33)
>12	1 (2.78)	3 (6.67)	1 (3.33)
Other/unsure	0	1 (2.22)	1 (3.33)

Comparison of the volumes intended and consumed before and during a LTR, an intended event, and the actual marathon are displayed in Table 4.5.

Table 4.5

Comparison of volumes intended and consumed before and during an intended long-training run (LTR), an intended marathon, and an actual marathon, respectively for participants in Hyannis Massachusetts Marathon

	Intended volume before marathon vs. intended volume before LTR	Volume before marathon vs. intended volume before LTR	Volume before marathon vs. intended volume before marathon	Intended volume during marathon vs. intended volume during LTR	Volume during marathon vs. intended volume during LTR	Volume during marathon vs. intended volume during marathon
Correlation	0.611	0.225	0.347	0.608	0.127	0.487
p value	0.001*	0.279	0.083	0.002*	0.562	0.008*
	n = 27	n = 25	n = 26	n = 23	n = 23	n = 29

Note: *Indicates significance

Moderate correlations of 0.61 were found between the intended volumes before and during the LTR and the marathon (Table 4.5). Other scenario volume comparisons showed weak to moderate/weak correlations ranging from 0.23 – 0.49 (Table 4.5).

A one-sided paired t-test was used to assess if the mean differences in volumes were significant between the various scenarios (Table 4.6). A positive t-value indicates that the volume listed first is greater than the volume listed second. A negative t-value indicates that the volume listed first is less than the volume listed second in each scenario.

Table 4.6

Differences in volumes among the three scenarios for the Hyannis Massachusetts marathon runners

One-sided paired t-test	(Intended volume before marathon) – (intended volume before LTR)	(Volume before marathon) – (intended volume before LTR)	(Volume before marathon) - (intended volume before marathon)	(Intended volume during marathon) – (intended volume during LTR)	(Volume during marathon) - (intended volume during LTR)	(Volume during marathon) – (intended volume during marathon)
t value	3.16	3.37	-1.00	0.22	4.49	3.68
p value	0.0020*	0.0013*	0.1642	0.1642	0.0001*	0.0005*
sample size	n = 27	n = 25	n = 26	n = 26	n = 23	n = 29

Note: *Indicates significance

Several questions asked runners to identify additional hydration practices for LTR's in the pre-race survey. First, 35% of runners reportedly weighed themselves before and after a LTR However, only 13% indicated that they weighed themselves before and after the race in the post-race survey with a 0 to 6 lb. difference. Two runners reported a 1 to 2 lb. difference, one runner reported a 4 to 6 lb. difference, and one runner reported no difference in weight. Second, 65% of runners carried their own hydration during a LTR, while 39% said they placed fluids along their route. Of the runners that did carry their own fluid, 43% carried 1 to 2 cups, 27% carried 3 to 4 cups, and 27% carried more than 4 cups. Third, the key factors that influenced the runners' hydration plan during a LTR included weather (83%), running intensity (76%), and availability of drinks (63%). Lastly, 59% of the runners said their intended hydration practices during training generally mimic their hydration practices during an event.

The participants were asked about their typical sources of hydration information (Table 4.7). Participants were allowed to select more than one source of information. Items32 are ordered as they appeared in the actual survey.

Table 4.7

Sources of hydration information for Hyannis Massachusetts marathon runners

Source	No. (%)
The running event website	7 (5.5)
Running club	5 (3.9)
Running coach	6 (4.7)
Registered Dietitian	2 (1.6)
Running friends	28 (22.0)
Personal trainer	2 (1.6)
Doctor/physician/medical professional	9 (7.1)
TV/Radio	3 (2.4)
Running magazine or book	24 (18.9)
Other Internet sources	28 (22.1)
Professional organizations, such as ACSM	3 (2.4)
Research or journal articles	8 (6.3)
Other	2 (1.6)

About half (54%) of the participants indicated familiarity with the term EAH. In addition, participants were asked to select, from a list, contributing factor (s) to EAH and also the methods to prevent EAH. Regarding contributing factors, the majority of answers included “high intensity exercise” (13%), “drinking too much” (20%), “temperature and humidity” (14%), “continuous exercise lasting over four hours” (12%), and “sodium or electrolyte deficit” (16%). Responses of 6% or less included “low intensity exercise”, “not drinking enough”, “extremely cool weather”, “not enough training preparation for the event”, “availability of drinks”, “age”, and “low or high body weight”. The last factor, low or high body weight, or low or high BMI is considered a risk factor for EAH. In this sample, there was one person potentially at risk for EAH based on BMI extremes of less than 20 and greater than 30 (Table 4.1).

When participants were asked to identify EAH preventive factors, the most common responses were “drinking sports drinks” and “educating myself on this topic”, both at 19%. “Drinking according to thirst”, 16% and “taking salt tablets”, 14% were also identified, while 5% noted “I am not sure how to prevent EAH”. In addition, 10% identified “following my hydration plan”, 12% “dressing appropriately for the weather”, and only 2% selected “high intensity exercise”. Finally, the runner’s top symptoms reported were lightheadedness (50%), nausea (32%) and headaches (9%).

Discussion

In this study, hydration strategies across the three scenarios were in moderate agreement and were significant, except when comparing the hydration strategy intended during the marathon to the actual marathon in the inexperienced group. This suggests intended behaviors for hydration both in training and competition, usually mimic the actual practice for the competition. The Theory of Planned Behavior supports the notion that intended behaviors predict actual behavior (Ajzen, 1985). The key component of the theory is that behavioral intent is influenced by the likelihood of having an expected and beneficial outcome (Ajzen, 1985). Thus, intended hydration practices should impact the actual, if a beneficial outcome is perceived by the runner. However, when comparing the intended hydration strategy to the actual in inexperienced runners, the agreement was low and insignificant. Thus, inexperienced runners seem to be unsure of their hydration strategy and perhaps may be more influenced by race day. Also, the lower agreement may be due to lack of knowledge on appropriate marathon running hydration in general. Further analysis indicated that only about half of the participants felt they had a solid understanding of a safe and effective hydration plan, even though 87% had read or been told about hydration on race day. This result is reflected by how the runners reported information sources on hydration. Similar to the other studies (Leggett et al., 2018; O'Neal et al., 2011; Williams et al., 2012), the majority of runners in the current study selected running friends, magazines, and other Internet sources, while very few selected professional organizations as key sources of information to assure strategic hydration. Thus, there seems to still be a need for further education to the marathon running community.

The results indicated that the 21% of the runners chose ad libitum as their hydration practice, while 13% chose drinking according to thirst. While these two practices seem similar, they are different. Drinking according to thirst is driven by a physiological drive to drink, while ad libitum means drinking according to one's pleasure (McDermott et al., 2017). Programmed drinking was selected the most frequently at 23%. However, none of the respondents indicated that they had worked with a professional nor had their sweat-rate measured. In the McCubbin et al. (2018) study, only 5% reported using commercial sweat testing services and 75% thought it was beneficial. In this study, no one had selected having a personalized hydration plan, which is defined by working with a professional. A personalized hydration plan may incorporate sweat rate and perhaps knowledge of weight loss or gain during a long run or marathon. Because sweat rate is quite variable, it is inappropriate to specify a "one size fits all" hydration plan for all runners (McDermott et al., 2017). Only 13% of the runners who completed the post-race survey (n=30) reported weighing themselves before and after the race. Two runners indicated having a 1 to 2 lb. change, one runner indicated no change, and the other runner indicated a 4 to 6 lb. change. Perhaps if a scale was provided at the event, as suggested by Bennett et al. (2020), more runners would have given weighing a consideration. Some have suggested that having scales at events could in itself increase awareness of the importance of avoidance of EAH (Bennett et al., 2020). Finally, there were two runners who reported high BMIs, a potential concern for EAH.

When comparing volumes in the three scenarios, there were weak to moderate correlations. For example, a weak correlation found between intended training and the intended marathon event could be due to several factors. First, the training run in this study was defined as greater than fifteen miles. Since there is a difference between 15 and 26 training miles, the volumes intended would presumably be greater the higher the mileage. Runners tend to drink more the longer the exercise time frame associated with a greater distance. Also, perhaps runners do not consume the same amount during training as they do in an event due to other factors, such as intensity or temperature. In addition, more fluids are available and accessible during an event. Also, runners may be more prone to carry their liquids during training. In fact, 65% of the runners intended to carry water or sports drinks during the LTR, while only 29% intended to carry fluids during the marathon event. In this sample, 37% did carry liquids during the actual marathon. Runners must have been counting on the hydration stops provided during the event.

There was a weak relationship when comparing intended volumes and the actual volume consumed before the marathon. The London study (Williams et al., 2012) does collect the intended volumes consumed before the marathon, but does not report this data. Perhaps runners actually intend to drink less or more than they actually do drink before the marathon. Maybe the timing before the marathon was not taken into consideration when the runners predicted their volumes. For most events, runners are required to arrive early. Due to the logistics of larger marathon events, this may be two or more hours before the race start. This timing may add to increased fluid consumption of runners prior to the event, or change their intended plans. This should be a consideration of both marathoners and marathon event planners. In addition, there was moderate correlation between the intended volume during a marathon when compared to an actual marathon. Although the correlation was moderate, we would predict this to be higher. Interestingly, there was a slightly higher moderate correlation between the intended volume during training and the intended during the marathon. Thus, it appears the runners' intentions were a bit more consistent than what they may actually do during an event in this sample. This is supported by the theory of planned behavior which emphasizes how intentions can predict behavior (Ajzen, 1985).

When assessing the differences, the volumes consumed in the marathon were significantly greater when compared to the volumes in both the intended LTR and the event. Consuming more during competition when compared to training may enhance the risk for EAH. Again, this increase in volumes consumed may be due to several factors, including the emotional state on race day (Boullosa et al., 2020). The excitement or anxiety of the race itself may impact planned behavior, especially in recreational runners. In addition, the intended volumes during the marathon were statistically greater than the volumes intended in a LTR. This could be due to the fact the LTR may be a shorter distance than the race.

Only about half of the participants had heard of the term EAH, but this does not mean that they understand the condition. Although other studies had asked questions about EAH (Leggett et al., 2018 and Williams et al. 2012), their questions included only one open-ended on the causes and effects of EAH. Unique to this study, two multiple choice questions were included in the pre-race survey. These questions were designed to test the runners' knowledge of both contributing factors to the onset and prevention of EAH. About half of the runners who acknowledged hearing of EAH were asked these additional questions. The participants were allowed to select multiple answers for both questions. The top three contributing factors to the onset of EAH selected were drinking too much, high temperatures and humidity, and sodium or electrolyte deficit. In another study, 75% of participants reported believing sodium ingestion during endurance exercise prevented EAH (McCubbin et al., 2018). Overhydration is a main contributor to EAH, while sodium or electrolyte deficit is still controversial as a risk factor (Bennett et al., 2020). Although sodium supplementation during exercise, especially in the heat, is advantageous to replace sodium losses in sweat, it does not prevent EAH when combined with overhydration (Bennett et al., 2020). Also, high ambient temperatures may cause someone to overhydrate, and is a possible risk factor for EAH. Both high intensity exercise and continuous exercise lasting over four hours received many responses. Both low intensity exercise and continuous exercise over four hours are also considered risk factors for EAH (McDermott et al., 2017, Thomas et al., 2016, Hew-Butler et al. 2017, Knechtle et al., 2019). Overall, the results show mixed knowledge of the EAH contributing factors.

The second EAH knowledge assessment question asked participants to select ways to prevent EAH. The top three responses included drinking according to thirst, drinking sports drinks, and educating myself on this topic. Also, 14% of runners selected taking salt tablets. This differs from the McCubbin et al. (2018) study on sodium beliefs where 74% of the participants indicated that sodium supplementation prevented EAH. The current study results indicate that these runners are mixed on their knowledge of EAH prevention. While drinking according to thirst and educating myself are preventive practices, drinking sports drinks and taking salt tablets are not necessarily preventive practices (Bennett et al., 2020; Hew-Butler et al., 2017).

While 69% percent of the runners reported intention to stop at the hydration stations during a marathon event, 83% said they actually did stop during the marathon. A moderate correlation was found when comparing if the runner intended to stop to if they actually stopped at a hydration station. However, when comparing the intended frequency of stops and the actual number of stops that occurred during the marathon, the correlation was weak. Of concern are the runners who stop at all hydration stations. In this research, 19% of the runners intended to slow down or stop at all hydration stations during a race, but only 12% of runners actually did say they slowed down or stopped. In this marathon, there were only fifteen hydrations stations. The placement and number of stops in this race may not reflect all races. Some marathons, such as the London Marathon, have hydration stations every mile from the third mile onward (Kipps et al., 2011), or approximately 23 stops. This study shows a lower percentage than the London study, who reported 22% of runners stopped at all stations (Williams et al, 2012). The concern is that stopping at every hydration stop as a hydration strategy may be not only inconsistent between events, but can actually contribute to EAH, especially for slower runners.

There are several limitations to this study. One limitation was the small sample size. Also, this survey involved a questionnaire in which runners reported on intended behaviors. The timing of the pre-race survey was meant to be close to the runners last training run to deter any memory lapse. Due to the challenges of measuring actual volumes consumed, the post-race survey recorded self-reported vs. measuring the actual volumes. In addition, the volume averages were calculated from the mean of each volume range, based on the design of the question. Fianlly, not all of the pre-race survey participants completed the post-race survey. Thus, the comparisons were only with those who did both surveys.

Conclusions

This pilot study shows insight to hydration practices in the 2020 Hyannis Marathon runners. This assessment compared three different hydration scenarios, intended during a long training run, intended for a marathon event, and the actual marathon. It appears that runners consumed more both before and during the race than intended. This may lead to an increased risk of EAH. Overall, lack of consistent hydration practices, specifically hydration strategy and knowledge of EAH, suggest that more education is essential to provide marathoners in order to optimize hydration, health, and performance.

CHAPTER 5. HYDRATION PRACTICES OF LONG-DISTANCE TRAIL RUNNERS COMPETING IN CONNECTICUT DURING COVID-19 (MANUSCRIPT 2)

Abstract

***Title*:** Hydration practices of long-distance trail runners competing in Connecticut during COVID-19.

***Context*:** Prior studies on long distance trail runners have yet to assess hydration practices in training and during an event in order to prevent EAH. Training should mimic an event to optimize performance. Optimal hydration practices in training are ideally replicated during competition. Hydration strategies, such as drinking according to thirst, have been identified as key to prevent EAH. Awareness and knowledge of EAH in long-distance trail runners have yet to be assessed.

Objective: The purpose of this research is to assess and compare the self-reported hydration practices of long-distance trail runners during an intended long training run, an intended event, and during an actual event.

Design: Cross-sectional pre- and post-survey design.

Setting: The Macedonia Trail Race and the Angevine Farm Trail Race. The Macedonia Trail Race was in Kent, CT. The temperature was 52 degrees F. to 74 degrees F. The Angevine Farm Trail Race was in Warren, CT. The temperature was 62 degrees F. to 74 degrees F. Both races were held during September, 2020 and had conditions that were partly cloudy and mild.

Participants: A total of 26 (of 310 registered) eligible runners volunteered to be participants. Of the 26 survey participants, 17 completed the post-race survey.

Main outcome Measure(s): Survey questions addressed hydration practices, including hydration strategies, volumes, and types of fluid consumed in three scenarios, a long training run

(LTR), an intended event, and an actual event. Additional data included demographics, training experience, sources of hydration information, and knowledge of EAH.

Results: There was a strong correlation (0.91) between intended volumes before the LTR and the intended event. When comparing volumes during the event to the intended event, the correlation was moderate (0.52). The intended volumes before the LTR were significantly greater than the intended volume before the event ($p<0.05$). Moderate agreement (64-85%) was found when comparing the hydration strategies in the intended and the actual events. The comparisons were statistically significant when measured by the Kappa statistic ($p < 0.05$). Runners reported drinking according to thirst an average of 30% acro3ss the three scenarios. Finally, this study found that 50% reported participant knowledge and awareness of EAH, while 62% felt they had a solid understanding an effective hydration plan.

Conclusion: In this study, trail runners reported differences in hydration practices when comparing an intended LTR, an intended trail event, and an actual trail event. This indicates a need for ongoing education on hydration practices and EAH. If runners mimic appropriate hydration practices during training when running an event, the risk of EAH may be decreased. The primary limitations of this study are the self-reported nature of historical data and small sample size.

Key Words: overhydration, exercise-associated hyponatremia (EAH), thirst, marathon training, long-distance running, trail running.

Key Points

- Moderate to strong agreement was found to be significant when comparing hydration strategies during an intended trail run, an intended trail event, and the trail race.

- Self-reported intended volumes consumed before the long training run were significantly greater than the intended volume consumed before the event.
- During the trail event, only 31% of the runners selected drinking according to thirst as their hydration strategy, which is identified as an important strategy to prevent EAH. There were no runners who had a personalized hydration plan.
- Although about half of the runners in this study were familiar with EAH, the majority did not identify the causes or prevention methods.

During 2020, Coronavirus disease 2019 (COVID-19) created a global pandemic that has continued to change and disrupt our lives. In addition to the loss of thousands of lives, the long-term economic impact has yet to be determined. The decline and closing of many businesses, including many levels of sporting events, has also impacted our personal lives. Whether a spectator or participant, sports and recreational activities have been cancelled (Gilat & Cole, 2020). In addition, many sport or fitness training facilities have also been limited or closed (Latella & Haff, 2020). Weekend warriors and recreational athletes, including long-distance runners have been challenged in finding events to compete. Also, trail runners may have reduced their training due to limited access to specific trail training routes, due to closures of state or regional parks. During a time where virtual races have become the norm, two trail races took place in western Connecticut in the fall of 2020. There are unique characteristics that differentiate trail running from road running. Due to the nature of trail running, many factors, such as fewer participants (lack of mass starts), the course being well dispersed in nature, less spectators on the course, and perhaps less popularity among recreational runners, have decreased the risk associated with COVID-19 compared to inner city road races. However, it can also be more challenging to have available medical tents due to remoteness and perhaps lower number of participants (Bennett et al., 2020). Thus, it is very important for competitors to advocate for their health while competing.

Optimal hydration is essential for endurance and ultra-endurance runners to optimize both performance and safety. Avoidance of dehydration and overhydration is key. Exercise-associated hyponatremia (EAH) occurs with a serum sodium level less than 135 mmol/L both during and 24 hours after exercise (McDermott et al., 2017). It is estimated 10-20% of marathon runners experience EAH during and/or after their run (McDermott et al., 2017). More recent estimates suggest EAH occurs less than one percent in marathon runners, but is more common in ultra-endurance, such as trail-running athletes at 23-28% (Bennett et al., 2020). Overhydration is the primary contributing factor to EAH (Bennett et al., 2020; McDermott et al. 2017). Many have suggested that drinking according to thirst or consuming fluids as thirst dictates is the recommended hydration strategy to prevent EAH (Bennett et al., 2020; Hew-Butler et al., 2017; Hoffman, 2019; Kipps et al., 2011; Leggatt et al., 2018). Others have suggested that having an individualized or personalized plan (Belval et al., 2019, McDermott et al., 2017; Thomas et al., 2016) is the optimal hydration strategy. Specifically, individualized hydration plans may consider sweat rate, environment, acclimatization state, body size, exercise duration, exercise intensity, and individual fluid preferences and tolerance (McDermott et al., 2017). Similarly, a personalized hydration plan is one that optimizes the performance and safety of athletes during their sporting event, while considering the physiological, behavioral, logistical, and psychological needs of the athlete (Beval et al., 2019). If an individualized or personalized plan is not available, then “drinking according to thirst” should be considered as the appropriate hydration strategy to avoid overdrinking and EAH (Bennett et al., 2020; McDermott et al., 2017). Additional hydration strategies include ad libitum drinking, which is to drink at one’s pleasure (McDermott et al., 2017), or programmed drinking, which is drinking pre-determined amounts of fluid with the purpose of minimizing fluid losses (Kenefick, 2018).

Understanding overall hydration practices of long-distance trail runners may help to assess their potential risk for EAH. Hydration practices not only include hydration strategies during training and competition, but also includes the carrying of hydration packs, whether or not the runner stops to hydrate during a run, and hydration before and after the run. If runners figure out what works in training to optimize performance and well-being, then these practices can be mimicked during an event. If ideal hydration practices are replicated in a race, then overhydration may be avoided. Training is an appropriate way to practice for the actual event to determine what hydration or fuel optimizes performance (Thomas et al., 2016). If individual hydration practices are influenced by factors in an event, such as availability of fluids, the event excitement, time of race, or influences of other runners, then occurrences of overhydration may be increased. Also, social and emotional state pre-race may impact behavior and performance, especially in recreational long-distance runners (Boullosa et al., 2020).

Determining exactly how much runners consume during an event or during training is very difficult to measure. Unless a runner’s hydration is carefully monitored, or if the runner carries what is necessary for hydration and drinks accordingly, it is difficult to practically measure the volume of fluid consumed. In addition, events provide hydration or aide stations during the race. During COVID-19, the trail races used in this study had only bottles or cans at their aide stations (no cups). Runners either drank the full bottle or can, drank a portion of it and disposed of the rest, used it to fill their own hydration packs, or placed a partially full bottle or can near the aid station to obtain in the following lap. In this study, the trail runners were required to carry their own hydration system to potentially fill at the aide stations. (Figure 5.1)

Figure 5.1

Picture from the aide station at the Macedonia Trail Race in Connecticut, September 2020

The purpose of this novel research was to assess and compare self-reported hydration practices of trail runners during training, during an intended trail event, and an actual trail running event. Similar research studies to date (Leggett et al., 2018; Williams et al., 2012) have yet to compare these three scenarios, nor do they address trail running. Also, the pre- and post-race survey is unique to this study and allows for comparison between intentional and actual hydration practices. Sources of hydration information, knowledge of EAH and hydration, and EAH prevention techniques were evaluated as part of this study.

Methods

Study design.

This was a cross-sectional pre- and post-questionnaire study that included individuals signed up to compete in one of two Connecticut trail races, including the Macedonia Trail Race or the Angevine Farm Trail Race during September, 2020. Approval was obtained from the

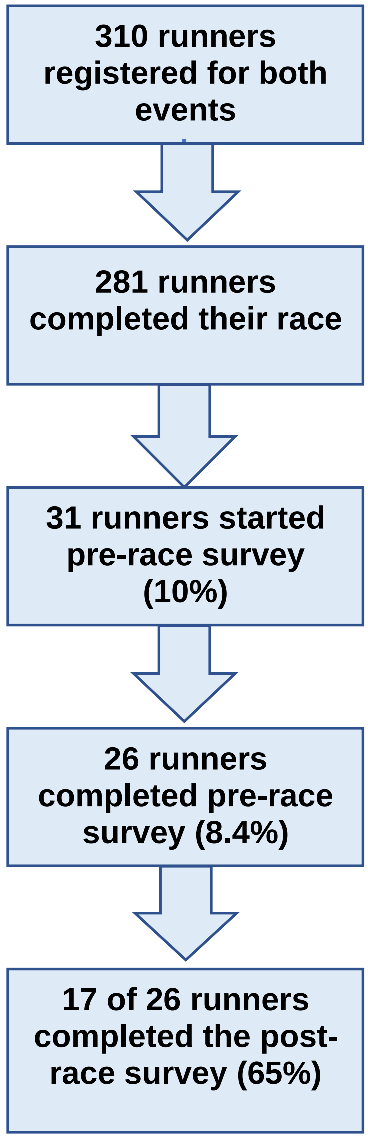
Institutional Review Board at North Dakota State University. Each participant provided assumed consent. Pre- and post-race surveys were designed to assess the hydration practices among individuals registered to compete in a race of one of the two events. There were three distances in the Macedonia Trail Race, including a 12K, a 25K, and a 50K option. The Angevine Farm Trail Race included both a half marathon and a 50K race option.

Participants.

Connecticut trail runners who registered for either event and were eligible to participate in the survey (s) as illustrated in Figure 5.2. Similar to other studies (Williams et al., 2012; Leggett et al., 2018), in which experienced (EXP) was defined as completing one event, this study defined experienced trail runners as those who had completed at least one trail event. Inexperienced (INEXP) trail runners were defined as those who had yet to complete a trail event.

Figure 5.2

Pre- and post-race research participant selection process



Instruments.

Online surveys were administered with Qualtrics (Provo, UT). The pre-race survey was sent 10 days before the Macedonia Trail Race and two days before the Angevine Farm Trail Race. The latter was supposed to be sent 10 days before the race and this was an error. The pre-race survey assessed the intended hydration practices during a long-training run (LTR) and a planned competitive trail event. The post-race survey was sent immediately after the both races, and runners were allowed two days to complete it. It evaluated the self-reported volumes before and during the trail race, as well as the hydration practices during the actual event. Prior to this study launch, a similar survey was tested among marathon runners in Hyannis, Mass (Young, under review). The purpose was to test the survey for consistency, face validity, understanding, and to suggest possible improvements. Minor revisions were made to improve the survey and tailor it to a trail running event. For example, the survey addressed two different races with a variety of distances.

The information from both surveys allowed for comparison of hydration practices during an intended training run, an intended event, and a trail event. The pre-race survey included 54 questions divided into six areas. These included demographic information (with self-reported weight and height used to determine BMI), trail running experience, sources of information on hydration, intended hydration practices before and during a LTR, intended hydration practices before and during a trail race event day, and knowledge of EAH. Running experience was assessed from a multiple-choice question adopted from McCubbin et al., (2018). The four questions related to knowledge of EAH were expanded from other studies (Leggett et al., 2018; Williams et al., 2012). A binary question similar to previous studies asked if runners “are familiar with EAH” and if they “had a solid understanding of hydration for a marathon” (Leggett et al. 2018; Williams et al., 2012). In order to assess the knowledge of the runners and EAH, one question asked them to select “contributing factors” and another asked them to “select ways to prevent EAH” to ascertain criterion validity.

The post-race survey was emailed to those who volunteered in the pre-race survey (see Figure 5.2). It probed for estimates of actual hydration consumption before and during the event and hydration practices. There were 23 multiple choice questions and two open-ended questions.

In this survey, there were also three questions relating to hydration stops and three questions related to carrying or wearing hydration packs. The majority of questions replicated the pre-race survey with the exception of three questions: one question regarding weight change, another probed for physiological symptoms during or after the run, and the last was an open-ended question asking for final comments.

Procedures.

Information describing this research was sent to registered race participants via email from the race director (Appendix M). In order to promote participation in the research, a description was posted on the event website on the home page and on their Facebook page. All participants were volunteers and no financial or other incentives were provided. In the pre-race survey, the participants were asked to provide their email address to elect to receive the post-race survey. Those who provided their email address received the post-race survey immediately after the race. In order to prevent any memory lapse, the participants were asked to complete it within 60 hours of the event. Reminder notices were sent via email both 24 and 48 hours after the event.

Statistical analysis.

All statistical analyses were performed using SAS version 9.4 (Cary, NC). The runners' demographic data, total and subcategory mean scores, and standard deviations were calculated using descriptive statistics in Qualtrics (Provo, UT). A subcategory refers to a breakdown of a main category, such as sex, age, or experience. Correlation tests were used to compare volumes consumed among the three scenarios, including an intended long training run, an intended trail-running event, and during the actual trail event. A one-sided paired t-test was used to test if there was a significant difference between combined volumes consumed both before and during, in each of the three scenarios. A Kappa agreement test was performed to evaluate the significance of agreement in the selection of hydration strategies in the three scenarios for all runners. Alpha was set at <0.05.

Results.

The descriptive statistics for participants are in Table 5.1. Overall, the runners trained on a regular basis and had substantial running experience. Some of the data was aggregated due to lack of heterogeneity (e.g. income, racial or ethnic category).

Table 5.1

Descriptive characteristics of participant runners in September 2020 trail races in Connecticut

CHARACTERISTIC (n=26)	NUMBER OF PARTICIPANTS (%)	Mean, +/- SD	Range
Age			
25-39	7 (26.92)	n/a	n/a
40-64	18 (69.23)	n/a	n/a
65 and older	1 (3.85)	n/a	n/a
Sex			
Male	20 (76.92)	n/a	n/a
Female	5 (19.23)	n/a	n/a
Prefer not to answer	1 (3.85)	n/a	n/a
Highest education completed			
Graduated high school	1 (3.85)	n/a	n/a
Trade or technical school	1 (3.85)	n/a	n/a
Graduated college	11 (42.31)	n/a	n/a
Graduate school	13 (50)	n/a	n/a
Marital status			
Single	5 (19.23)	n/a	n/a
Married	13 (50.00)	n/a	n/a
Divorced	6 (23.08)	n/a	n/a
Level of income			
$25,000 - $74,999	8 (30.77)	n/a	n/a
>$75,000	17 (65.38)	n/a	n/a
Prefer not to answer	1 (3.85)	n/a	n/a
Racial or ethnic category			
White	22 (84.62)	n/a	n/a
Other	4 (15.38)	n/a	n/a
BMI			
All **	25 (100)	23.68, 2.72	20.09 – 28.79
Male (n=20)	20 (80)	24.22, 2.68	20.09 – 28.79
Female (n=5)	5 (20)	22.01, 2.43	20.17 – 26.15
Prior trail races			
0-1	6 (23.08)	n/a	n/a
2-4	3 (13.04)	n/a	n/a
5-9	5 (19,23)	n/a	n/a
10 or more	12 (46.15)	n/a	n/a
Fastest times		*Hours: minutes*	*Hours: minutes*
Macedonia 12K	6 (23.08)	2:08, 0.52	1:33 – 2:44
Macedonia 25K	12 (46.15)	3:17, 0.56	2:00 – 4:40
Macedonia 50K	2 (7.69)	6:55, 1:32	5:50 – 8:00
Angevine Farm half marathon	5 (19.23)	1:15, 0.10	1:37 – 2:03
Angevine Farm 50K	1 (3.85)	5:03	5:03 – 5:03
Expected times			
Macedonia 12K	6 (23.08)	1:36, 0.14	1:20 – 2:00
Macedonia 25K	12 (46.12)	3.33, 0.49	2:10 – 4:45
Macedonia 50K	2 (7.69)	7.15, 1:03	6:30 – 8:00
Angevine Farm half marathon	5 (19.23)	2.17, 0.17	1:58 – 2:39
Angevine Farm 50K	1 (3.85)	6:00	6:00 – 6:00
Trail Running Club			
Yes	7 (26.92)	n/a	n/a
No	19 (73.08)	n/a	n/a
Total weekly training hours			
Under 5 hours	1 (3.85)	n/a	n/a
5-8 hours	12 (46.15)	n/a	n/a
8-10 hours	6 (23.08)	n/a	n/a
Greater than 10 hours	7 (26.92)	n/a	n/a

**Note*: one runner did not answer both hours and minutes for this question and was excluded

Runners were asked to define their hydration strategy under all three scenarios - intended during training, intended during a trail running event, and the actual trail running event as part of a multiple-choice question (Table 5.2). Experienced trail runners were defined as those who had completed at least one trail race. Inexperienced trail runners had yet to complete a trail race.

Table 5.2

Frequency of the hydration strategies in experienced (EXP) vs. inexperienced runners (INEXP)

Frequency of the hydration strategies in EXP vs. INEXP runners	Intended Long Training Run n = 21		Intended Trail Event n = 23		Actual Event n = 16	
Hydration Strategy	EXP (n = 19)	INEXP (n = 2)	EXP (n = 20)	INEXP (n = 3)	EXP (n = 14)	INEXP (n = 2)
I do not have one	0	0	0	0	0	1 (50.00)
As much as possible	0	0	1 (5.00)	1(33.33)	0	0
According to thirst	6 (31.58)	0	7 (35.00)	0	5 (35.71)	0
Ad libitum	8 (42.11)	0	9 (45.00)	0	7 (50.00)	0
Programmed	2 (10.53)	1(50.00)	1 (5.00)	1(33.33)	1 (7.14)	0
Personalized plan	0	0	0	0	0	0
Trial & error	3 (15.79)	0	2 (10.00)	0	1 (7.14)	0
Other	0	1(50.00)	0	1 (33.33)	0	1 (50.00)

Note: Sample sizes may vary due to those who intended to drink during the LTR or intended marathon.

Hydration strategies were compared between the scenarios. The percentage represents the agreement in runners' selection of the hydration strategy when comparing two scenarios. In addition, the Kappa test of agreement indicates statistical significance when comparing the various hydration strategies (Table 5.3).

Table 5.3

Agreement between various hydration strategies in all Connecticut trail runners

Hydration Strategy	Hydration Strategy	% Agreement Kappa statistic p value
Intended during LTR	Intended during trail event	86% K =0.804 p<.0001* n=21
Intended during trail event	Actual during trail event	75% K = 0.634 p<.0001* n=16
Intended during LTR	Actual during trail event	64.3% K = 0.470 p <.0055* n=14

Indicates statistical significance

Runners reported what and how much they intended to drink during a LTR, an intended trail event, and during the actual trail event (Table 5.4).

Table 5.4

Drink type and total volume intake during an intended long-training run (LTR), an intended trail event, and the actual trail event

	Intended Training Frequency (%)	Intended Event Frequency (%)	Actual Event Frequency (%)
BEFORE:			
Water	16 (50.00)	9 (51.4)	12 (48)
Sports Drinks	7 (21.88)	8 (21.6)	4(16)
Coffee	8(25.00)	10 (27.00)	7 (28)
Other	1 (3.13)	0	2 (8)
Amount: (in cups)			
None	0	0	0
1-2	6 (30.00)	9 (42.86)	6 (40)
3-5	9 (45.00)	10 (47.62)	6 (40)
>5	4 (20.00)	2 (9.52)	1 (6.67)
Other	1 (5.00)		2 (13.33)
DURING:			
Water	9 (42.86)	11(37.93)	7 (43.75)
Sports Drinks	1 (4.76)	6 (20.69)	3 (18.75)
Both	10 (47.62)	10 (34.48)	4 (25.00)
Other	1 (4.76)	2 (6.90)	2 (12.50)
Amount: (cups)			
1-3	8 (38.10)	6 (26.09)	3 (18.75)
4-6	3 (14.29)	8 (34.78)	6 (37.50)
7-9	6 (28.57)	4 (17.40)	5 (31.25)
10-12	2 (9.52)	2 (8.70)	2(12.50)
>12	2 (9.52)	2 (8.70)	0
Other/unsure		1 (4.40)	0

The comparison between the intended and actual volumes, both before and during, an intended LTR, an intended trail- race, and the trail race event are displayed in Table 5.5.

Table 5.5

Comparison of volumes intended and consumed before and during an intended long-training run (LTR), an intended trail event, and the actual trail event, respectively for participants in the Connecticut trail races

	Intended volume before LTR vs. intended volume before event	Volume before event vs. intended volume before LTR	Volume before event vs. intended volume before event	Intended volume during event vs. intended volume during LTR	Volume during event vs. intended volume during LTR	Volume during event vs. intended volume during event
Correlation p value sample size	0.910 0.0001* n = 11	0.356 0.283 n = 11	0.276 0.362 n = 13	0.603 0.0223* n = 14	0.059 0.842 n = 14	0.521 0.046* n = 15

Indicates statistical significance

A one-sided paired t-test was used to assess if the mean differences in volumes were significant between the three scenarios (Table 5.6). A positive t-value indicates that the volume listed first is greater than the volume listed second. A negative t-value indicates that the volume listed first is less than the volume listed second in each scenario.

Table 5.6

Differences in volumes among the three scenarios for Connecticut trail runners

One-sided paired t-test	(Intended volume before event) – (intended volume before LTR)	(Volume before event) – (intended volume before LTR)	(Volume before event) - (intended volume before event)	(Intended volume during event) – (intended volume during LTR)	(Volume during event) - (intended volume during LTR)	(Volume during event) – (intended volume during event)
t value p value sample size	-1.82 0.0424* n = 19	-0.91 0.1927 n = 11	t = -0.32 p = 0.378 n = 13	0.22 0.415 n = 21	0.44 0.332 n = 14	0.65 0.263 n = 15

Note: *Indicates significance

Several questions asked runners to identify additional hydration practices in the pre-race survey. First, 39% of runners reportedly weighed themselves before and after a run. However, only 18% indicated that they weighed themselves before and after the race in the post-race survey. One runner reported a 2 to 4 lb. loss and another runner reported a 4 to 6 lb. loss. Second, 92% of runners carried their own hydration during a training run, while 35% said they placed fluids along their route. Of the runners that did carry their own fluid, 25% carried one to two cups, 21% carried three to four cups, and 50% carried more than four cups. Third, the key factors that influenced the runners' hydration plan during a LTR included weather (30%), running intensity (31%), and availability of drinks (14%). Lastly, 92% of the runners said their intended hydration practices during training generally mimic their hydration practices during an event.

The participants were asked about their typical sources of hydration information (Table 5.7). Runners were allowed to select more than one source of information. Items are ordered as they appeared in the actual survey.

Table 5.7

Sources of information on hydration for Connecticut trail runners

Source	No. (%)
The running event website	5 (8.8)
Running club	2 (3.5)
Running coach	2 (3.5)
Registered Dietitian	1 (1.8)
Running friends	9 (16.8)
Personal trainer	1 (1.8)
Doctor/physician/medical professional	1 (1.8)
TV/Radio	2 (3.5)
Running magazine or book	14 (24.5)
Other Internet sources	11 (19.3)
Professional organizations, such as ACSM	2 (3.5)
Research or journal articles	5 (8.8)
Other	3 (5)

Exactly half of the participants indicated familiarity with the term EAH. In addition, participants were asked to select from a list of contributing factors to EAH and also to choose methods to prevent EAH. The majority of answers for contributing factors included "high intensity exercise" (11%), "drinking too much" (24%), "temperature and humidity" (11%), "continuous exercise lasting over 4 hours" (13%), and "sodium or electrolyte deficit" (20%).

Responses of 7% or less included “low intensity exercise”, “not drinking enough”, “extremely cool weather”, “not enough training preparation for the event”, “availability of drinks”, “age”, and “low or high body weight”. The last factor, low or high body weight, or low or high BMI is considered a risk factor for EAH. No individuals in this sample reported BMI extremes of less than 20 and greater than 30 (Table 5.1).

When participants were asked to identify EAH prevention factors, the most common responses were “drinking sports drinks” (15%), “educating myself on this topic” (13%), “following my hydration plan” (17%), and “taking salt tablets” (17%). “Drinking according to thirst” (11%), “educating myself on this topic” (13%), and knowing the “signs and symptoms” (15%) were also identified. Finally, the runner’s top symptoms reported during the race were lightheadedness (13%), muscle or joint pain (26%), and cramps (22%).

Discussion

When comparing hydration strategies between the three scenarios, a moderate to strong agreement was found and all were statistically significant. The highest level of agreement (86%) was the comparison of an intended LTR to an intended event. In comparing the intended strategy during an event to the actual trail event, the agreement was 75%. This suggests intended behaviors are related to the actual, and to each other. The Theory of Planned Behavior supports the notion that intended behaviors predict actual behavior (Ajzen, 1985). The key component of the theory is that behavioral intent is influenced by the likelihood of having an expected and beneficial outcome (Ajzen, 1985). Thus, intended hydration practices should impact the actual, if a beneficial outcome is perceived by the runner. The lowest agreement (64%) was the comparison of an intended LTR to the actual event. This may be influenced by a possible lack of preparation for the event, especially during COVID-19. Access to trails at a local park and/or a long trail distance may have been limited. Also, lack of hydration knowledge may be a factor as well. As mentioned previously, only 38% of runners did not feel they had a solid understanding of the safest and most effective way to hydrate for a long-distance trail running competition, while 92% had read or been told about hydration on race day. In addition, the runners reported their sources of hydration information. Similar to other studies (Leggett et al., 2018; O'Neal, 2011; Williams et al., 2012), the majority of runners in the current study selected running friends, magazines, and other Internet sources, while very few selected professional organizations as key sources of information to assure strategic hydration. Thus, there continues be a need for further education to the trail running community.

The results indicated that about 38% of the runners chose ad libitum as their hydration strategy, while about 30% chose drinking according to thirst across the three scenarios. While these two practices seem similar, they are different. Drinking according to thirst is driven by a physiological drive to drink, while ad libitum means drinking according to one's pleasure (McDermott et al., 2017). Programmed drinking and "trial and error" were each selected both at 14%. However, none of the respondents indicated that they had worked with a professional nor had their sweat rate measured. In the McCubbin et al. (2018) study, only 5% reported using commercial sweat testing services and 75% thought it was beneficial. Thus, in this study, no one had selected having a personalized hydration plan, which would be defined by working with a professional. A personalized hydration plan may incorporate sweat rate and perhaps knowledge of weight loss or gain during a long training run or marathon. Because sweat rate for adults is quite variable (ranging from 0.5 to 4.0 L/hr), it is inappropriate to specify a "one size fits all" hydration plan for all runners (McDermott et al., 2017). Only 17% of the runners who completed the post-race survey reported weighing themselves before and after the race. Of the three runners who did weigh themselves, two reported a small weight loss and one reported staying the same. Perhaps if a scale was provided at the event, as suggested by Bennett et al. (2020), more runners would have given weighing a consideration. Having scales at events could in itself increase awareness of the importance of avoidance of EAH (Bennett et al., 2020). Finally, there were no runners at risk for EAH based on BMI extreme estimates.

When comparing volumes in the three scenarios, there were weak to moderate correlations. For example, a weak correlation between the intended LTR and the intended trail event could be due to several factors. First, the LTR in this study was defined as greater than ten miles. Since there was a wide variation in race distances, the volumes intended would be presumably greater the higher the mileage. Also, perhaps runners may not consume the same amount during training as they do in an event due to other factors, such as intensity or temperature. Typically, fluids will available during an event. Trail runners are more apt to carry their fluids via a hydration belt or vest. In fact, in this study, 92% of the runners intended to carry water or sports drinks during the LTR, while 80% intended to carry fluids during the trail running event. In this sample, 90% did carry liquids during the actual trail race (they were required). Due to the length of these races, runners would still count on the hydration stops provided during the event. In the Macedonia Trail Race, there were 1 to 8 stops, depending on the length of race completed. In the Angevine Farm Race, there were 3 stops on the half marathon and 9 stops on the 50K. This is significantly less than typical road races such as the London Marathon which is reported having 24 stops along the course (Williams et al., 2012).

Although there was a strong correlation when comparing intended volumes before an event to volumes before a LTR, there were weak relationships when comparing the actual volumes consumed before the event to either the intended scenarios. Interestingly, the intended volume before the LTR was significantly greater than the intended volume before the event. Perhaps runners had planned to drink less before the actual trail race. Also, maybe the start time of the race was not taken into consideration when the runners predicted their volumes. For most events, runners are required to arrive early. This timing may change the amount consumed prior to the event. This should be a consideration of event planners (Bennett et al., 2020). Also, the excitement of the event in itself may change behaviors, especially in recreational runners (Boullosa et al., 2020). In addition, in this study, only 23% of runners said they drink before a LTR, while 42% intended to drink before the event. However, 88% reported drinking before the actual event, which is similar to 92% of participants in the London Marathon (Williams et al., 2012). There were moderate correlations between the intended volumes both before and during a long-distance running event, when compared to a LTR. Although the correlation was moderate, we would predict this to be higher. However, the intended volume during the event was significantly greater than the intended volume during the LTR.

Half of the participants had heard of the term EAH, but this does not mean that they understand the condition. Although other studies had asked questions about EAH (Leggett et al., 2018 and Williams et al. 2012), their questions included one open-ended on the causes and effects of EAH. Unique to this study, two multiple choice questions were included in the pre-race survey. These questions were designed to test the runners' knowledge of both contributing factors to the onset and prevention of EAH. The participants were allowed to select multiple answers for both questions. In the first question, the top three contributing factors to the onset of EAH selected were drinking too much, continuous exercise lasting over 4 hours, and sodium or electrolyte deficit. In another study, sodium ingestion was reported by 75% of participants to prevent EAH (McCubbin et al., 2018). Overhydration and continuous exercise are consistently recognized as risk factors for EAH, while sodium or electrolyte deficit is still controversial, and physiologically different for each individual and situation; and therefore, not an identified risk factor (Bennett et al., 2020). Also, high ambient temperatures may cause someone to overhydrate, and are a possible risk factor for EAH. Both low intensity exercise and continuous exercise over four hours may contribute to the onset of EAH (Hew-Butler et al. 2017; Knechtle et al., 2019; McDermott et al., 2017; Thomas et al., 2016). Overall, the results in this sample showed relatively strong knowledge of EAH contributing factors.

The second EAH knowledge assessment question asked participants to select ways to prevent EAH. The top responses included drinking sports drinks, following my hydration plan, taking salt tablets, knowing the signs and symptoms and educating myself on this topic. These results indicate that the runners had some knowledge of EAH prevention. While drinking according to thirst and educating myself are preventive practices, drinking sports drinks and taking salt tablets are not necessarily preventive practices (Bennett et al., 2020; Hew-Butler et al., 2017).

There are several limitations to this study. The primary limitation is the small sample size. Also, this survey involved a questionnaire in which runners reported on intended behaviors. Due to the challenges of measuring actual volumes consumed, the post-race survey recorded self-reported volumes vs. measuring actual volumes consumed. The volume averages were calculated from the mean of each volume range, based on the design of the question. Also, the definition of inexperienced runners may have been too limiting. In addition, not all of the pre-race survey participants completed the post-race survey, Thus, the comparisons were only with those who did both surveys.

Conclusions

This study shows insight to the hydration practices in long-distance trail runners. This assessment compared three different running scenarios, an intended long training run, an intended trail event, and the actual trail event. Overall, trail runners in this sample displayed some consistent hydration practices, specifically hydration strategy, knowledge of EAH, and preventive techniques. However, the study suggests that more education is essential to provide trail runners in order to optimize hydration, health, and performance.

CHAPTER 6. COMPARISON OF HYDRATION PRACTICES OF LONG-DISTANCE RUNNERS DURING COVID-19: A CROSS-SECTIONAL STUDY (MANUSCRIPT 3)

Abstract

***Title*:** Comparison of hydration practices of long-distance runners during COVID-19: a cross-sectional study.

***Context*:** Prior studies on long-distance runners have yet to compare general hydration practices intended during training and an event. Due to the lack of long-distance race events during COVID-19, intended hydration practices were assessed instead of actual. Optimal practices in training are essential to replicate in an event. Hydration strategies, such as drinking according to thirst, were evaluated as prevention for EAH. Awareness and knowledge of EAH in long-distance runners have yet to be assessed in intended training or an intended event.

Objective: The purpose of this research was to assess and compare the self-reported intended hydration practices of long-distance runners during a long training run and an event.

Design: Cross-sectional survey design.

Setting: Online survey utilizing both the North Dakota State University community and a Connecticut running group listserv(s) in October, 2020.

Participants: A total of 298 volunteers started the survey and 203 completed it.

Main outcome Measure(s): Survey questions addressed hydration practices, including hydration strategies, volumes, and types of fluid consumed before and during an intended long-distance training run (LTR) and intended race. Additional data included demographics, training experience, sources of hydration information, and knowledge of EAH.

Results: The comparison of self-reported hydration strategies between an intended LTR and an intended event show moderate agreement. B oth were statistically significant when

estimated by Kappa ($p < 0.05$). When comparing intended volumes during an intended LTR and an intended event, there was a correlation of 0.74. The intended volumes during an event were significantly greater than the intended volumes during a LTR. Runners reported "drinking according to thirst" 24% of the time during an intended LTR, compared to 23% of the time for their intended event. Finally, this study found that 59% reported knowledge and awareness of EAH, while 89% felt they had a solid understanding an effective hydration plan.

Conclusion: In this study, long-distance runners reported some differences in planned hydration practices when comparing an intended long training run to an intended event. This indicates a need for ongoing education on hydration practices and EAH. If runners mimic appropriate hydration practices during training when running an event, the risk of EAH may be decreased. The primary limitation of this study was the self-reported nature of historical data.

Key Words: overhydration, exercise-associated hyponatremia (EAH), thirst, marathon training, long-distance running, trail running.

Key Points

- Moderate to strong agreement was found to be significant when comparing intended hydration strategies between a long training run and an event.
- The intended volumes during the event were significantly greater than the intended volume during the long training run.
- Runners selected drinking according to thirst as their hydration strategy in both an intended LTR (24%) and an intended event (23%), which is identified as an important strategy to prevent EAH. Only two runners reported having a personalized hydration plan in their intended LTR and three runners reported having one in the intended event.

- While over half of the runners in this study were familiar with EAH, the majority did not identify the causes or preventive measures.

During 2020, COVID-19 created a global pandemic that has continued to change and disrupt our lives. In addition to the loss of thousands of lives, the long-term economic impact has yet to be determined. The decline and closing of many businesses, including many levels of sporting events, has also impacted our personal lives. Whether a spectator or participant, sports and recreational activities had been cancelled (Gilat & Cole, 2020). In addition, many sport or fitness training facilities had also been limited or closed (Latella & Haff, 2020). Weekend warriors and recreational athletes, including long-distance runners have been challenged in finding events to compete. While a few trail events had occurred during COVID-19, virtual races have become the norm. There are unique characteristics that differentiate trail and road running, which has allowed some trail events to occur. For example, many factors, such as fewer participants (lack of mass starts), the course being well dispersed in nature, less spectators, and perhaps less popularity among recreational runners, have decreased the risk of having the trail races take place during COVID-19. However, it can also be more challenging to have available medical tents due to remoteness and perhaps lower number of participants (Bennett et al., 2020). Thus, it is very important for runners to advocate for their own personal safety while competing.

Optimal hydration is essential for endurance and ultra-endurance runners to optimize both performance and health. Avoidance of dehydration and overhydration is key. Exercise-associated hyponatremia (EAH) occurs with a serum sodium level less than 135 mmol/L both during and 24 hours after exercise (Bennett et al., 2020; McDermott et al., 2017). It is estimated 10-20% of marathon runners experience EAH during and/or after their run (McDermott et al., 2017). More recent estimates suggest EAH occurs in less than one percent in marathon runners, but is more common in ultra-endurance athletes at 23-28% (Bennett et al., 2020). In addition, 7.1 cases per 100,000 are reported by the Department of Defense, with the highest being reported in the Marine Corps (Bennett et al., 2020). Requirements of long-distance running and obstacle courses in extreme conditions led to increased EAH. Not only are long-distance events a concern, but EAH cases are also reported in half-marathons and shorter distances. Overhydration is the primary contributing factor to EAH (Bennett et al., 2020). Many have suggested that drinking according to thirst or consuming fluids as thirst dictates is the recommended hydration strategy to prevent EAH (Hew-Butler et al.,2017; Hoffman, 2019; Kipps et al., 2011; Leggatt et al., 2018). Others have suggested that having an individualized or personalized plan (Belval et al., 2019; McDermott et al., 2017; Thomas et al., 2016) is the optimal hydration strategy. Specifically, individualized hydration plans may consider sweat rate, environment, acclimatization state, body size, exercise duration, exercise intensity, and individual fluid preferences and tolerance (McDermott et al., 2017). Similarly, a personal hydration plan is one that optimizes the performance and safety of athletes during their sporting event, while considering the physiological, behavioral, logistical, and psychological needs of the athlete (Beval et al., 2019). If an individualized or personalized plan is not available, then "drinking according to thirst" should be considered as the appropriate hydration strategy to avoid overdrinking and EAH (Bennett et al., 2020; McDermott et al., 2017). Additional hydration strategies include ad libitum drinking, which is to drink at one's pleasure (McDermott et al., 2017). Programmed or prescribed drinking is drinking pre-determined amounts of fluid with the purpose of minimizing fluid losses (Kenefick, 2018).

Understanding overall hydration practices of long-distance runners may help to assess their potential risk for EAH. Hydration practices not only include hydration strategies during training and competition, but also includes the carrying of hydration packs, whether or not the runner stops to hydrate during a run, and hydration before and after the run. If runners figure out what works in training to optimize performance and well-being, then these practices can be mimicked during an event. If ideal hydration practices are replicated in a race, then overhydration may be avoided. Training is an appropriate way to practice for the actual event to determine what hydration or fuel optimizes performance (Thomas et al., 2016). If individual hydration practices are influenced by factors in an event, such as availability of fluids, the event excitement, time of race, or influences of other runners, then occurrences of overhydration may be increased. Also, social and emotional state pre-race may impact behavior and performance, especially in recreational long-distance runners (Boullosa et al., 2020).

Determining exactly how much runners consume during an event or during training is very difficult to measure. Unless a runner's hydration is carefully monitored, or if the runner carries what is necessary for hydration and drinks accordingly, it is difficult to practically measure the volume of fluid consumed. Runners may plan to have strategically placed hydration hidden along their training course or along their virtual "competition" course. Group events traditionally provide hydration or aide stations during the race. Not only does the race cup size vary (generally 5-8 ounces), but the amount of fluid in the cup varies as well. Also, the amount of liquid consumed by the athlete will differ. Some liquid may be spilled, consumed, and some thrown on the ground or in waste baskets. During COVID-19, some trail races that did occur only had bottles or cans at the aide stations because open cups were not allowed.

The purpose of this novel research was to assess and compare self-reported hydration practices of long-distance runners during an intended LTR and an intended event. The subjects included both road and trail runners. Similar hydration research studies to date (Leggett et al., 2018; Williams et al., 2012) have yet to compare intended hydration practices of long-distance runners during training and an event. In addition, sources of hydration information, knowledge of EAH and hydration, and EAH prevention techniques were evaluated as part of this study.

Methods

Study design.

This was a cross-sectional study that targeted long-distance runners who volunteered to complete a hydration survey (Appendix K). Approval was obtained from the Institutional Review Board at North Dakota State University. Each participant provided assumed consent after starting the survey. The survey was designed to compare the intended hydration practices of a long training run (LTR) and an event.

Participants.

Participants were recruited from two main sources in October 2020. The first group were volunteers from North Dakota State University (Fargo, North Dakota) online community (19,249 individuals), including students, faculty, and staff. The second included a running group of 1,421 members of the Steep Endurance organization (Connecticut, USA).

There were 298 runners who initially signed up for the survey. Of the 298 volunteers, 203 completed the online survey. The other 95 surveys were discarded for being incomplete. Similar to other studies (Williams et al., 2012; Leggett et al., 2018), in which experienced was defined as completing one event, this study defined experienced runners as those who had completed at least one ten-mile run. Inexperienced long-distance runners were defined as those who had yet to complete a ten-mile run.

Instruments.

The survey assessed the intended hydration practices during a LTR and a long-distance event. The survey link was available for two weeks for participants to complete. Prior to this study launch, a similar survey was tested among Hyannis MA marathon runners and with Connecticut rail runners (Young, under review). The purpose was to test the survey for consistency, face validity, understanding, and to suggest possible improvements. Minor revisions were made to improve the survey and tailor it to long-distance runners. For example, this survey included not only road and trail runners, but also accommodated different levels of experience by having a variety of race distances above 10 miles.

The information from the survey allowed for comparison of hydration practices during an intended LTR and an intended event. The survey included 57 questions divided into six areas. These included demographic information (self-reported weight and height were used to determine BMI), running experience, sources of information on hydration, and the intended hydration practices before and during a LTR and an event, and knowledge of EAH. Running experience was assessed from a multiple-choice question adopted from McCubbin et al. (2018). The four questions related to knowledge of EAH were expanded from other studies (Leggett et al., 2018; Williams et al., 2012). A binary question similar to previous studies asked if runners "are familiar with EAH" and if they "had a solid understanding of hydration for a long-distance run" (Leggett et al. 2018; Williams et al., 2012). In order to further assess the knowledge of the runners and EAH, one question asked them to select "contributing factors" and another asked them to "select ways to prevent EAH" to ascertain criterion validity. At the end of the survey, the runners were asked if they had a solid understanding of safe and effective hydration. The last one was an open-ended question asking for final comments on hydration for long-distance running.

Procedures.

The survey was administered with Qualtrics (Provo, UT). A description of the research was in a letter from the researcher describing the study in the via the listserv(s) (Appendix N). Also, the survey link was posted to a trail running Facebook page. Again, once the survey link was opened, a letter describing the research was presented to the participant. Once the participant clicked the link for the survey, consent was implied and the survey began.

Statistical analysis.

All statistical analyses were performed using SAS version 9.4 (Cary, NC). The runners' demographic data, total and subcategory mean scores, and standard deviations were calculated using descriptive statistics in Qualtrics (Provo, UT). A subcategory refers to a breakdown of a main category, such as sex, age, or experience. A Kappa test was used to evaluate the significance of agreement in the selection of hydration strategies in both scenarios for all runners, experienced and inexperienced. Correlation tests were used to compare intended volumes consumed during a LTR and an intended event. A one-sided paired t-test was used to test if there was a significant difference between the intended volumes consumed before and during a LTR, and the intended volumes consumed both before and during an event. A chi-square test of independence was used to see if the hydration strategy is associated with running mileage. Alpha was set at <0.05 to indicate significance.

Results.

The descriptive statistics for participants are in Table 6.1. Overall, the runners trained on a regular basis and had substantial running experience.

Table 6.1

Descriptive characteristics of participant runners in a hydration survey during COVID-19

CHARACTERISTIC (n=203)	NUMBER OF PARTICIPANTS (%)	Mean, +/- SD	Range
Age			
18-24	9 (4.39)	n/a	n/a
25-39	56 (27.32)	n/a	n/a
40-64	131 (63.90)	n/a	n/a
65 and older	8 (3.90)	n/a	n/a
Sex			
Male	107 (52.45)	n/a	n/a
Female	96 (47.06)	n/a	n/a
Prefer not to answer	1 (0.49)	n/a	n/a
Highest education completed			
Graduated high school	2 (0.98)	n/a	n/a
Trade or technical school	4 (1.96)	n/a	n/a
Some college	16 (7.84)	n/a	n/a
Graduated college	83 (40.53)	n/a	n/a
Graduate school	99 (48.53)	n/a	n/a
Marital status			
Single	32 (15.69)	n/a	n/a
Married	141 (69.12)	n/a	n/a
Divorced	19 (9.31)	n/a	n/a
Widowed	2 (.98)	n/a	n/a
Domestic Partnership	10 (4.90)	n/a	n/a
Level of income			
<$25,000	7 (3.43)	n/a	n/a
$25,000 - $49,999	20 (9.80)	n/a	n/a
$50,000 - $74,999	27 (13.24)	n/a	n/a
>$75,000	133 (65,20)	n/a	n/a
Prefer not to answer	17 (8.33)	n/a	n/a
Racial or ethnic category			
White	188 (92.16)	n/a	n/a
Other	16 (7.84)	n/a	n/a
BMI			
All	233 (100)	23.54, 2.68	16.74 – 35.15
Male	123 (52.79)	23.98, 2.43	18.55 – 35.15
Female	109 (46.78	22.81, 2.77	16.74 – 31.56
Prior long-distance runs (>10 miles)			
0-1	8 (3.96)	n/a	n/a
2-4	15 (7.39)	n/a	n/a
5-9	16 (7.88)	n/a	n/a
10 or more	164 (80.79)	n/a	n/a
Level of training			
Professional or elite athlete	3 (1.48)	n/a	n/a
Aspiring professional athlete	3 (1.48)	n/a	n/a
Competitive in age group	91 (44.83)	n/a	n/a
Training regularly	90 (44.33)	n/a	n/a
Training sometimes	13 (6.40)	n/a	n/a
Other	3(1.48)	n/a	n//a
Trail Running Club			
Yes	105 (51.72)	n/a	n/a
No	96 (48.28)	n/a	n/a
Total weekly training hours			
Under 5 hours	18 (8.37)	n/a	n/a
5-8 hours	86 (42.36)	n/a	n/a
8-10 hours	50 (24.63)	n/a	n/a
Greater than 10 hours	49 (24.14)	n/a	n/a

Runners were asked to define their hydration strategy in both scenarios - intended during a LTR and intended during an event as part of a multiple-choice question (Table 6.2).

Table 6.2

Frequency of the hydration strategies in an intended long training run (LTR) and an intended event

Hydration strategy	Intended LTR Frequency (%)	Intended Event Frequency (%)
I do not have one	9 (5.11)	5 (2.65)
As much as possible	4 (2.27)	7 (3.70)
According to thirst	42 (23.86)	44 (23.38)
Ad libitum	43 (24.43)	35 (18.52)
Programmed	39 (22.16)	46 (24.34)
Personalized plan	2 (2.14)	3 (1.59)
Trial & error	25 (14.20)	28 (14.81)
Other	12 (6.82)	21 (11.11)

Note: Sample sizes may vary due to those who intended to drink during the LTR or intended event.

Hydration strategies of runners in the two scenarios were compared for agreement and statistical significance. The percentage represents the agreement in runners' selection of the hydration strategy when comparing two scenarios. The Kappa test indicates the statistical significance of agreement when comparing the various hydration strategies (Table 6.3).

Table 6.3

Agreement between various hydration strategies in all runners

Hydration Strategy	Hydration Strategy	% Agreement Kappa statistic p value
Intended during LTR ALL (n=181)	Intended during event	74% K =0.674 p<.0001*
Intended during LTR EXP (n=178)	Intended during event	73% K = 0.669 p<.0001*
Intended during LTR- INEXP (n=3)	Intended during event	100% K = 1.0 p <.0833

***** Indicates statistical significance

In addition, a chi-square test of independence was used to see if the hydration strategy was associated with weekly running mileage (< 25 miles, low and > 25 miles, high). In assessing intended hydration strategies during the event, the chi-square was 6.74 (p = 0.234). In assessing the intended hydration strategies during a LTR, the chi-square was 3.57 (p = 0.613). In both cases, the tests were not significant. Thus, "low" or "high" mileage did not impact the hydration strategy for either scenario.

Runners reported what and how much they intended to drink during a LTR and an intended event (Table 6.4).

Table 6.4

Drink type and total volume intake during an intended long training run (LTR) and an intended event

	Intended Training Frequency (%)	Intended Event Frequency (%)
BEFORE:		
Water	142 (45.95)	147 (44.55)
Sports Drinks	54 (17.48)	68 (21.61)
Coffee	94 (30.42)	91 (27.58)
Other	19 (6.15)	24 (7.27)
Amount: (in cups)		
None	1 (0.58)	0
1-2	106 (61.63)	100 (56.50)
3-5	52 (30.23)	64 (36.16)
>5	11 (6.40)	11 (6.21)
Unsure	2 (1.16)	2(1.13)
DURING:		
Water	44 (25.00)	63 (25.61)
Sports Drinks	8 (4.55)	35 (14.23)
Both	107 (60.8)	125 (50.81)
Other	17 (9.66)	23 (9.35)
Amount: (cups)		
1-3	66 (37.50)	44 (23.28)
4-6	49 (27.84)	60 (31.75)
7-9	25 (14.20)	29 (15.34)
10-12	18 (10.23)	16 (8.47)
>12	9 (5.11)	28 (14.81)
Other/unsure	9 (5.11)	12 (6.35)

Volumes both before and during an intended LTR and an event are compared (Table 6.5).

Table 6.5

Comparison of intended volumes consumed before and during an intended long training run (LTR) and an intended race, respectively for participants in the hydration survey

	Intended volume before LTR vs. intended volume before event	Intended volume during event vs. intended volume during LTR	Intended volume before event vs. intended volume during LTR	Intended volume during event vs. intended volume before event
Correlation	0.641	0.742	0.182	0.249
p value	0.0001*	0.0001*	0.0233*	0.0009*
sample size	n = 177	n = 171	n = 155	n = 173

Note: *Indicates significance

A one-sided paired t-test was run to assess if the mean differences in volumes were significant between the various scenarios (Table 6.6). A positive t-value indicates that the volume listed first is greater than the volume listed second.

Table 6.6

Differences in volumes between an intended long training run (LTR) and an intended event

One-sided paired t-test	(Intended volume before event) – (intended volume before LTR)	(Intended volume during event) – (intended volume during LTR)
t value	1.06	5.99
p value	0.1444	0.0001*
sample size	n = 177	n = 171

Note: *Indicates significance

Several questions asked runners to identify additional hydration practices for LTR's in the survey. First, 42% of runners reportedly weighed themselves before and after a run. Second, 83% of runners carried their own hydration during a LTR, while 51% said they placed fluids along their route. Of the runners that did carry their own fluid, 32% carried 1-2 cups, 23% carried 3-4 cups, and 38% carried more than 4 cups. Third, the key factors that influenced the runners' hydration plan during a LTR included weather (33%), running intensity (27%), and availability of drinks (17%). Lastly, 77% of the runners said their intended hydration practices during training generally mimic their hydration practices during an event.

The participants were asked about their typical sources of hydration information (Table 6.7). Runners were allowed to select more than one source of information.

Table 6.7

Sources of information on hydration for long-distance runners

Source	No. (%)
The running event website	67 (9.42)
Running club	46 (6.47)
Running coach	48 (6.75)
Registered Dietitian	20 (2.81)
Running friends	124 (17.44)
Personal trainer	17 (2.39)
Doctor/physician/medical professional	139 (19.55)
TV/Radio	7 (.96)
Running magazine or book	139 (19.55)
Other Internet sources	120 (16.88)
Professional organizations, such as ACSM	31 (4.36)
Research or journal articles	55 (7.74)
Other	16 (2.25)

Fifty-nine percent of the participants indicated familiarity with the term EAH. In addition, participants were asked to select from a list of contributing factors to EAH and a list of methods to prevent EAH. The majority of answers for contributing factors included “drinking too much” (21%), “temperature and humidity” (12%), “sodium or electrolyte deficit” (19%), and high intensity exercise (12%). Other responses reported were “continuous exercise lasting over 4 hours” (11%), “low intensity exercise” (2%), “not drinking enough” (2%), “extremely cool weather” (3%), “not enough training preparation for the event” (4%), “availability of drinks” (8%), “age” (5%), and “low or high body weight” (12%). The last factor, low or high body weight, or low or high BMI may increase the risk for EAH. In this sample, there were 22 runners (11%) identified to possibly be at risk for EAH based on BMI extremes of less than 20 and greater than 30 (Table 6.1).

When participants were asked to identify EAH prevention factors, the most common responses were "educating myself on this topic" (14%), knowing the "signs and symptoms" (16%), and "taking salt tablets" (16%). "Drinking according to thirst" (12%), "drinking sports drinks" (11%), and "following my hydration plan" (11%), and were also identified.

Reported race times for various distances are in Table 6.8.

Table 6.8

Reported race times for various event distances by long-distance runners

RACE (# of participants)	Mean (hrs: mins)	Range (hrs: mins)
Half marathon (201)	1:47	1:01 – 3:45
Marathon (170)	3:58	2:35 – 9:17
25K (49)	2:46	1:49 – 4:45
50K (81)	6:16	3:24 – 10:30

Discussion

In this study, intended hydration practices are assessed and compared to each other. When comparing hydration strategies between an intended training run and an event, a relatively strong agreement (73.5%) was found to be statistically significant. This indicates that runners were mostly selecting the same hydration strategy in the intended LTR and in the intended event. Thus, intentions were reported to be the same. The Theory of Planned Behavior supports the notion that intended behaviors predict actual behavior (Ajzen, 1985). The key component of the theory is that behavioral intent is influenced by the likelihood of having an expected and beneficial outcome (Ajzen, 1985). Thus, intended hydration practices should impact the actual, if a beneficial outcome is perceived by the runner. When looking at experienced runners, the agreement was basically the same at 73.0%. This is likely due to the high number of experienced runners in this sample. However, 27% of runners did not select the same hydration strategy between an intended training and an event. One explanation may be the lack of hydration knowledge. Hydration strategies should be the same for any type of long-distance run. The volumes consumed may differ but the way one drinks should be the same. As mentioned previously, 38% of runners did not feel they had a solid understanding of the safest and most effective way to hydrate for a long-distance run competition, while 93% had been told or heard of hydration on race day. In addition, the runners reported their sources of hydration information. Similar to other studies (Leggett et al., 2018; O'Neal, 2011; Williams et al., 2012), the majority of runners in the current study selected running friends, magazines, and other Internet sources, while very few selected professional organizations as key sources of information to assure strategic hydration. Unique to this study, 20% of runners did select a doctor or another medical professional as a source of hydration information. However, there seems to still be a need for further education to the long-distance running community regarding hydration.

The results indicated that the 24% of the runners chose drinking according to thirst as their intended hydration practice in training and an event. The ad libitum hydration strategy was reported at 24% during an intended LTR and 19% during an intended event. While these two practices seem similar, they are different. Drinking according to thirst is driven by a physiological drive to drink, while ad libitum means drinking according to one's pleasure (McDermott et al., 2017). Programmed or prescribed drinking was reported at 22% in the intended LTR and 24% in the intended event. Fourteen percent of the runners selected "trial and error" in both scenarios. In this study, four of the respondents indicated that they had worked with a professional and nine runners (5%) had their sweat rate measured. This is similar to the McCubbin et al. (2018) study who found only 5% reported using commercial sweat testing services and 75% thought it was beneficial. A personalized hydration plan may incorporate sweat rate and perhaps knowledge of weight loss or gain during a long run or marathon. Because sweat rate is quite variable, it is inappropriate to specify a "one size fits all" hydration plan for all runners (McDermott et al., 2017, Thomas et al., 2016). Also, 42% of the runners in this sample intended to weigh themselves before and after the race. Perhaps if strategically placed, calibrated scales were provided at all planned long-distance events, as suggested by Bennett, et al. (2020), more runners would give weighing a consideration. Having scales at events could in itself increase awareness of the importance of avoidance of EAH. Finally, in this study, 9% of the runners may be at risk for EAH based on BMI extremes, which is a BMI estimated at less than 20 or greater than 30.

When comparing volumes in both scenarios, there were moderate relationships. There was a slightly higher correlations found between the intended volumes during a LTR and an event. In addition, the volumes intended during an event were significantly greater than the LTR. Several factors may explain the discrepancy in volumes during the LTR vs. an event. One factor was the variability in the distance of long training runs. In this study, a LTR was defined as greater than ten miles. Since there is a wide variation in event distances, the volumes intended would be presumably greater the higher the mileage. Perhaps runners may not consume the same amount during training as they do in an event due to other factors, such as intensity or temperature. Typically, fluids will available during an event. Also, this study included both trail and road runners. Trail runners are more apt to carry their fluids via a hydration belt or vest. In this study, 83% of the runners intended to carry water or sports drinks during the LTR, while 70% intended to carry fluids during the running event. In summary, some differences may be explained by the increased event distance, increased availability of fluids, or even the runners' anticipated behavior changes on event day (Boullosa et al., 2019).

There was a moderate correlation when comparing intended volumes before an event and the intended volumes before a LTR. Although the intended volume before the event was greater than the volume before a LTR, it was no significant. The volumes may differ again due to the dependency on the length of the run. Also, anticipated event day preparation may impact drinking habits. In addition, in this study, 85% of runners said they drink before a LTR, while 87% intended to drink before the event. This was similar to 91.7% of participants in the London Marathon had a hydration plan for before the marathon (Williams et al., 2012). In contrast, only 43% of participants had a hydration plan for after the event.

Although 59% percent of the participants had heard of the term EAH, this does not mean that they understand the condition. Other studies had asked questions about EAH (Leggett et al., 2018; Williams et al. 2012), including an open-ended on the causes and effects of EAH. Unique to this study, two multiple choice questions were included in survey. These questions were designed to test the runners' knowledge of both contributing factors to the onset and prevention of EAH. The participants were allowed to select multiple answers for both questions. In the first question, the top three contributing factors to the onset of EAH selected were drinking too much, sodium or electrolyte deficit, and high temperatures and humidity. In another study, sodium ingestion was reported by 75% of participants to prevent EAH (McCubbin et al., 2018). While overhydration and high temperatures and humidity are main EAH factors, sodium or electrolyte deficit is still controversial as a risk factor (Bennett et al., 2020). High ambient temperatures may cause someone to overhydrate, and is a possible risk factor for EAH. The next three most frequent responses were high intensity exercise, continuous exercise over 4 hours, and availability of drinks. Both low intensity exercise and continuous exercise over four hours are also considered risk factors for EAH (Hew-Butler et al. 2017; Knechtle et al. 2019; McDermott et al., 2017; Thomas et al., 2016). The availability of drinks may contribute to the onset of EAH only if someone overdrinks. Overall, the results in this sample show the runners have some knowledge of the EAH contributing factors.

The second EAH knowledge assessment question asked participants to select ways to prevent EAH. The top responses included taking salt tablets, knowing the signs and symptoms and educating myself on this topic. The next three most frequent responses included drinking according to thirst, drinking sports drinks, and following my hydration plan While drinking according to thirst and educating myself are preventive practices, drinking sports drinks and taking salt tablets are not necessarily preventive practices (Bennett et al., 2020; Hew-Butler et al., 2017).

There are a few limitations to this study. One of the limitations is the use self-reported data. Next, this survey involved a questionnaire in which runners reported on intended behaviors, vs. actual behaviors during a racing event. Also, due to COVID-19, the survey was completed at a time that was most likely not close to an actual event. Thus, participants had to report their practices from memory of their last race. Also, the nature of recruitment for participants reflects some self-selection bias to the sample group. Because the survey was online, the participants who were interested in the topic would most likely open and complete the survey. In order to increase the number of participants, the survey was sent to several different types of groups, including those not specific to the running community. In addition, the long-distance run was defined at over ten miles to accommodate both trail and road runners. This may have been limiting in this study. Also, based on the reported experience in running volume and perhaps weekly hours of training, there may be variance in how runners define a long-distance training run. Future studies may define experience/inexperience based on more parameters. Finally, the volume averages were calculated from the mean of each volume range, based on the design of the question. Future studies may include actual volume to increase accuracy.

Conclusions

This research reports the intended hydration practices of long-distance runners, which ultimately provides insight into their actual behavior. This study compared the hydration practices of an intended long training run to an intended event. Hydration practices include volumes, strategy, types of fluids, consumption before and during an event, use of aid stations, and of hydration packs. Drinking to thirst was selected 24% of the time in each scenario. This hydration strategy is recommended to prevent EAH. Overall, this experienced sample displayed consistent hydration practices, specifically intended hydration strategies and volumes. Although awareness of EAH was high, only some of the contributing factors to the onset of EAH and preventive techniques were identified. This study suggests that more education is still essential in order to optimize hydration, performance and health in long-distance running.

CHAPTER 7. CONCLUSIONS

The primary purpose of this research was to assess and compare hydration practices of long-distance runners. The secondary purpose was to assess awareness and knowledge of EAH. This cross-sectional survey design compared hydration practices in training, an intended event, and an actual event. Optimal hydration practices will improve performance, as well as prevent EAH. Training is the time to practice for an actual event. This research expanded the concept of hydration practices and EAH to include both risk and preventive factors.

The original goal of the research was to survey marathoners associated with a specific race. Due to COVID-19, races were cancelled throughout 2020. However, the pilot study occurred before the outbreak. Also, the Connecticut rail races occurred in the fall of 2020 despite COVID-19. In addition, a survey for long-distance runners, not associated with a race, was administered. Therefore, there were three related studies within this research that targeted both road and trail long-distance runners. Each survey study was modified to accommodate the specific running group or associated race. First, the Hyannis Marathon was used as the pilot study to survey marathon runners both before and after the race. Second, long-distance trail runners from two different events in Connecticut participated in a pre-and post-race survey as well. In lieu of surveying runners from an actual race, the third survey study targeted long-distance runners. Because there was not a specific event, this study reviewed intended hydration practices for long-distance runners in general.

Each study assessed hydration practices both before and during training, an intended event, and/or an actual event, depending on the study. The definition of hydration practices was expanded to include not only hydration strategies and volumes, but also many other factors, such as the number of times the runner stopped in a race to hydrate, the carrying of a hydration pack, the type of fluids they drank before and during the run, and if they placed fluids on an actual route in advance. Due to the association with EAH risk, the hydration strategy was of upmost importance in this study. The survey included eight hydration strategy options for runners. Drinking according to thirst is recommended to prevent EAH in lieu of having a personalized or individualized plan (Bennett et al., 2020). A very small number of runners selected this as an option across all the studies.

Overall findings were categorized into volumes consumed, hydration strategy selected, and EAH knowledge. Similar results were found in each study. First, when assessing volumes consumed, higher correlations were generally found when comparing intended events in all three studies. In other words, runners intended to drink the same volumes during training and an intended event. However, there was a quite a range of correlation across all three studies indicating there was variation in volumes selected in the different scenarios. Future studies may attempt to include a way to normalize volumes reported. All studies showed agreement in the selected hydration strategies among the scenarios and most were significant. However, the researchers felt this agreement should be higher and optimally, runners should be selecting the same hydration strategy in training or an event. In assessing the hydration strategy of "drinking according to thirst", an average of 30% of the time was reported among the CT trail race runners, compared to 17% of the time for Hyannis marathoners, and 23% of the time for the long-distance runners in the general survey. Finally, EAH awareness was reported between 50-59% of the time in all studies. Although this is promising, the researchers suggest all runners should be aware and knowledgeable of EAH. Also, the selection of preventive and contributing factors did not necessarily show consistency across studies and perhaps show lack of EAH knowledge.

The main limitations of this research were the self-reported nature of the survey design and small sample size in two of the studies. Access to long-distance running events was extremely challenging during COVID-19, with the majority of events being cancelled. Also, experience of runners was defined by whether the runner had completed one long-distance run. In Hyannis, experience was defined as having completing one marathon. In the trail races, experience was defined as completing a 10-mile trail run. In the general survey, that included both road and trail runners, experience was defined as completing a 10-mile run. The definitions of experience may be limiting. There were several survey questions related to a runners' experience, other than distance. Training hours per week, volume of running, and potentially race times are factors in running experience. For future research, categories of experience may be created to include several factors (Yates et al., 2018).

Overall, the approach was novel and meaningful results were found in the three studies. More education on optimal hydration practices and EAH is necessary for long-distance runners to improve both performance and health, and prevent EAH.

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APPENDIX A. RUNNER'S SCIENCE SURVEY (MOHSENI ET AL. 2011)

MAYO CLINIC

Runners' Science Survey

Identifying Data

1.	Name:	
2.	DOB:	/ /
3.	Email:	
4.	Phone #:	
5.	Bib #:	
6.	Height:	ft in
7.	Weight:	lbs
8.	Gender:	☐ Male ☐ Female
9.	Race:	☐ Asian ☐ Black
		☐ Caucasian ☐ Other ________
	Ethnicity:	☐ Hispanic ☐ Not Hispanic

Health Factors

10.	Have you had any running-related injury or injuries within the PAST YEAR?	Yes ☐	No ☐
11.	If YES, please specify location (Check all that apply. Please DO NOT include blisters or cramping.):	☐ lower back ☐ hip ☐ upper leg/thigh ☐ knee ☐ lower leg/tibia ☐ ankle ☐ foot ☐ toenail loss ☐ other: ________ ________	
12.	Approximately how long ago was the most recent injury?	days	
13.	Have you had any prior orthopedic surgery?	Yes ☐	No ☐
14.	If yes, indicate type:		
15.	Do you take joint supplements on a regular basis?	Yes ☐	No ☐
16.	Do you take an NSAID (Motrin, Advil, Ibuprofen, Aspirin, Aleve) on a regular basis?	☐	☐
17.	Do you have a history of breast cancer?	☐	☐
18.	If yes, is cancer active?	☐	☐
19.	If yes, are you currently receiving chemo or radiation?	☐	☐

Training

20.	Which event are you racing?	☐ Full Marathon ☐ Half Marathon		
21.	Number of Previous:	____ Full Marathons ____ Half Marathons		
22.	Longest training run in the 3 months prior to this race:	miles		
23.	Peak weekly mileage in the 3 months prior to this race:	miles/wk		
24.	Typical number of days/week you ran during training:	days/wk		
25.	How many training runs did you complete that were ≥ 20 miles?			
26.	Number of years you have been running regularly:	years		
27.	Miles/week you were running *before* start of training for this event:	miles/wk		
28.	Did you use a training program?	Yes ☐	No ☐	
	If yes, which one?			

		Regularly	Sometimes	Never
29.	Do you warm-up or stretch prior to running?	☐	☐	☐
30.	Do you strength or weight train?	☐	☐	☐
31.	Do you cross train (bike, swim, etc.)?	☐	☐	☐
32.	Do you participate in other sports?	☐	☐	☐
33.	Did you train on: Hilly terrain?	☐	☐	☐
34.	Trails?	☐	☐	☐
35.	Sand or beach?	☐	☐	☐
36.	In the dark?	☐	☐	☐
37.	At altitude?	☐	☐	☐
38.	In what state did you train primarily?			

39. If you experienced an injury or injuries within the PAST YEAR to what do you attribute this? (Check all that apply.)

☐ Too many long runs OR ☐ Too few long runs

☐ Tempo or speed work (shorter faster runs)

☐ Terrain. Indicate type: ________________

☐ Running too many miles too soon in training

☐ Shoes ☐ Other: ________________

40. What part of your foot do you land on when running?

☐ Heel ☐ Midfoot ☐ Forefoot

Page 1 of 2

MAYO CLINIC

RESEARCH STAFF ONLY			
	Research Staff Initials:		
		YES	NO
1.	Race completed:	☐	☐
2.	Release of Information signed:	☐	☐
3.	HIPAA Waiver signed:	☐	☐
4.	If race completed, race time and pace:	hrs mins secs	min/miles

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From Mohseni. Used with permission.

APPENDIX B. FOLLOWUP MAIL SURVEY 2011 (MOHSENI ET AL., 2011)

Recently you took part in a Mayo Clinic research study of runners participating in the Annual National Marathon to Fight Breast Cancer in Jacksonville, Florida. As part of your participation, we explained that we may be contacting you in the future to discuss your race outcome and information about any injuries you may have sustained during the race and your recovery. The survey below should not take more than 5 minutes to complete

1. "Did you finish the event that you were registered for?" ☐ Yes ☐ No

   "If no, please explain: ____________________

2. "Did you experience any race-related injuries during the event or in the days after the race?" ☐ Yes ☐ No

   IF YES, please answer (a), (b), (c), and (d) below:

   a. "Please specify location (check all that apply).
   Please DO NOT include blisters or cramping."

DURING THE RACE	DAYS AFTER THE RACE
☐ Lower back	☐ Lower back
☐ Hip	☐ Hip
☐ Upper leg/thigh	☐ Upper leg/thigh
☐ Knee	☐ Knee
☐ Lower leg/tibia	☐ Lower leg/tibia
☐ Ankle	☐ Ankle
☐ Foot	☐ Foot
☐ Toenail loss	☐ Toenail loss
☐ Other: ____________	☐ Other: ____________

   b. "If you experienced an injury or injuries, to what do you attribute this/these? (Check all that apply.)"
   - ☐ Too many long runs *OR* ☐ Too few long runs
   - ☐ Tempo or speed work (shorter faster runs)
   - ☐ Terrain (Please indicate type, i.e. hills, concrete, trails, etc.)
     Type: ______________
   - ☐ Running too many miles too soon in training
   - ☐ Shoes
   - ☐ Other: ______________

   c. "Were you evaluated by a healthcare provider for this/these injury(ies)?" ☐ Yes ☐ No

      i. What type of provider did you see? (Check all that apply.) ☐ Urgent Care ☐ ER ☐ Primary Care ☐ Other Type: ________

   d. "Were you admitted to the hospital for your injuries?" ☐ Yes ☐ No

3. “Do you have any comments, questions or concerns about your participation in this study?”

☐ Yes ☐ No

a. ____
____
____

Thank you for taking the time to complete this survey for the Marathon Research Study. We know your time is valuable and we appreciate your effort and congratulate you for your participation in the National Marathon to Fight Breast Cancer and hope to see you at next year’s race!

APPENDIX C. ENDURANCE 1 ATHLETE QUESTIONNAIRE (MCCUBBIN ET AL. 2019)

Endurance Athlete Questionnaire

Demographics

Q1 What is your sex? Male Female

Q2 What is your age in years? ______________

Q3 Which sport/sports do you currently train and compete in? ________________________

Q4 For how many years have you been competing in endurance sports? ______________

Q5 How would you best describe yourself and your level of training?

Professional athlete, training regularly

Aspiring professional athlete, training regularly

Actively competitive age group athlete, training regularly

Interest in general health and fitness, training regularly

Interest in general health and fitness, training sometimes

Sodium Information Sources

Q26 From the following list, please select any individual(s) or information sources that have influenced whether you choose/do not choose to consume a certain amount of sodium or sodium containing products relating to your endurance training or competition (*please tick all responses that apply to you – more than one answer is allowed).*

I've never considered the use of sodium with sport

Doctor/Physician Pharmacist Dietitian or Nutritionist

Coach Trainer Manager

Parent Relative Fellow athlete

Friend Health food store attendant

TV/radio Journal Articles

Food &/or supplement company advertising

Magazines Internet Self researched/experimented

Other ____

Intended Practices

Q27 In the days leading up to a race (that will have a duration of more than 2 hours), would you aware of consuming a certain amount of salt/sodium from food, fluids or supplements?

Yes No

Sometimes (please provide comments) _____________________________________

Q28 Would you plan to eat more, less or the same amount of salt/sodium in the days leading up to a race compared to day-to-day when you are training

I would plan to consume MORE sodium in the days before a race compared to when I'm training

I would plan to consume THE SAME AMOUNT of sodium in the days before a race compared to when I'm training

Q29 How long before a race (that will have a duration of more than 2 hours) would you be aware of consuming a certain amount of sodium from food, fluids or supplements (answer can be in hours, days or weeks)? ____________________________

Q30 What foods, drinks or supplements do you plan to consume to increase the amount of salt/sodium in the lead up to a race? (can choose more than one)

Eat more regular foods that are higher in salt/sodium

Adding salt (table salt, sea salt, rock salt, etc.) to food/drinks

Sports, rehydration or other electrolyte drinks (bottled)

Sports, rehydration or other electrolyte drinks (made from powder)

Sports, rehydration or other electrolyte drinks (dissolvable tablets)

Salt/electrolyte capsules or tablets

Other – please specify: ____

Q31 Regardless of sodium, would the overall amount of food you plan to eat change in the days leading in to an endurance race or competition, compared to your day-to-day diet in training?

I would eat MORE food overall

I would eat LESS food overall

I would eat about THE SAME amount of food overall

Q32 DURING a race (that will have a duration of more than 2 hours), would you be aware of consuming sodium from food, fluids or supplements?

Yes No

Sometimes (please provide comments) ____

Q33 How much sodium would you aim to take (can answer in milligrams (mg) OR amounts of certain foods and drinks OR based on a percentage of expected losses)?

Specify amount here ____, OR

I'm not sure

Q34 Please tick all of the sodium-containing products you are planning to consume immediately before and during your next race/event

The sports drink provided by the race organisers

The gels provided by the race organisers

The energy bars/chews provided by the race organisers

My own sports drink (sold as a sports product, not a rehydration products)

My own rehydration drink (sold as a rehydration formula, not a sports product)

My own dissolvable electrolyte tablets

Salt or electrolyte tablets/capsules

My own homemade drink formula (please provide details if possible)

Energy gels I purchased myself

Energy bars/chews I purchased myself

Coconut water (plain or flavoured)

Vegemite sandwich

Other ____

Commercial Sweat Testing Experiences

Q35 Have you PREVIOUSLY had your sweat tested to measure the amount of salt/sodium/electrolytes in it (not including research studies)?

Yes No

Q36 If yes, what was your main goal or motivation for having your sweat tested (can choose more than 1 answer)?

To improve my performance in training and/or competition

To reduce the risk of muscle cramping during training and/or competition

To reduce the risk of hyponatremia during training and/or competition

Other: ____

Q37 Do you feel that the results of your sweat test allowed you to better reach the goal/s stated in question 24 (above)?

Yes No Not Sure

APPENDIX D. SURVEY QUESTIONS (CHLIBKOVA ET AL., 2017)

“Have you ever heard how much you should drink prior to, during and after the race?”

“If so, where did you get the information?” Not compared*

“Do you have any plan for your fluid intake before the race?”

“If yes, how much?” (with a specification 1 h before the race)

“Do you have any plan for your fluid intake during the race?”

“If yes, how much?” (with a specification during the whole race)

“Do you have any plan for your fluid intake after the race?”

“If yes, how much?” (with a specification 1 h after the race)

“What affects your drinking strategy during the race?”

“Have you ever heard about hyponatremia?”

“Do you know the causes and consequences of hyponatremia?”

“Do you drink only sports drinks, just water or both?”

“Do you plan to drink at the fluid station during the race?”

“Do you know the volume of the drinks which are offered at the fluid station?”

“Do you run/ride with your own fluids?”

APPENDIX E. LONDON MARATHON SURVEY (LEGGETT ET AL., 2018)

Appendix. Questionnaire[a] Continued on Next Page

Many thanks for taking part in this questionnaire. If you are not clear about any of the questions, please feel free to ask the researcher. Please answer the questions in order by putting a tick in the box or writing an answer on the line.

Background information about you as a runner:

1) Is this your first marathon?
   Yes _____ (and if Yes, please go to question 3)
   No _____
   If this is not your first marathon, how many previous marathons have you run? (please tick)
   1 _____
   2–4 _____
   5–9 _____
   10 or more marathons _____
2) What is your fastest time? _____h _____min
3) What is your estimated finishing time? _____h _____min
4) Are you running on behalf of a charity?
   Yes _____
   No _____
   If Yes, which charity? ____
5) Are you a member of a Running club?
   Yes _____
   No _____
6) Gender:
   Male _____
   Female _____
7) Age: _____y
8) How tall are you? _____
9) What is your weight? _____

Information on drinking on marathon day:

10) Have you read about or been told about drinking fluids on marathon day?
   Yes _____
   No _____ (if No, please go to question 11)
   If Yes, where have you received this information from? (please tick all that apply)
   London Marathon magazine _____
   London Marathon Web site _____
   Running club _____
   Running coach _____
   Running friends _____
   Running magazine _____ (if so, which magazine?) ___________________
   Running book _____ (if so, which book?) _______________________
   From the charity for which you are running _____
   Other sources of information (please specify; eg, other online source, smartphone app, library book etc)
   ____

Before the marathon:

11) Do you have any plans about drinking in the morning before the start of the marathon?
Yes _____
No _____ (if No, please go to question 15)
12) If Yes, what are you planning to drink? _____________________________
13) How much are you planning to drink? ______________________________
14) When are you planning to drink this? ______________________________

During the marathon:

15) Do you have any plans about drinking during the race?
Yes _____
No _____ (if No, please go to question 19)
16) If Yes, what are you planning to drink? _____________________________
17) How much are you planning to drink? ____________________________
18) At what stages of the race are you planning to drink?
____
____
19) Some people carry their own drinks from the start of the race – do you intend to do that?
Yes _____
No _____ (if No, please go to question 25)
20) If Yes, what drink will you carry? _______________________________
21) What volume will you carry? __________________________________
22) Do you plan to drink water provided in bottles at water stations during the race?
Yes _____
No _____ (if No, please go to question 25)
23) If yes, at how many water stations will you take bottles of water? _____
24) How much of each bottle do you anticipate that you will drink?
A few sips _____
Several mouthfuls _____
Half the bottle _____
Most or all of the bottle _____
25) Do you plan to drink the sports drink (Lucozade) provided at the drink stations during the race?
Yes _____
No _____ (if No, please go to question 28)
26) If Yes, at how many drink stations will you take a sports drink? _____
27) How much of each pack do you anticipate that you will drink?
A few sips _____
Several mouthfuls _____
Half the pack _____
Most or all of the pack _____
28) What is the volume of each water bottle given out on the course?
(please estimate if you don't know exactly) _____mls
29) What is the volume of each pack of sports drinks given out on the course?
(please estimate if you don't know exactly) _____mls
30) What factors may affect how much you drink in order of importance?
(please mark '1' for the most important for you, '2' for the second, '3' for the third most important and '4' for the least important)
My plan _____
How thirsty I feel _____
The temperature on race day _____
Other (please specify) _____________________________
31) Have you practised drinking water during your training?
Yes _____
No _____
32) Have you practised drinking a sports drink during your training?
Yes _____
No _____

After the marathon:

33) Do you have any plans about drinking in the 6 hours after the marathon?
Yes _____
No _____ (if No, please go to question 37)
34) If Yes, what are you planning to drink? _____________________________
35) How much are you planning to drink? ____________________________
36) How often are you planning to drink? ____________________________

Appendix. Continued From Previous Page

Information about fluids:

37)	Do you feel that you know enough about what and how much to drink on marathon day? Yes _____ No _____ If No, what would help you to be better informed for future races? ____ ____
38)	Have you heard of the term 'hyponatraemia' (low salt or sodium levels) Yes _____ No _____ If Yes, what is your understanding of its causes and effects? ____ ____
39)	Do you have any other comments about drinking fluids on marathon day? ____ ____

Many thanks for completing this questionnaire. Please return it to the researcher.

[a] The questionnaire is reproduced in its original form except that underlined spaces replaced boxes for answers.

APPENDIX F. HYANNIS PRE-RACE SURVEY

A. Please answer **<u>all</u>** questions to the best of your ability. You will not be able to "backtrack". Please note that the survey will not move ahead until an answer has been selected. If you are unsure of an answer, please select "unsure." Please note that ***one cup equals 8 ounces or 237 ml*** for all questions, unless the question indicates otherwise. Thank you.

The picture below is a reminder of an 8 ounce measuring cup and a seven ounce dixie cup.

B. **Demographic Information**

1. What is your age in years?
    a. Less than 18 (IF LESS THAN AGE 18, THE SURVEY WILL END)
    b. 18-24
    c. 25-39
    d. 40-64
    e. 65 and older

2. What is your sex?
    a. Male
    b. Female
    c. Prefer not to answer

3. Additional Information
    a. Indicate Highest Level of Education Completed

1. Some high school or less
2. Graduated high school
3. Trade or technical school
4. Some college
5. Graduated college
6. Graduate school
7. Prefer not to answer

b. Marital Status
    1. Single
    2. Married
    3. Divorced
    4. Widowed
    5. Domestic partnership
    6. Prefer not to answer

c. Level of Income
    1. < $25,000
    2. $25,000 - $49,999
    3. $50,000 - $74,999
    4. > $75,000
    5. Prefer to not answer

d. Racial and Ethnic Category
    1. African American or Black
    2. American Indian or Alaskan Native
    3. Asian or Pacific Islander
    4. Latino or Hispanic
    5. Mixed Race
    6. White
    7. Another ethnic background
    8. Prefer not to answer

C. Running Experience

3. Is this your first marathon? YES/NO; if yes, go to question **6**.

4. If this is not your first marathon, how many prior marathons have you run?
    a. 1
    b. 2-4
    c. 5-9
    d. 10 or more

5. What is your fastest marathon time? _______ hours _______ minutes ______not sure

6. What time are you expecting to finish the marathon? ________hours______minutes________ Not sure ______

7. Are you running on behalf of a charity? YES/NO

8. Are you a member of a running club? YES/NO

9. How tall are you? _______feet ______ inches

10. How much do you weigh? _______pounds

11. How would you best describe yourself and level of training? Please select one:
    a. Professional or elite athlete
    b. Aspiring professional athlete, training regularly
    c. Actively competitive in age group athlete, training regularly
    d. Interest in general health and fitness, training regularly
    e. Interest in general health and fitness, training sometimes
    f. Other ____

12. What are your total training hours per week on average? Please include any cross training.
    a. Under 5 hours
    b. 5-8 hours
    c. 8-10 hours
    d. Greater than 10

D. Sources of information on hydration

13. Have you read or been told about drinking fluids on marathon day? YES/NO (if NO, please go to question **15)**

14. If yes, where have you received this information? (please check all that apply)
    a. The running event website
    b. Running club
    c. Running coach
    d. Registered Dietitian
    e. Running friends
    f. Personal trainer
    g. Doctor/Physician/another medical professional
    h. TV/Radio
    i. Running magazine or book

j. Other Internet sources
k. Professional organizations, such as the American College of Sports Medicine, or the National Association of Athletic Training
l. Research or journal articles
m. Other ______________________________

E. *Intended* hydration practices during a long training run (assume a long training run is > 15 miles)

15. Do you generally intend to drink ***before*** the start of a long training run? YES/NO (if NO, please go to question **19**)

16. If yes, what do you drink ***before*** a long training run? (check all that apply
    a. Water ______
    b. Sports drinks _____
    c. Coffee ______
    d. Other____

17. When are you planning to do this? (choose all that apply)
    a. 3-4 hours before training run
    b. 2-3 hours before training run
    c. 1-2 hours before training run
    d. Less than one hour before training
    e. Other _________________________

18. How much do you intend to drink ***before*** your long training run in total? (**ONE CUP = 8 OUNCES or 237 ML**)
    a. 1-2 cups
    b. 3-5 cups
    c. More than 5 cups
    d. I do not intend to hydrate before a training run

19. Do you intend to drink ***during*** your long training run? YES/NO (if no, go to question **23**)

20. If yes, what do you intend to drink ***during*** the long run?
    a. Water only
    b. Sports drinks only
    c. Water and sports drinks
    d. Other____

21. How much do you intend to drink ***during*** your long training run (> than 15 miles) in total fluid? (**ONE CUP = 8 OUNCES, or 237 ML**)
    a. 1-3 cups
    b. 4-6 cups
    c. 7-9 cups
    d. 10-12 cups
    e. > 12 cups
    f. Other_______

22. What is your *intended* hydration plan ***during*** a long training run (> than 15 miles)?
    a. I do not have one
    b. I drink according to thirst (thirst tells me when to drink)
    c. I drink ad libitum (when I feel like it)
    d. I follow programmed drinking (for example, I always drink 1 cup/hr)
    e. I have a personalized hydration plan (is one that has been defined by a professional); if YES,
        a. Did you work with a Registered Dietitian? YES/NO
        b. Did you work with another professional? YES/NO
    f. I base my intended hydration plan on trial and error over time
    g. Other ____

23. Did you ever have your sweat rate measured? YES/NO (If NO, please go to question **25**)

24. If you have had it measured, what is your sweat rate?
    a. 0.5-1.0 Liters/hr
    b. 1.0 – 2.0 Liters/hr
    c. 2.0 -3.0 Liters/hr
    d. 3.0 – 4.0 Liters/hr
    e. > 4.0 Liters/hr

25. Do you ever weigh yourself before and after a run? YES/NO

26. What influences your hydration plan during a long training run (> 15 miles)? Please check all that apply:
    a. Weather
    b. Running intensity
    c. People I am running with
    d. Availability of drinks
    e. Pain or cramping
    f. Because I am supposed to
    g. Other____

27. Do you carry your own water or sports drinks when completing a long training run (> than 15 miles)? YES/NO. (if no, go to question **29**)

28. What volume will you carry? (**ONE CUP = 8 OUNCES or 237 ML**)
    a. 1-2 cups
    b. 3-4 cups
    c. More than 4 cups
    d. Other ________________________________

29. Do you ever have water or fluids placed along your training route? YES/NO

30. Will your *intended* hydration practices during training generally mimic your *intended* hydration practices during an event? YES/NO

F. *Intended* hydration practices on marathon event day

31. Do you have plans to drink ***before*** the start of the event? YES/NO (if no, please go to question **35**)

32. If yes, what are you planning to drink? (please check all that apply)
    a. Water
    b. Sports drinks
    c. Coffee
    d. Other____

33. When are you planning to do this? (please check all that apply)
    a. 3-4 hours before the event
    b. 2-3 hours before event
    c. 1-2 hours before event
    d. Less than one-hour event
    e. Other ____

34. About how much do you intend to drink (total fluids) ***before*** the marathon? (**ONE CUP = 8 OUNCES or 237 ML**)
    a. 1-2 cups
    b. 3-5 cups
    c. More than 5 cups
    d. I do not intend to hydrate before the event
    e. Unsure

35. Do you intend to drink ***during*** the marathon? YES/NO (if no, go to question **45**)

36. What is your *intended* hydration plan ***during*** a marathon?
    a. I do not have one
    b. I drink according to thirst (thirst tells me when to drink)
    c. I drink ad libitum (when I feel like it)
    d. I follow programmed drinking (i.e. I always drink 1 cup per hour)
    e. I have a personalized plan (a professional has helped me to create)
        a. Did you work with a Registered Dietitian YES/NO
        b. Did you work with another professional? YES/NO
    f. I base my hydration plan on “trial and error” from my experiences over time
    g. Other ____

37. How much do you intend to drink in total ***during*** the marathon? (**ONE CUP = 8 OUNCES OR 237 ML)**
    a. 1-3 cups
    b. 4-6 cups
    c. 7-9 cups
    d. 10-12 cups
    e. More than 12 cups
    f. Unsure

38. What influences your hydration plan during a marathon event? Please check all that apply.
    a. Weather
    b. Running intensity
    c. People I am running with
    d. Availability of drinks
    e. Pain or cramping
    f. Because I am supposed to
    g. Other____

39. What do you intend to drink during the marathon? (Please check all that apply)
    a. Water
    b. Sports drinks
    c. Water and sports drinks
    d. Other____

40. Do you intend to slow down or stop at hydration stations provided during the race? YES/NO (if NO, go to question **41**).

41. If yes, about how many times do you intend to slow down or stop at a hydration station?
    a. 1-2 stations

b. 3-5 stations
c. 6-8 stations
d. 8-10 stations
e. 11 or greater stations
f. All stations
g. Unsure

42. On average, how much do you intend to drink at ***each*** hydration station? (cup sizes may vary, please estimate: **(ONE CUP = 8 OUNCES or 237 ML)**
    a. A few sips
    b. Several mouthfuls
    c. Half the cup
    d. Most of the cup
    e. More than one cup

43. Do you intend to carry your own water/sports drinks? YES/NO. (If no, go to question **45**)

44. What volume will you carry? (**ONE CUP = 8 OUNCES or 237 ML**)
    a. 1-2 cups
    b. 3-5 cups
    c. More than 5 cups
    d. Other

G. ***Intended* hydration practices *after* the marathon?**

45. Do you have a specific hydration plan for ***after*** the event? YES/NO (if NO, please go to question **46)**.
    a. I intend to drink as much as possible
    b. I have a specific hydration plan
    c. I will drink according to thirst
    d. I will drink ad libitum (when I feel like it)
    e. Other____
    f. Unsure

H. Knowledge of EAH (Exercise-associated hyponatremia)

46. Have you heard of the term exercise-associated-hyponatremia, or EAH? YES/NO (if NO, please go to question **49**)

47. What are some of the contributing factors to the onset of EAH? Please select all that apply.
    a. High intensity exercise

b. Low intensity exercise
c. Drinking too much
d. Not drinking enough
e. High temperatures & humidity
f. Extremely cool weather
g. Continuous exercise lasting over 4 hours
h. Not enough training preparation for the event
i. Availability of drinks (water and sports drinks)
j. Low or high body weight
k. Sodium or electrolyte deficit
l. Other ____

48. Do you know how to prevent EAH? Please check all that apply.
    a. Drinking according to thirst
    b. Drinking sports drinks
    c. Avoiding high intensity exercise
    d. Dressing appropriately for the weather
    e. Following my hydration plan
    f. Taking salt tablets
    g. I am not sure how to prevent EAH
    h. Educating myself on this topic
    i. Other____

49. Do you feel you have a solid understanding of the safest and most effective way how to hydrate for a marathon? YES/NO

50. Do you have any other comments that you would like to add on hydration during a marathon, or your personal hydration plan?
    ____
    ____

51. Please add your optional contact information so that we can send you the follow-up post-race survey
    a. Email ____
    b. Confirm mail____

Thanks for completing this questionnaire. Your input is important and valued. **If you provide your email, you will be emailed a post-race survey to assess how much you did drink during the marathon. Without directly measuring what you drank, please attempt to keep a mental total of how much you drank during the marathon.**

APPENDIX G. HYANNIS POST RACE SURVEY

A. Hydration practices on marathon event day (please note ONE CUP = 8 OUNCES or 237 ML)

1. Did you drink ***before*** the start of the event? YES/NO (if no, go to question **5**)

2. If yes, what did you drink? (Please check all that apply).
    a. Water
    b. Sports drinks
    c. Coffee
    d. Other ____

3. When did you drink ***before*** the marathon? (Please check all that apply)
    a. 3-4 hours before the event
    b. 2-3 hours before the event
    c. 1-2 hours before the event
    d. Less than one hour before the event
    e. Other____

4. About how many cups did you drink ***before*** the marathon? (**ONE CUP = 8 OUNCES or 237 ML**)
    a. 1-2 cups
    b. 3-5 cups
    c. More than 5 cups
    d. I do not intend to hydrate before the race

5. Did you drink ***during*** the marathon? YES/NO (if NO, go to question **16**)

6. What was your hydration plan ***during*** the marathon?
    a. I did not have one
    b. I drank according to thirst (thirst tells me when to drink)
    c. I drank ad libitum (when I feel like it)
    d. I followed programmed drinking (i.e. I always drink 1 cup per hour)
    e. I had a personalized plan
        1. Did you work with a Registered Dietitian? YES/NO
        2. Did you work with another professional? YES/NO
        3. Did you have your sweat rate measured? YES/NO
    f. I based my hydration plan on "trial and error" from my experiences over time
    g. Other ____

7. About how much total fluid did you drink ***during*** the marathon? (**ONE CUP = 8 OUNCES or 237 ML**). Estimate as close as possible.
    a. 1-3 cups
    b. 4-6 cups
    c. 7-9 cups

d. 10-12
e. More than 12 cups
f. Other____

8. What influenced your hydration plan during the marathon? Please check all that apply.
   a. Weather
   b. Running intensity
   c. People I am running with
   d. Availability of drinks
   e. Pain or cramping
   f. Because I am supposed to
   g. Other____

9. If yes, what did you drink?
   a. Water
   b. Sports drinks
   c. Water and sports drinks
   d. Other ____

10. Did you slow down or stop at hydration stations provided during the course? YES/NO (if NO, go to question **13**)

11. About how many times did you slow down or stop at the hydration stations during the course?
    a. 1-2 stations
    b. 3-5 stations
    c. 6-8 stations
    d. 9-11 stations
    e. Greater than 11 stations
    f. All stops
    g. Unsure

12. Approximately how much did you drink at each hydration stop?
    a. A few sips
    b. Several mouthfuls
    c. Half the cup
    d. Most of the cup
    e. More than one cup
    f. Other ____

13. Do you carry your own water/sports drinks? YES/NO. (if no, go to question **16**)

14. What type of drink(s) did you carry? (check all that apply)
    a. Sports drinks
    b. Water

c. Both sports drinks and water
d. Other (please specify) ___________________________________

15. What volume of drinks did you carry? (**ONE CUP = 8 OUNCES or 237 ML**)
    a. 1 cup
    b. 2-5 cups
    c. More than 5 cups
    d. Other _____________________________________

B. Hydration practices after the marathon

16. Did you follow your hydration plan ***during*** the marathon? YES/NO

17. Did you follow your post-race hydration plan? YES/NO

18. Did you weigh yourself before and after the marathon? YES/NO (If NO, please go to question 21).

19. If yes, did you gain or lose weight? GAIN/LOSE

20. If you gained or lost weight, please indicate the amount of weight gain or lost.
    a. 1-2 lb. difference
    b. 2-4 lb. difference
    c. 4-6 lb difference
    d. 6-8 lb difference
    e. > 8 lb difference
    f. Other ___________________________________

21. Did you have any specific symptoms during or after the marathon? Please check all that apply.
    a. Nausea
    b. Vomiting
    c. Lightheadedness
    d. Headaches
    e. Weight gain
    f. Other____

22. Is there any other information that you would like to share that would help us to understand your race-related hydration plan and actions?
    ____
    ____
    ____

Thanks for completing this survey and participating in the research.

APPENDIX H. HYANNIS WEBSITE

Attention Marathon Runners:

Please participate in a brief survey on intended and actual hydration patterns in marathon running, and on the understanding of Exercise Associated Hyponatremia. A local doctoral student (lives in Hull), Suzanne Young, from North Dakota State University (NDSU) is conducting this survey and we have elected to be her pilot study. You will receive an email in the next few days. The instructions will be in the email. Your identity is not shared with anyone. Your completion of the survey will be very much appreciated and will contribute to this area of research.

APPENDIX I. CONNECTICUT TRAIL RUN PRE-RACE SURVEY

A. Hydration practices on marathon event day (please note ONE CUP = 8 OUNCES or 237 ML)

1. Did you drink ***before*** the start of the event? YES/NO (if no, go to question **5**)

2. If yes, what did you drink? (Please check all that apply).
   a. Water
   b. Sports drinks
   c. Coffee
   d. Other ____

3. When did you drink ***before*** the marathon? (Please check all that apply)
   a. 3-4 hours before the event
   b. 2-3 hours before the event
   c. 1-2 hours before the event
   d. Less than one hour before the event
   e. Other____

4. About how many cups did you drink ***before*** the marathon? (**ONE CUP = 8 OUNCES or 237 ML**)
   a. 1-2 cups
   b. 3-5 cups
   c. More than 5 cups
   d. I do not intend to hydrate before the race

5. Did you drink ***during*** the marathon? YES/NO (if NO, go to question **16**)

6. What was your hydration plan ***during*** the marathon?
   a. I did not have one
   b. I drank according to thirst (thirst tells me when to drink)
   c. I drank ad libitum (when I feel like it)
   d. I followed programmed drinking (i.e. I always drink 1 cup per hour)
   e. I had a personalized plan
      1. Did you work with a Registered Dietitian? YES/NO
      2. Did you work with another professional? YES/NO
      3. Did you have your sweat rate measured? YES/NO
   f. I based my hydration plan on "trial and error" from my experiences over time
   g. Other ____

7. About how much total fluid did you drink ***during*** the marathon? (**ONE CUP = 8 OUNCES or 237 ML**). Estimate as close as possible.
   a. 1-3 cups
   b. 4-6 cups
   c. 7-9 cups

d. 10-12
e. More than 12 cups
f. Other____

8. What influenced your hydration plan during the marathon? Please check all that apply.
   a. Weather
   b. Running intensity
   c. People I am running with
   d. Availability of drinks
   e. Pain or cramping
   f. Because I am supposed to
   g. Other____

9. If yes, what did you drink?
   a. Water
   b. Sports drinks
   c. Water and sports drinks
   d. Other ____

10. Did you slow down or stop at hydration stations provided during the course? YES/NO (if NO, go to question **13**)

11. About how many times did you slow down or stop at the hydration stations during the course?
    a. 1-2 stations
    b. 3-5 stations
    c. 6-8 stations
    d. 9-11 stations
    e. Greater than 11 stations
    f. All stops
    g. Unsure

12. Approximately how much did you drink at each hydration stop?
    a. A few sips
    b. Several mouthfuls
    c. Half the cup
    d. Most of the cup
    e. More than one cup
    f. Other ____

13. Do you carry your own water/sports drinks? YES/NO. (if no, go to question **16**)

14. What type of drink(s) did you carry? (check all that apply)
    a. Sports drinks
    b. Water

c. Both sports drinks and water
d. Other (please specify) ____________________________________

15. What volume of drinks did you carry? (**ONE CUP = 8 OUNCES or 237 ML**)
    a. 1 cup
    b. 2-5 cups
    c. More than 5 cups
    d. Other ______________________________________

B. Hydration practices after the marathon

16. Did you follow your hydration plan ***during*** the marathon? YES/NO

17. Did you follow your post-race hydration plan? YES/NO

18. Did you weigh yourself before and after the marathon? YES/NO (If NO, please go to question 21).

19. If yes, did you gain or lose weight? GAIN/LOSE

20. If you gained or lost weight, please indicate the amount of weight gain or lost.
    a. 1-2 lb. difference
    b. 2-4 lb. difference
    c. 4-6 lb difference
    d. 6-8 lb difference
    e. > 8 lb difference
    f. Other ____________________________________

21. Did you have any specific symptoms during or after the marathon? Please check all that apply.
    a. Nausea
    b. Vomiting
    c. Lightheadedness
    d. Headaches
    e. Weight gain
    f. Other____

22. Is there any other information that you would like to share that would help us to understand your race-related hydration plan and actions?
    ____
    ____
    ____

Thanks for completing this survey and participating in the research.

APPENDIX J. CONNECTICUT TRAIL RUN POST-RACE SURVEY

Thanks for filling out the survey before the trail running event in September. The following questions will help us understand if your planned hydration was implemented during the actual event. ***Congratulations on finishing the race!***

As a reminder, please answer **<u>all</u>** questions to the best of your ability. You will not be able to "backtrack". Please note that the survey will not move ahead until an answer has been selected. If you are unsure of an answer, please select "unsure." Please note that ***one cup equals 8 ounces or 237 ml*** for all questions, unless the question indicates otherwise. Keep in mind one liter is equal to about 4 cups. Also, please note the volume of your hydration pack. It is most likely in liters. ***Thank you.***

A. Hydration practices on event day (please note ONE CUP = 8 OUNCES or 237 ML).

1. Did you drink ***before*** the start of the event? YES/NO (if no, go to question **5**)

2. If yes, what did you drink? (Please check all that apply).
   a. Water
   b. Sports drinks
   c. Coffee/tea
   d. Other ____

3. When did you drink ***before*** the event? (Please check all that apply)
   a. 3-4 hours before the event
   b. 2-3 hours before the event
   c. 1-2 hours before the event
   d. Less than one hour before the event
   e. Other____

4. About how many cups did you drink ***before*** the event? (**ONE CUP = 8 OUNCES or 237 ML**)
   a. 1-2 cups (8 – 16 oz)
   b. 3-5 cups (24 – 40oz)
   c. More than 5 cups (40oz)
   d. I do not intend to hydrate before the race
   e. Other ____

5. Did you drink ***during*** the event? YES/NO (if NO, go to question **16**)

6. If yes, what did you drink?
    a. Water
    b. Sports drinks
    c. Water and sports drinks
    d. Other ____

7. What was your hydration plan ***during*** the event?
    a. I did not have one
    b. I drank as much as possible
    c. I drank according to thirst (thirst tells me when to drink)
    d. I drank ad libitum (when I felt like it)
    e. I followed programmed drinking (i.e. I always drink 1 cup per hour)
    f. I had a personalized hydration plan (IF YES,)
        1. Did you work with a Registered Dietitian? YES/NO
        2. Did you work with another professional? YES/NO
        3. Did you calculate my own personalized hydration plan? YES/NO
    g. I based my hydration plan on "trial and error" from my experiences over time
    h. Other ____

8. About how much total fluid did you drink ***during*** the event? (**ONE CUP = 8 OUNCES or 237 ML**). Estimate as close as possible.
    a. 1-3 cups (8 – 24 oz)
    b. 4-6 cups (32 - 48oz)
    c. 7-9 cups (56 – 72 oz)
    d. 10-12 cups (80 – 96 oz)
    e. More than 12 cups (96 oz)
    f. Other____

9. What influenced your hydration practices during the event? Please check all that apply.
    a. Weather
    b. Running intensity
    c. People I ran with
    d. Availability of drinks
    e. Pain or cramping
    f. Because I am supposed to
    g. Other____

10. Did you slow down or stop at the aid stations provided during the course? YES/NO (if NO, go to question **13**)

11. About how many times did you slow down or stop at the aid stations during the course?
    a. 1-2 times
    b. 3-4 times

c. 5-6 times
d. 7-8 times
e. I stopped at all aid stations
f. Unsure

12. Do you carry your own water/sports drinks? YES/NO. (if no, go to question **16**)

13. What type of hydration pack/bottles/system do you use? ____
    a. How many ounces does it hold? __________ounces (please remember that one cup = 8 ounces = 237 ml and one liter contains about 4 cups).

14. What type of drink (s) did you carry? (check all that apply)
    a. Sports drinks
    b. Water
    c. Both sports drinks and water
    d. Other (please specify) ____

15. What volume of drinks did you carry? (**ONE CUP = 8 OUNCES or 237 ML**)
    a. 1- 2cups (8 -16 oz)
    b. 3-4 cups (24 - 32 oz)
    c. More than 4 cups (>32 oz)
    d. Other ____

16. What was your actual race time (or estimated time if you finished DNF)? ________ hrs __________minutes

17. Did you follow your hydration plan ***during*** the race? YES/NO

18. Did you follow your post-race hydration plan? YES/NO

19. Did you weigh yourself before and after the race? YES/NO (If NO, please go to question **22**).

20. If yes, did you gain or lose weight, or stay the same? GAIN/LOSE/STAY THE SAME. If you answered stayed the same, please go **22**.

21. If you gained or lost weight, please indicate the amount of weight gained or lost.
    a. 1-2 lb. GAIN
    b. 1-2 lb. LOSS
    c. 2-4 lb. GAIN
    d. 2-4 lb. LOSS
    e. 4-6 lb. GAIN
    f. 4-6 lb. LOSS
    g. 6-8 lb GAIN
    h. 6-8 lb. LOSS

i. Other ________________________________

22. Did you have any specific symptoms ***during*** the race? Please check all that apply.
    a. Nausea
    b. Vomiting
    c. Lightheadedness
    d. Headaches
    e. Muscle or joint pain
    f. Tingling in fingers or toes
    g. Seeing stars
    h. Cramps
    i. Other____
    j. None

23. Did you have any specific symptoms ***after*** the race? Please check all that apply.
    a. Nausea
    b. Vomiting
    c. Lightheadedness
    d. Headaches
    e. Muscle or joint pain
    f. Tingling in fingers or toes
    g. Seeing stars
    h. Cramps
    i. Other____
    j. None

24. Is there any other information that you would like to share that would help us to understand your race-related hydration plan and actions?
    ____
    ____
    ____

Thanks again for completing this survey and participating in the research. Your input is very valuable.

APPENDIX K. HYDRATION SURVEY FOR LONG-DISTANCE RUNNERS

Please answer **<u>all</u>** questions to the best of your ability. You will not be able to "backtrack". Please note that the survey will not move ahead until an answer has been selected. If you are unsure of an answer, please select "unsure." Please note that ***one cup equals 8 ounces or 237 ml*** for all questions, unless the question indicates otherwise. Also, if you carry a hydration pack, please know that hydration packs are typically in liters. One liter is about 4 cups; thus, a 4-liter hydration pack would carry about 16 cups of fluids. Thank you.

The picture below is a reminder of an 8 ounce measuring cup and a seven ounce dixie cup.

A. **Demographic Information**

1. What is your age in years?
   a. Less than 18 (IF LESS THAN AGE 18, THE SURVEY WILL END)
   b. 18-24
   c. 25-39
   d. 40-64
   e. 65 and older

2. What is your sex?
    a. Male
    b. Female
    c. Prefer not to answer

3. Additional Information
    a. Indicate Highest Level of Education Completed
        1. Some high school or less
        2. Graduated high school
        3. Trade or technical school
        4. Some college
        5. Graduated college
        6. Graduate school
        7. Prefer not to answer

    b. Marital Status
        1. Single
        2. Married
        3. Divorced
        4. Widowed
        5. Domestic partnership
        6. Prefer not to answer

    c. Level of Income
        1. < $25,000
        2. $25,000 - $49,999
        3. $50,000 - $74,999
        4. > $75,000
        5. Prefer to not answer

    d. Racial and Ethnic Category
        1. African American or Black
        2. American Indian or Alaskan Native
        3. Asian or Pacific Islander
        4. Latino or Hispanic
        5. Mixed Race
        6. White
        7. Another ethnic background
        8. Prefer not to answer

B. Long-Distance Running Experience

4. What type of long-distance running do you do? (consider 10 or more miles in a single run)

a. Trail running only
b. Road running only
c. Both
d. Other____
e. NONE – I do not run long-distance events (SURVEY STOPS)

5. How many long-distance running events (10 or more miles) have you completed?
   a. 0 (I have yet to do an event but plan to in the near future)
   b. 1
   c. 2-4
   d. 5-9
   e. 10 or more

6. What is your longest running distance that you have completed in the last few of years?
   a. 10-13 miles
   b. 14-16 miles
   c. 17-20 miles
   d. 21-24 miles
   e. >25 miles

7. What is your fastest half marathon road run time?
   _______ hours ________minutes _______ not sure ______ n/a_________

8. What is your fastest marathon road run time?
   ______ hours _______ minutes _______ not sure _______ n/a _________

9. What is your fastest 25K trail run race time?
   ______ hours ________minutes ______not sure________ n/a___________

10. What is your fastest 50K trail run race time?
    ______ hours ______ minutes_________ not sure ________ n/a_________

11. What is your fastest (other) long-distance race time? Length of race ___________
    ________hours ________minutes _________ not sure __________ n/a

12. Are you a member of a running club? YES/NO

13. How tall are you? _______feet ______ inches

14. How much do you weigh? _______pounds

15. How would you best describe yourself and level of training? Please select one:
    a. Professional or elite athlete
    b. Aspiring professional athlete, training regularly
    c. Actively competitive in age group athlete, training regularly
    d. Interest in general health and fitness, training regularly
    e. Interest in general health and fitness, training sometimes
    f. Other ____

16. What are your total training hours per week on average? Please include any cross training.
    a. Under 5 hours per week
    b. 5-8 hours per week
    c. 8-10 hours per week
    d. Greater than 10 hours per week

C. Sources of information on hydration

17. Have you read or been told about drinking fluids during a long-distance running event day? YES/NO (if NO, please go to question **20)**

18. If yes, where have you received this information? (please check all that apply)
    a. The running event website
    b. Running club
    c. Running coach
    d. Registered Dietitian
    e. Running friends
    f. Personal trainer
    g. Doctor/Physician/another medical professional
    h. TV/Radio
    i. Running magazine or book
    j. Other Internet sources
    k. Professional organizations, such as the American College of Sports Medicine, or the National Association of Athletic Training
    l. Research or journal articles
    m. Other ____________________________

D. *Intended* hydration practices during a long training run

19. What would *typically* be your longest training run? Assume this length for the following questions regarding a long training run.
    a. 10-13 miles
    b. 14-16 miles
    c. 17-20 miles
    d. 21-24 miles

e. >25 miles

20. Do you generally intend to drink ***before*** the start of a long training run? YES/NO (if NO, please go to question **25**)

21. If yes, what do you drink ***before*** a long training run? (check all that apply)
    a. Water ______
    b. Sports drinks _____
    c. Coffee/tea______
    d. Other____

22. When are you planning to do this? (check all that apply)
    a. 3-4 hours before training run
    b. 2-3 hours before training run
    c. 1-2 hours before training run
    d. Less than one hour before training
    e. Other _______________________

23. How much do you intend to drink ***before*** your long training run in total? (**ONE CUP = 8 OUNCES or 237 ML**)
    a. 1-2 cups (8 – 16 oz)
    b. 3-5 cups (24 – 40 oz)
    c. More than 5 cups (40 oz)
    d. I do not intend to hydrate before my training run
    e. Unsure___________________

24. Do you intend to drink ***during*** your long training run? YES/NO (if no, go to question **29**)

25. If yes, what do you intend to drink ***during*** the long training run?
    a. Water only
    b. Sports drinks only
    c. Water and sports drinks
    d. Other____

26. How much do you intend to drink ***during*** your long training run in total fluid? (**ONE CUP = 8 OUNCES, or 237 ML**)
    a. 1-3 cups (8 – 24 oz)
    b. 4-6 cups (32 – 48 oz)
    c. 7-9 cups (56 – 72 oz)
    d. 10-12 cups (80 – 96 oz)
    e. > 12 cups (96 oz)
    f. Other_______

27. What is your *intended* hydration strategy ***during*** a long training run?
    a. I do not have one
    b. I drink as much as possible
    c. I drink according to thirst (thirst tells me when to drink)
    d. I drink ad libitum (when I feel like it)
    e. I follow programmed drinking (for example, I always drink 8 oz/hr)
    f. I have a personalized hydration plan (is one that has been defined by a professional) if YES,
        i. Did you work with a Registered Dietitian? YES/NO
        ii. Did you work with another professional? YES/NO
        iii. Did you calculate your own personalized hydration plan YES/NO
    g. I base my intended hydration plan on trial and error over time
    h. Other ____

28. Did you ever have your sweat rate measured? YES/NO (If NO, please go to question **31**)

29. If you have had it measured, what is your sweat rate?
    a. 0.5-1.0 Liters/hr
    b. 1.0 – 2.0 Liters/hr
    c. 2.0 -3.0 Liters/hr
    d. 3.0 – 4.0 Liters/hr
    e. > 4.0 Liters/hr
    f. Unsure

30. Do you ever weigh yourself before and after a run? YES/NO

31. What factors influence your hydration practices during a long training run? Please check all that apply:
    a. Weather
    b. Running intensity
    c. People I am running with
    d. Availability of drinks
    e. Pain or cramping
    f. Because I am supposed to
    g. Other____

32. Do you carry your own water or sports drinks when completing a long training run? YES/NO. (if no, go to question **36**)

33. What type of hydration pack/bottles/system do you use?
____
    a. How many ounces does it hold? ___________ ounces (please remember that one cup=8 ounces=237 ml and a liter contains about 4cups)

34. What volume will you carry? (**ONE CUP = 8 OUNCES or 237 ML**)
    a. 1-2 cups (8 – 16 oz)
    b. 3-4 cups (24 – 32 oz)
    c. More than 4 cups (32 oz)
    d. Other ______________________________

35. Do you ever have water or fluids placed along your training route? YES/NO

36. Will your *intended* hydration practices during training generally mimic your *intended* hydration practices during an event? YES/NO

37. Do you have a specific hydration plan for ***after*** your long training run? YES/NO

E. *Intended* hydration practices on your race event day (assume your race day is close to the mileage that you did during training).

38. Do you have plans to drink ***before*** the start of the event? YES/NO (if no, please go to question **43**)

39. If yes, what are you planning to drink? (please check all that apply)
    a. Water
    b. Sports drinks
    c. Coffee/tea
    d. Other____

40. When are you planning to do this? (please check all that apply)
    a. 3-4 hours before the event
    b. 2-3 hours before event
    c. 1-2 hours before event
    d. Less than one-hour event
    e. Other ____

41. About how much do you intend to drink (total fluids) ***before*** the event? (**ONE CUP = 8 OUNCES or 237 ML**)
    a. 1-2 cups (8 – 16 oz)
    b. 3-5 cups (24 – 40 oz)
    c. More than 5 cups (>40 oz)
    d. I do not intend to hydrate before the marathon event

e. Unsure

42. Do you intend to drink ***during*** the event? YES/NO (if no, go to question **53**)

43. What is your *intended* hydration strategy ***during*** an event?
    a. I do not have one
    b. I drink as much as possible
    c. I drink according to thirst (thirst tells me when to drink)
    d. I drink ad libitum (when I feel like it)
    e. I follow programmed drinking (i.e. I always drink 1 cup per hour)
    f. I have a personalized plan (a professional has helped me to create) If YES,
        i. Did you work with a Registered Dietitian? YES/NO
        ii. Did you work with another professional? YES/NO
        iii. Did you calculate your own personalized hydration plan? YES/NO
    g. I base my hydration plan on "trial and error" from my experiences over time
    h. Other ____

44. What influences your hydration practices during a long-distance event? Please check all that apply.
    a. Weather
    b. Running intensity
    c. People I am running with
    d. Availability of drinks
    e. Pain or cramping
    f. Because I am supposed to
    g. Other____

45. How much do you intend to drink in total ***during*** a long-distance event? (**ONE CUP = 8 OUNCES OR 237 ML)**
    a. 1-3 cups (8 – 24oz)
    b. 4-6 cups (24 – 48oz)
    c. 7-9 cups (56 – 72oz)
    d. 10-12 cups (80 – 96 oz)
    e. More than 12 cups (96 oz)
    f. Unsure

46. What do you intend to drink during the long-distance running event?
    a. Water
    b. Sports drinks
    c. Water and sports drinks
    d. Other____

47. Do you intend to slow down or stop at hydration stations provided during the race? YES/NO (if NO, go to question **50**).

48. If yes, about how many times do you intend to slow down or stop at a hydration station?
    a. 1-2 times
    b. 3-4 times
    c. 5-6 times
    d. 7-8 times
    e. I stop at ALL of the stations
    f. Unsure

49. Do you intend to carry your own water/sports drinks? YES/NO. (If no, go to question **53**)

50. What type of hydration pack/bottles/system do you use?
    ____
    a. How many ounces does it hold? __________ ounces *(please remember that one cup=8 ounces=237 ml and a liter contains about 4 cups)*

51. What volume will you carry? (**ONE CUP = 8 OUNCES or 237 ML**)
    a. 1-2 cups (8 – 16 oz)
    b. 3-5 cups (24 – 40oz)
    c. More than 5 cups (40 oz)
    d. Other __________________

52. Do you have a specific hydration plan for ***after*** the intended event? YES/NO

F. Knowledge of EAH (Exercise-associated hyponatremia)

53. Have you heard of the term exercise-associated-hyponatremia, or EAH? YES/NO (if NO, please go to question **57**)

54. What are some of the contributing factors to the onset of EAH? Please select all that apply.
    a. High intensity exercise
    b. Low intensity exercise
    c. Drinking too much
    d. Not drinking enough
    e. High temperatures & humidity
    f. Extremely cold weather
    g. Continuous exercise lasting over 4 hours
    h. Not enough training preparation for the event

i. Availability of drinks (water and sports drinks)
j. Low or high body weight
k. Sodium or electrolyte deficit
l. Age
m. Other ______________________________________

55. What are some ways or strategies to prevent EAH? Please check all that apply.
    a. Drinking according to thirst
    b. Drinking sports drinks
    c. Avoiding high intensity exercise
    d. Dressing appropriately for the weather
    e. Following my hydration plan
    f. Taking salt tablets
    g. I am not sure how to prevent EAH
    h. Educating myself on this topic
    i. Knowing the signs and symptoms of EAH
    j. Monitoring weight changes before or after a run
    k. Other____

56. Do you feel you have a solid understanding of the safest and most effective way to hydrate for a long-distance running race event? YES/NO

57. Do you have any other comments that you would like to add on hydration during a long-distance running event, or your personal hydration plan or strategy?
    ____
    ____
    ____

Thanks for completing this questionnaire and contributing to my hydration research in long-distance running. Your input is important and valued.

APPENDIX L. RECRUITMENT EMAIL/IMPLIED CONSENT (HYANNIS)

North Dakota State University (NDSU)
Department of Health, Nutrition, and Exercise Sciences
E. Morrow Lebedeff Hall 316H
NDSU Dept. 2620
PO Box 6050
Fargo, ND 58108-6050
701.231.7479

The comparison of hydration practices of runners during an intended training run, an intended marathon, and the Hyannis Marathon

Dear Runner:

My name is Suzanne Young. I am a doctoral student in the Department of Health, Nutrition, and Exercise Sciences at North Dakota State University. I am conducting a research project to assess the hydration practices of marathon runners. It is our hope, that with this research, we will learn more about hydration practices of marathon runners during intended training, an intended event, and the actual marathon. We will also assess the hydration strategies during an event and knowledge of exercise-associated hyponatremia (EAH). EAH is a condition involving low blood sodium and excess water within the cells during or within 24 hours of physical activity.
Because you are a participant in the Hyannis Marathon, you are invited to take part in this research project. Your participation is entirely your choice, and you may change your mind or quit participating at any time, with no penalty to you.

By taking part in this research, you may benefit by learning more about hydration practices by reading the various terms and questions. Also, the survey in itself may intrigue you to learn more about this topic. In addition, your participation may benefit the running community by advancing the knowledge in this area of research.

It should take about 10-15 minutes to complete the pre-race survey. At the end of the survey, you will be asked to provide an email address to complete an optional second survey after your completed marathon race. This second post-race survey should take only 5 minutes to complete. The second survey is important to establish comparisons between planned and actual fluid consumption in conjunction with your race. After we receive your second optional survey, we will “match” the two surveys together for comparison, then delete your email address from our records. We appreciate your participation in both surveys.

We will keep private all research records that identify you. Your information will be combined with information from other people taking part in the study. We will write about the combined information that we have gathered. You will not be identified in these written materials. We may publish the results of the study; however, we will keep your name and other identifying information private.

If you have any questions about this project, please contact me, Suzanne Young at (617) 320- 9801 and suzanne.young@ndsu.edu, or contact my faculty advisor, Dr. Sherri Stastny, Professor in Health, Nutrition, and Exercise Sciences at (701) 238-0633 or sherri.stastny@ndsu.edu.

You have rights as a research participant. If you have questions about your rights or complaints about this research, you may talk to the researcher or contact the NDSU Human Research Protection Program at (701) 231-8995, toll-free at (855)-800-6717, by email at ndsu.irb@ndsu.edu, or by mail at: NDSU HRPP Office, NDSU Dept. 4000, P.O. Box 6050, Fargo, ND 58108-6050.

Thank you for your taking part in this research.

To access the survey, please click on the link below:

LINK (Qualtrics link)

APPENDIX M. RECRUITMENT EMAIL/IMPLIED CONSENT (CONNECTICUT)

North Dakota State University (NDSU)
Department of Health, Nutrition, and Exercise Sciences
E. Morrow Lebedeff Hall 316H
NDSU Dept. 2620
PO Box 6050
Fargo, ND 58108-6050
701.231.7479

The comparison of hydration practices of long-distance runners during an intended training run, an intended marathon, and self-reported practices during two CT trail races.

Dear Runner:

My name is Suzanne Young. I am a doctoral student in the Department of Health, Nutrition, and Exercise Sciences at North Dakota State University. I am conducting a research project to assess the hydration practices of long-distance trail runners. It is our hope, that with this research, we will learn more about hydration practices of trail runners during intended training, an intended event, and the actual marathon. We will also assess the hydration strategies during an event and knowledge of exercise-associated hyponatremia (EAH). EAH is a condition involving low blood sodium and excess water within the cells during or within 24 hours of physical activity.
Because you are a participant in either the Macedonia Trail Race or the Angevine Farm Trail Race, you are invited to take part in this research project. Your participation is entirely your choice, and you may change your mind or quit participating at any time, with no penalty to you.

By taking part in this research, you may benefit by learning more about hydration practices by reading the various terms and questions. Also, the survey in itself may intrigue you to learn more about this topic. In addition, your participation may benefit the running community by advancing the knowledge in this area of research.

It should take about 10-15 minutes to complete the pre-race survey. At the end of the survey, you will be asked to provide an email address to complete an optional second survey after your completed your race. This second post-race survey should take only 5 minutes to complete. The second survey is important to establish comparisons between planned and actual fluid consumption in conjunction with your race. After we receive your second optional survey, we will “match” the two surveys together for comparison, then delete your email address from our records. We appreciate your participation in both surveys.

We will keep private all research records that identify you. Your information will be combined with information from other people taking part in the study. We will write about the combined information that we have gathered. You will not be identified in these written materials. We may publish the results of the study; however, we will keep your name and other identifying information private.

If you have any questions about this project, please contact me, Suzanne Young at (617) 320- 9801 and suzanne.young@ndsu.edu, or contact my faculty advisor, Dr. Sherri Stastny, Professor in Health, Nutrition, and Exercise Sciences at (701) 238-0633 or sherri.stastny@ndsu.edu.

You have rights as a research participant. If you have questions about your rights or complaints about this research, you may talk to the researcher or contact the NDSU Human Research Protection Program at (701) 231-8995, toll-free at (855)-800-6717, by email at ndsu.irb@ndsu.edu, or by mail at: NDSU HRPP Office, NDSU Dept. 4000, P.O. Box 6050, Fargo, ND 58108-6050.

Thank you for your taking part in this research.

To access the survey, please click on the link below:

LINK (Qualtrics link)

APPENDIX N. RECRUITMENT EMAIL/IMPLIED CONSENT (GENERAL)

North Dakota State University (NDSU)
Department of Health, Nutrition, and Exercise Sciences
E. Morrow Lebedeff Hall 316H
NDSU Dept. 2620
PO Box 6050
Fargo, ND 58108-6050
701.231.7479

The comparison of hydration practices of long-distance runners during an intended training run and an intended event during COVID-19.

Dear Runner:

My name is Suzanne Young. I am a doctoral student in the Department of Health, Nutrition, and Exercise Sciences at North Dakota State University. I am conducting a research project to assess the hydration practices of long-distance runners. It is our hope, that with this research, we will learn more about hydration practices of runners during an intended training run and an intended event. We will also assess the knowledge of exercise-associated hyponatremia (EAH). EAH is a condition involving low blood sodium and excess water within the cells during or within 24 hours of physical activity. Because you are associated with the Steep Endurance organization or with NDSU, you are invited to take part in this research project. Your participation is entirely your choice, and you may change your mind or quit participating at any time, with no penalty to you.

By taking part in this research, you may benefit by learning more about hydration practices by reading the various terms and questions. Also, the survey in itself may intrigue you to learn more about this topic. In addition, your participation may benefit the running community by advancing the knowledge in this area of research.
It should take about 10-15 minutes to complete the survey. Please complete within a week at your convenience.

We will keep private all research records that identify you. Your information will be combined with information from other people taking part in the study. We will write about the combined information that we have gathered. You will not be identified in these written materials. We may publish the results of the study; however, we will keep your name and other identifying information private.

If you have any questions about this project, please contact me, Suzanne Young at (617) 320- 9801 and suzanne.young@ndsu.edu, or contact my faculty advisor, Dr. Sherri Stastny, Professor in Health, Nutrition, and Exercise Sciences at (701) 238-0633 or sherri.stastny@ndsu.edu.

You have rights as a research participant. If you have questions about your rights or complaints about this research, you may talk to the researcher or contact the NDSU Human Research Protection Program at (701) 231-8995, toll-free at (855)-800-6717, by email at ndsu.irb@ndsu.edu, or by mail at: NDSU HRPP Office, NDSU Dept. 4000, P.O. Box 6050, Fargo, ND 58108-6050.

Thank you for your taking part in this research.

To access the survey, please click on the link below:

LINK (Qualtrics link)