

MAINTENANCE OF HEALTH AND DISTANCE RUNNING PERFORMANCE  
THROUGH HYDRATION KNOWLEDGE AND PRACTICES

by

Brett A. Davis

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Dissertation Committee:

Dr. Jennifer L. Caputo, Chair

Dr. Richard S. Farley

Dr. John M. Coons

Dr. Dana K. Fuller

This work is dedicated to my wife Pattie Lane.

Although I do not deserve you, God has blessed me by putting you into my life.

Thank you for your unwavering love, support, and patience. You have always been my biggest fan, and I could not imagine seeing this arduous journey to its end without you by my side. Now that this journey is ending, I am excited to see what the future holds and to embark on the next journey with you.

I love you always,

Brett

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## ABSTRACT

Over hydration and dehydration are common amongst recreational runners and often leading to adverse health and performance outcomes. The evaluation of hydration knowledge, sources of hydration information, and hydration practices among recreational runners can help identify optimal methods for disseminating information relative to hydration practices. Therefore, the purpose of the first study in this dissertation was to assess hydration knowledge and sources of hydration information among recreational runners of varying ability ( $N = 161$ ). In the second study, the hydration practices of the runners were assessed.

Runners were separated into groups (low, moderate, or high) based on training volume, expected race performance, and running experience (VPE). Hydration knowledge was greater in the moderate VPE group ( $43.9 \pm 12.8$ ) than the low ( $40.9 \pm 18.2$ ) and high VPE ( $32.6 \pm 21.2$ ,  $p = .005$ ) groups. All runners rated advice from other runners as more important than any other source ( $p < .05$ ). Advice from health professionals, scientific research articles, and internet and print articles were rated as more important ( $p < .05$ ) than guidelines from sport science organizations, which were rated as more important ( $p < .05$ ) than advertisements. Experiencing adverse performance and health effects as result of dehydration was reported by 80% and 58% of the runners, respectively. During races of half-marathon distance or longer 51% of runners reported using a drinking schedule; however, only 22% of runners reported using change in body weight to determine sweat rate and fluid needs. Consumption of fluids

during training in the heat was reported by 71% of runners; yet, 54% of runners' perceived inadequate fluid intake before and during exercise as the cause of dehydration leading to adverse performance and health effects. The inconvenience of carrying fluids while running and the inconvenience of scheduling fluid delivery or placing fluids along the route before the run were reported as barriers to consuming fluids during training by 60% and 50% of runners, respectively. Hydration status monitoring was reported by 68% of runners. A greater percentage of high VPE runners (83%) monitored hydration status compared to low VPE runners (58%,  $p = .041$ ). Monitoring hydration status via urine color was reported by 92% of runners; however, most runners ( $n = 54$ ) utilizing this method incorrectly made color judgments based on the color of urine in the toilet.

Overall, hydration knowledge was poor among the recreational runners in this study, partly due to the runners obtaining hydration advice from disreputable or obsolete sources and limited interaction with knowledgeable healthcare professionals. In addition, the recreational runners in this study exhibited poor fluid intake behaviors during training and racing, and poor implementation of techniques to determine sweat rate, fluid needs, and assess hydration status. As a result, the incidence of adverse performance and health effects stemming from dehydration was high among the sample.

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## CHAPTER I

### INTRODUCTION

Endurance runners train and compete in a range of environmental conditions. Running, especially when performed in the heat, can result in significant dehydration and increases in core and skin temperature. Elevations in body temperature cause physiological responses such as increased skin blood flow and increased sweat rate, with evaporation being the primary mechanism of heat loss from the body. Dehydration is associated with excessive thirst, muscle cramping, delayed onset of sweating, decreased heat tolerance, and early onset of fatigue. Thus, if sweat losses are not adequately replaced with the ingestion of fluid, a body water deficit can develop, exercise performance may be hindered, and health adversely effected.

Few recreational runners train under the supervision of a coach, athletic trainer, or other healthcare professionals who have advanced knowledge regarding appropriate hydration strategies for the prevention of heat illness and maintenance of athletic performance (O'Neal et al., 2011; Winger, Dugas & Dugas et al., 2010). Thus, recreational runners must possess adequate hydration knowledge in order to develop and implement appropriate hydration strategies to help sustain exercise performance and prevent the occurrence of heat-related illness. Sports science organizations such as the American College of Sports Medicine (ACSM) and the National Athletic Trainers Association (NATA) have published guidelines on fluid replacement and the prevention of heat related illness (Binkley, Beckett, Casa, Kleiner & Plummer, 2002; Casa et al.,

2000; Casa et al., 2015; Sawka et al., 2007) intended to provide education and guidance. However, a recent survey of 276 recreational runners (O'Neal et al., 2011) indicated only 42% of the runners always consumed fluids during runs in the heat, and only 20% of the runners monitored their hydration status. Subsequently, 70% of runners reported experiencing decreased performance as the result of dehydration, 44% of runners reported experiencing multiple incidences of decreased performance, and 54% of the most highly experienced recreational runners in the sample experienced symptoms of heat-related illness as the result of dehydration. These findings suggest that few recreational runners pay heed to the recommendations made by the ACSM and NATA. Yet, further research assessing hydration knowledge and hydration practices among recreational runners is sparse.

Distance runners who exercise in hot environments for prolonged periods at high intensities, with limited access to fluids are susceptible to dehydration-induced performance decrements and heat-related injuries. Thus, survey-based assessments of hydration knowledge and hydration practices employed by recreational runners are warranted. These assessments will add to the body of literature by documenting the knowledge and practices of runners, and will provide information that can be used to develop or revise educational programs and materials intended to help reduce the occurrence of heat-related illness and maximize running performance under hot conditions.

### *Overall Purpose*

The investigations within this dissertation were designed to assess hydration knowledge, to identify sources of hydration information, and to evaluate the hydration

practices employed by recreational runners of varying abilities. The purpose of the first study was to determine the level of hydration knowledge possessed and elucidate the primary sources of hydration information utilized by recreational runners at varying levels of competition. The purpose of the second study was to determine the hydration practices employed by recreational runners at varying levels of competition.

### *Significance of Studies*

Determining the level of hydration knowledge possessed by recreational runners is important in determining areas in which further education are needed. Increased hydration knowledge may translate to improved hydration practices and subsequently, decrease the incidence of heat related illness and maximize running performance under hot conditions. Additionally, determining the primary sources that recreational runners use to obtain information on hydration practices may provide insight into the most effective method of disseminating accurate information regarding hydration. This information may also be used to update and improve hydration guidelines published by organizations such as the ACSM and the NATA.

## CHAPTER II

### LITTERATURE REVIEW

The following review of the literature begins with a description of body fluid compartments and shifts in body fluid within the body. The deleterious effects of dehydration on physiological function and exercise performance are discussed along with an examination of guidelines on hydration strategies for the prevention of dehydration and heat illness. The review then transitions to an examination of hydration knowledge and practices among recreational runners, and an examination of the primary sources of information used by recreational runners to attain hydration information. Next, the review addresses the need for research assessing hydration knowledge and practices among recreational, as well as, the need for research evaluating the primary sources of information that recreational runners use to attain hydration information. The review concludes by elaborating on how results from such assessments could be used to enhance current guidelines on appropriate hydration practices and determine the most effective method of disseminating accurate information to recreational runners.

#### ***Body Water Loss and Fluid Shift***

Water is the largest component of the human body and accounts for 45–75% of body mass. An average 75 kg male is comprised of approximately 60% water, which equates to 45 L (Sawka, 1992; Sawka & Coyle, 1999). An individual's body composition will determine total body water content because adipose tissue is

approximately 10% water and muscle tissue is approximately 75% water (Sawka, 1988). Additionally, glycogen content of the muscle will alter water content because of the osmotic pressure exerted by glycogen granules inside of the muscle's sarcoplasm (Neufer et al., 1991). Thus, in comparison to sedentary individuals, trained athletes will have a greater total body water content as a result of their larger muscle mass and greater intramuscular glycogen stores. Water within the body is distributed between the intracellular fluid (ICF) and extracellular fluid (ECF) compartments. For the average 75 kg male, the ICF compartment contains approximately 30 L of water, whereas the ECF compartment contains 15 L of water, with ~ 4 L in plasma and ~ 11 L stored in the interstice of organs and tissues (Sawka & Coyle, 1999). These volumes are not static, fluid exchange is dynamic with varying water turnover rates among compartments. Disturbances such as exercise and heat stress also alter the volumes and turnover rates among compartments (Mack & Nadel, 1996).

Water transfer between the ICF compartment and interstitium relies upon an osmotic gradient. Water transfers from regions of low solute to high solute concentrations through osmosis, to maintain an equilibrium in solute concentrations across the cell membrane. Cell membranes are freely permeable to water and selectively permeable to solutes. Thus, water is exchanged between the ICF and ECF compartments to equalize osmotic gradients. The primary cation in ECF is sodium, while the primary anions are chloride and bicarbonate. These ions comprise ~95% of the osmotically active components of the ECF and changes in these ion concentrations will alter ICF volumes. In ICF, the primary cations are potassium and magnesium while proteins serve as the

primary anions. Ion pumps in the cell membrane maintain marked differences in potassium and sodium concentrations in the EFC and IFC.

The transfer of water between interstitial and intravascular spaces occurs through the capillary beds. Hydrostatic and osmotic pressures at the capillary membrane determine whether net filtration (i.e. water leaving the vascular space) or net absorption (i.e. water entering the vascular space) will occur. In general, filtration occurs at the arterial end of the capillary bed while absorption occurs at the venous end of the capillary bed. Due to greater surface area and permeability at the venous end, most capillary networks have a greater capacity for absorption than filtration (Sawka & Coyle., 1999).

Sweat loss will also impact the ICF and ECF compartments. Sweat rates during running vary based on ambient temperature; however, a rate of  $1.5 \text{ L}\cdot\text{h}^{-1}$  is common (Davis et al., 2014; Lee, Nio, Lim, Teo & Byrne, 2010; O'Neal et al., 2013; Sawka, 1992) and can exceed  $3 \text{ L}\cdot\text{h}^{-1}$  in elite marathon runners (Armstrong, Hubbard, Jones & Daniels, 1985). It is difficult for endurance runners to match fluid consumption with sweat losses during exercise. Previous reports indicate that ad libitum fluid replacement during runs in temperate and hot environments results in "voluntary dehydration" (O'Neal et al., 2012; Passe, Horn, Stofan, Horswill, & Murray, 2007). Passe, Horn, Stofan, Horswill, and Murray (2007) held a competitive 10 mile outdoor race (mean ambient temperature =  $20.5 \pm 0.7^\circ\text{C}$ , relative humidity =  $76.6\% \pm 1.7\%$ ) among 18 seasoned marathoners. Despite free access to 710 ml of a chilled sports beverage at miles 2, 4, 6, and 8, runners only replaced ~31% of their sweat losses via fluid ingestion during the run. O'Neal et al. (2012) reported that runners completing a 1 hour run in a wet-bulb-



globe-temperature (WBGT) of  $\sim 24^{\circ}\text{C}$  replaced  $\sim 15\%$  of their sweat losses despite being provided access to 237 ml of chilled water every 2.5 km throughout the run. If fluid intake does not match sweat loss then hypohydration will occur. Nose, Morimoto, and Ogura (1983) investigated the redistribution of body water among fluid compartments and body organs. Rats were dehydrated by 10% body mass by heat exposure for 6 to 8 hours. The body water losses apportioned from the ICF and ECF compartments equated to 41% and 59% of total fluid losses, respectively. Furthermore, the water deficit among body organs was reported to be 40% from the muscle, 30% from the skin, 14% from the viscera, and 14% from the bone. The water content of both the brain and the liver were unchanged. From these results, the authors concluded that hypohydration caused a redistribution of body water primarily from ICF and ECF compartments of muscle and skin to preserve blood volume.

In summary, the ICF and ECF compartments contain 66% and 33% of total body water content, respectively. The ECF compartment is comprised of blood plasma and fluids contained in the interstice of body tissues. These volumes are not static and disturbances such as exercise and heat stress will alter the volume of each compartment. Fluid exchange between body water compartments is governed by osmotic pressures, and changes in solute concentration of ECF will alter the volume of ICF. During exercise, the majority of body water lost comes from the ECF compartment causing a redistribution of water from the ICF compartments of muscle and skin in an attempt to maintain blood volume. If water losses are not replaced, the resulting dehydrated state will lead to cardiovascular perturbations.

## ***Physiological Responses to Dehydration***

### *Cardiovascular Responses*

Dehydration during exercise with limited heat stress results in increased heart rate and decreased stroke volume, but has little effect on cardiac output and mean arterial pressure compared to euhydrated levels (Allen, Smith, & Miller, 1977; Sawka, & Coyle, 1999; Sproles, Smith, Byrd, & Allen, 1976; Tankersley, Zappe, Meister, & Kenney, 1992). Sproles et al. (1976) dehydrated a group of wrestlers on two separate occasions by 3.7% and 6.8% of body mass, respectively through a combination of exercise and food restriction. Moderate intensity cycling (approximately 50%  $\text{VO}_2$  max) after dehydration demonstrated a respective heart rate increase of 13.4 and 17.2 beat per minute and stroke volume decreases of 17.4 ml and 28.8 ml in the 3.7% and 6.8% conditions, respectively. Cardiac output was decreased by  $0.5 \text{ L}\cdot\text{min}^{-1}$  after 3.7% body mass loss and decreased by  $1.7 \text{ L}\cdot\text{min}^{-1}$  after 6.8% body mass loss. Tankersley et al. (1992) also reported significantly higher heart rates when collegiate cyclist exercised at 55%  $\text{VO}_{2 \text{ max}}$  while dehydrated by 1.9% of body mass.

Hypohydration and heat stress have additive effects on cardiovascular strain during exercise. The combination of exercise and heat strain results in competition between central and peripheral circulation for a limited blood volume. As body temperature rises, cutaneous blood vessels dilate causing a decrease in venous resistance and pressure. Additionally, during hypohydration, blood volume is reduced resulting in decreased central venous pressure and end diastolic volume (Nose et al., 1994) which reduces stroke volume and increases heart rate. These physiological perturbations,

combined with the redistribution of blood flow to cutaneous vascular beds, reduces central venous pressure, venous return, and cardiac output.

A gradual increase in heart rate resulting from decreased stroke volume during prolonged exercise at a constant work rate, known as cardiovascular drift, is accentuated by environmental temperature, hypohydration, and progressively increasing dehydration during exercise. Nadel, Cafarelli, Roberts, and Wenger (1979) examined the circulatory responses of fit young men completing 25 minutes of semi-recumbent cycling at 40% and 70%  $\text{VO}_{2\text{ max}}$  in ambient temperatures of 20°, 26°, and 36°C. During exercise at 40%  $\text{VO}_{2\text{ max}}$  there were no notable differences in heart rate and cardiac output in the 20° and 26°C environments. However, cardiac output was significantly higher ( $1.3\text{ L}\cdot\text{min}^{-1}$ ) due to a significantly higher heart rate ( $15\text{ beats}\cdot\text{min}^{-1}$ ) during exercise in the 36°C environment. During exercise at 70%  $\text{VO}_{2\text{ max}}$  in the 36°C environment, stroke volume fell over time; however, cardiac output was maintained at levels similar to that in cooler environments due to a  $20\text{ beat}\cdot\text{min}^{-1}$  increase in heart rate. The authors hypothesized that participants were able to maintain cardiac output during cycling at both exercise intensities because the hydrostatic pressure the heart had to overcome was reduced while sitting in a semi-recumbent position. Nadel, Fortney, and Wenger (1980) had moderately fit young men complete 30 min of cycling at 55%  $\text{VO}_{2\text{ max}}$  at an ambient temperature of approximately 35°C following a 2.7% body mass reduction induced via 4 days of diuretic administration. Following 10 minutes of exercise, heart rate was consistently 6–8  $\text{beats}\cdot\text{min}^{-1}$  higher in the dehydrated state compared to euhydration levels. Mountain and Coyle (1992b) examined the effect of varying levels of dehydration, induced by

consumption of varying volumes of fluid, during 2 hours of exercise in the heat. The decrease in cardiac output and progressive increase in heart rate were strongly correlated with the magnitude of dehydration incurred during the exercise bout.

In conjunction, these findings highlight the importance of maintaining hydration for the preservation of cardiovascular function during activity. Distance runners often struggle to consume enough fluids to offset sweat losses during prolonged exercise and, are therefore, susceptible to impaired cardiovascular function. To offset the deleterious effects of dehydration on the cardiovascular system during exercise, endurance athletes should focus on entering exercise in a euhydrated state by replacing sweat and electrolyte losses following exercise and between exercise bouts. In addition, any decrease in cardiovascular function will also cause decreases in thermoregulation as these systems are intertwined (Charkoudian, 2003).

#### *Thermoregulatory Responses*

Hypohydration causes elevated core temperature responses during exercise in temperate (Buono & Wall, 2000; Greenleaf & Castle, 1971) and hot environments (Mountain & Coyle, 1992b; Montain, Sawka, Latzka & Valeri, 1998; Sawka, Young, Francesconi, Muza, & Pandolf, 1985). Buono and Wall (2000) induced a 5% body mass loss, through a combination of fluid restriction and exercise, prior to completing 1 hour cycling bouts in a temperate (23°C, 40% relative humidity) and a hot environment (33°C, 40% relative humidity). Hypohydration increased core temperature by 0.08°C and 0.16°C with each percent body mass lost during exercise in the temperate and hot environments. Sawka et al. (1985) examined the effect of 3%, 5%, and 7% body mass loss on

thermoregulatory responses during 140 minutes of treadmill walking in a hot-dry environment (49°C, 20% relative humidity). Increases in core temperature were linearly related to increases in body mass loss, with an increase of approximately 0.18°C in core temperature with each percent body mass lost. Mountain and Coyle (1992b) examined core temperature responses during 2 hours of cycling following 3% and 5% body mass loss. These authors reported a similar increase of ~0.12°C in core temperature with each percent body mass lost.

Hypohydration also decreases dry and evaporative heat loss during exercise in the heat. Mountain and Coyle (1992a) reported that progressive dehydration during 2 hours of moderate intensity cycling (65%  $\text{VO}_2 \text{ max}$ ) in a 33 °C environment reduced forearm skin blood flow by 17% compared to when fluid replacement prevented dehydration. Buono and Wall (2000) demonstrated that 5% body mass loss during exercise in the heat (33 °C, 40% RH) resulted in a 30% decrease in skin blood flow compared to euhydration. Mountain and Coyle (1992b) evaluated skin blood flow changes during prolonged exercise following 3%, 5%, and 7% body mass loss. Forearm skin blood flow progressively decreased as the level of dehydration increased. Buono and Wall also reported that during exercise in the heat following 5% body mass, whole body sweat rate was decreased by 211  $\text{g}\cdot\text{m}^{-2}\cdot\text{h}$ . Further, Armstrong et al. (1997) reported that percent body mass loss was inversely related to sweat sensitivity. These findings suggest that hypohydration inhibits heat transfer to the environment by decreasing the thermal gradient between the core and periphery. Further, whole body sweat rate and sweat

sensitivity are decreased as result of hypohydration, thus, decreasing evaporative heat loss during exercise in the heat.

Collectively, these findings suggest that hypohydration inhibits thermoregulation during exercise, especially in the heat, by reducing the thermal gradient between the core and the skin by altering skin blood flow, sweat rate, and sweat sensitivity. These alterations in thermoregulatory responses will result in decreased heat transfer to the environment due to the convergence of core and skin temperatures resulting in a faster increase in core body temperature during exercise. González-Alonso et al. (1999) examined the independent effects of initial core body temperature and rate of body heat storage on the development of fatigue during exercise in the heat. Despite altering initial core temperature or heat storage rate, participants fatigued at similar core and muscle temperatures of 40.1°-40.2 °C and 40.7 °-40.9 °C. Furthermore, time to exhaustion was inversely related to initial core temperature and was significantly shorter during a higher rate of heat storage. Additionally, Casa et al. (2010) reported that hypohydration resulted in significantly higher core temperatures and increased performance time during trail running in the heat. Thus, it is likely that initiating endurance exercise in a hypohydrated state will result in increased cardiovascular strain and diminished thermoregulation leading to decrements in endurance performance.

### ***Hypohydration and Aerobic Exercise Performance***

Hypohydration has been shown to reduce maximal aerobic power output. Several researchers have demonstrated that in a temperate environment, maximal aerobic power decreases when a 3% body mass loss is reached or exceeded (Buskirk, Iampietro, & Bass,

1958; Caldwell, Ahonen, & Nousiainen, 1984; Sawka, 1992). Alternately, it has been shown that performance decrements can occur earlier in hot conditions. Yoshida, Takanishi, Nakai, Yorimoto, and Morimoto (2002) indicated that a body mass loss of approximately 2% decreased power output and aerobic performance during an aerobic step test in the heat (approximately 29°C WBGT).

Hypohydration has been shown to decrease aerobic endurance performance in a number of athletic events. Armstrong, Costill, and Fink (1985) examined the effects of hypohydration on competitive running performance. Male runners ( $N = 8$ ) competed in races of 1, 500, 5,000, and 10,000 meter races when euhydrated and after a 2% body mass loss was induced via diuretic administration. Race performance at all distances was hampered with a 3% increase in time in the 1,500 meter race and 5% increases in times in the 5,000 and 10,000 meter races. Davis et al. (2014) examined the effects of hypohydration on 10 km running performance. Runners completed two 10 km time trials, one while euhydrated and one after a 2% body mass loss. On the evening prior to each 10 km time trial, participants completed a 75 minute run (WBGT approximately 26°C). Participants returned to the laboratory the following morning (approximately 12 hours later) to complete a 10 km time trial. During the dehydration trial, participants were provided a fluid replacement volume equivalent to 75% of sweat losses incurred during the 75 minute evening run. During the euhydrated trial, participants were provided a fluid replacement volume equivalent to 150% of sweat losses incurred during the 75 minute evening run. Dehydration increased rate of perceived exertion (RPE) and increased performance time during the 10 km run. Bardis, Kavouras, Arnaoutis,

Panagiotakos, and Sidossis (2013) examined the effect of mild dehydration on performance time during 5 km of intense cycling. Immediately prior to the 5 km cycling performance trial, participants completed 1 hour of steady state cycling with or without fluid replacement. A 2.2% body mass loss was induced during the 1 hour of cycling without fluid replacement. Dehydration resulted in a 5.8% increase in performance time and a significantly higher RPE immediately upon completion of cycling. Burge, Carey, and Payne (1993) examined the effect of 3% body mass loss on simulated 2,000 meter rowing performance. These investigators reported that hypohydration resulted in a 5% decrease in power output and an increase in performance time by approximately 22 seconds.

Hypohydration has deleterious effects on submaximal exercise performance as well. Ladell (1955) had participants attempt to complete 140 minute walks in a 38°C environment while consuming varying volumes of salt and water. When consuming neither water nor salt, the authors reported that 9 of 12 participants experienced heat exhaustion while only 3 of 41 participants experienced heat exhaustion when consuming water during the walk. Sawka et al. (1985) had 8 participants attempt 140 min treadmill walks in a 49°C environment when euhydrated and at hypohydration levels equivalent to 3%, 5%, and 7% body mass loss. All participants completed the 140 minute walk during the 3% hypohydration trial. Only 5 participants completed the walk during the 5% hypohydration trial, and 6 participants discontinued exercise after approximately 65 minutes in the 7% hypohydration trial. Several participants discontinued exercise in the 5% and 7% hypohydration trials as a result of heart rhythm abnormalities. Sawka et al.



(1992) had participants walk to volitional exhaustion in a hot-dry environment (42°C, 20% relative humidity) when euhydrated or following an 8% body mass loss. These experiments were designed so that combined exercise intensity and environmental conditions would not allow a thermal equilibrium to be reached; thus, heat exhaustion would eventually occur. Volitional exhaustion occurred after 121 and 55 minutes in euhydrated and hypohydrated conditions. Additionally, during hypohydration trials, heat exhaustion occurred at a core temperature which was approximately 0.4°C lower than when euhydrated.

In summary, hypohydration impairs submaximal and maximal exercise performance, especially when exercising in the heat. Hypohydration also alters an athlete's perception of exercise intensity. This causes the athlete to work at a lower intensity resulting in decreases in time to exhaustion and time trial performance. To avoid these decrements in performance, athletes, athletic trainers, and coaches must have knowledge of how to design and implement appropriate hydration strategies.

### ***Hydration Guidelines***

The high rates of heat illness experienced by athletes served as the impetus for the creation of fluid replacement guidelines. Cooper, Ferrara, and Broglio (2006) reported that out of 1,000 college football players in the southeastern United States, 4.74 players experienced exertional heat illness between August and October in 2003. The Center for Disease Control and Prevention (CDC) found that approximately 9,000 high school athletes are affected by heat illness each year (CDC, 2010). These statistics highlight the importance of assessing hydration status and developing proper rehydration strategies

before, during, and after exercise for the prevention of heat illness. Several national organizations have published guidelines with respect to fluid replacement during physical activity. The NATA published a position stand on fluid replacement and exercise in 2000 (Casa et al., 2000). The ACSM published its most recent position stand on fluid replacement for athletes in 2007 (Sawka et al., 2007) which was intended to replace the organizations previous position stand on fluid replacement published in 1996 (Convertino et al., 1996). These positions stands have become the primary guidelines on fluid replacement and exercise utilized by athletes, athletic trainers, and coaches in the United States.

#### *Developing and Modifying Hydration Strategies*

While the guidelines from these two organizations are mostly congruent, there are subtle differences. The guidelines published by the NATA (Casa et al., 2000) focus on child and young adult athletes while the ACSM guidelines (Sawka et al., 2007) provide additional information regarding older adults and sex differences related to rehydration after exercise. In general, both organizations recommend developing individualized rehydration programs for athletes based on sweat losses during exercise. Sweat losses can be determined easily by assessing acute body mass changes during exercise. This methodology assumes that a 1 ml sweat loss equals a 1 g loss in body mass. Sweat losses can be calculated by subtracting post-exercise nude body mass from pre-exercise nude body mass with correction for voids and fluids consumed during exercise. However, both organizations note that rehydration strategies must be reassessed periodically as sweat rate is altered by factors including: body mass, body surface area, exercise

duration, exercise intensity, clothing or equipment worn during exercise, environmental conditions (temperature and relative humidity), and heat acclimation.

The National Athletic Training Association (Casa et al., 2000) and the ACSM (Sawka et al., 2007) noted that age may modify the construction of individualized rehydration strategies. The NATA guidelines (Casa et al., 2000) indicate that special attention should be placed on pre-pubescent and adolescent athletes as they may not fully understand the health and performance implications associated with dehydration. For these athletes, the NATA guidelines (Casa et al., 2000) emphasize making the most palatable beverages accessible during and after exercise, as well as, educating coaches and parents on proper rehydration. The ACSM guidelines (Sawka et al., 2007) note that when developing rehydration protocols for older adults (> 65 years old), special consideration should be given to the fact older adults have an age-related blunting of thirst sensation and are slower to restore body fluids following exercise as a result of a progressive decline in the number of functioning nephrons. In addition to age considerations, the ACSM guidelines (Sawka et al., 2007) emphasize that sex differences may need to be considered when developing rehydration strategies as it has been reported that women have higher water turnover rates, and altered hormonal responses to osmotic stimuli, which may increase renal water and electrolyte losses. However, these sex differences are subtle and may not be of consequence as estrogen (both endogenous and exogenously administered) and progesterone enhance water and electrolyte retention in the kidneys.

It is crucial for athletes to know how to determine sweat losses, and how to properly modify hydration strategies for specific populations. Additionally, the ability to accurately assess hydration status is pivotal. Assessing hydration status allows athletes, athletic trainers, and coaches the ability to determine those who are hypohydrated and in need of intervention.

#### *Assessing Hydration Status*

Both the NATA (Casa et al., 2000) and the ACSM (Sawka et al., 2007) position stands provide information on assessing hydration status prior to exercise. Body mass changes are the easiest way to assess hydration state. First, a baseline body mass should be established by measuring body mass at the same time each day on three consecutive days. This baseline body mass should represent euhydration during periods of ad libitum fluid and food consumption. Body mass should be measured either immediately upon waking in the morning after voiding or at the same time each day immediately prior to exercise. Both organizations suggest that fluctuations from day to day of < 1% of body mass are normal and represent that the athlete is well hydrated. However, this method has limitations, as body mass is affected by factors such as time of meal consumption or defecation and regular exercise may result in body mass changes that are not associated with body fluid changes. Urine color may also be used to assess hydration status, but can be subjective in classification. Measurement of urine specific gravity (USG) is less subjective and can be obtained easily. It is recommended that athletes have a pre-exercise USG measure of < 1.020 which indicates euhydration (Casa et al. 2000; Sawka et al., 2007). The ACSM and the NATA position stands also include that measures of

plasma volume and plasma osmolality can be utilized to determine pre-exercise hydration state; however, these methods are not readily accessible to the public. No matter which method is utilized to determine hydration status, once an athlete has been identified as dehydrated, proper measures should be taken to restore body water balance.

#### *Fluid Replacement Before, During, and After Exercise*

In regards to fluid replacement, both organization's guidelines support consuming fluids before, during, and after exercise. Prior to exercise, the ACSM (Sawka et al., 2007) suggests that athletes should slowly consume  $5-7 \text{ ml}\cdot\text{kg}^{-1}$  approximately 4 hours before the exercise bout. If athletes continue to show indices of dehydration such as no urine production, dark-colored urine, or highly concentrated urine, then an additional  $3-5 \text{ ml}\cdot\text{kg}^{-1}$  should be ingested approximately 2 hours prior to the exercise bout.

Additionally, consuming fluids with  $20-50 \text{ mEq}\cdot\text{L}^{-1}$  of sodium and/or consuming salty snacks or sodium-containing foods will help to stimulate thirst and retain the consumed fluids. In the NATA guidelines (Casa et al., 2000), it is recommended that to ensure pre-exercise hydration, athletes should consume 500-600 ml of water or sports beverage 2 to 3 hours prior to and an additional 200-300 ml of water or sports drink 10 to 20 minutes prior to exercise.

Both the ACSM (Sawka et al., 2007) and the NATA (Casa et al., 2000) position stands agree that the goal of fluid consumption during exercise should be to prevent body mass losses of  $> 2\%$ . The NATA (Casa et al., 2000) suggests that this generally requires a fluid consumption rate of 200 to 300 ml every 10 to 20 minutes. Athletic trainers and coaches can prescribe specific fluid replacement needs during exercise based on sweat

rates, sport dynamics, and individual tolerance. The ACSM stand (Sawka et al., 2007) stresses that fluid replacement strategies during exercise be individualized based on sweat rates, exercise duration, and fluid consumption opportunities as sweat rates during exercise commonly range from 0.4-1.8 L·h<sup>-1</sup>. During exercise bouts lasting greater than 3 hours, such as marathon running, special care should be taken to calculate fluid replacement needs to avoid excessive dehydration or dilutional hyponatremia.

Following exercise, there is agreement between the ACSM and the NATA position stands (Casa et al., 2000; Sawka et al., 2007) that the aim of post-exercise fluid consumption is to replace all fluid and electrolyte losses incurred during exercise. Further, both organizations recommend consuming water, sodium, and carbohydrates during post-exercise recovery. The ACSM (Sawka et al., 2007) reports that, if time permits, normal consumption of snacks and meals containing salt, along with an adequate volume of plain water, will also ensure complete rehydration. However, if recovery time between exercise bouts is < 12 hours, then an athlete should consume 1.5 L of fluid per kilogram of body mass loss (Sawka et al., 2007). According to the NATA guidelines (Casa et al., 2000), it is ideal to completely rehydrate within 2 hours following an exercise bout and athletes should consume a volume of fluid which is 25%-50% more than sweat losses to ensure a return to a euhydrated state within 4-6 hours. Guidelines from both organizations indicate the consumption of sports drinks may be helpful in restoring carbohydrate and sodium losses during recovery; however, drinks containing a carbohydrate content greater than 8% should be avoided as these beverages decrease the rate of fluid leaving the stomach and the rate of fluid absorbed by the intestines.

Additionally, the ACSM (Sawka et al., 2007) advocates the consumption of meals and snacks during recovery, if possible, because this encourages fluid consumption, and helps to replenish sodium losses, which are important for maximizing fluid retention.

In summary, the ACSM and the NATA guidelines advocate developing individualized fluid replacement strategies based on sweat rates and that sweat rates should be assessed periodically. Sweat rates can be calculated by measuring pre- to post-exercise body mass changes. Prior to exercise, ACSM advocates athletes slowly consume 5-7 ml·kg<sup>-1</sup> of fluid 4 hours before exercise. For those still showing signs of dehydration, an additional 3-5 ml·kg<sup>-1</sup> of fluid should be ingested 2 hours prior to the exercise. The NATA guidelines recommend that athletes consume 500-600 ml of fluid 2 to 3 hours prior to and an additional 200-300 ml of water or sports drink 10 to 20 minutes prior to exercise.

The goal of fluid consumption during exercise should be to prevent body mass losses of > 2%. Following exercise, athletes should normally consume salty snacks and meals along with ad libitum fluid consumption to restore euhydration, but if recovery between exercise bouts is short (approximately 6-12 hours) then athletes should consume fluid volumes equivalent to 125% to 150% of sweat losses. Though these guidelines provide the means to develop proper rehydration protocols, it is still unclear to what extent athletes are familiar with or utilize these guidelines.

#### ***Level and Sources of Hydration Knowledge among Athletes***

Endurance running is popular among recreational athletes. Yet, few investigations have measured hydration knowledge and practices among recreational

runners. Stover et al. (2006) surveyed fluid-intake habits and measured pre-exercise hydration status via measurement of pre-exercise USG among 329 recreational exercisers. In this sample, 301 participants reported an exercise frequency of  $\geq 3$  days per week, 233 participants reported exercising for  $\geq 1$  hour per day, and moderate-to-high was the most commonly reported intensity of exercise. Results indicated that 64% of the participants believed that they were euhydrated prior to beginning exercise; however, analysis of the pre-exercise USG measurements indicated that 46% of the participants were dehydrated (i.e.  $USG \geq 1.020$ ) at the onset of exercise. Additionally, participants reported only consuming 0-12 oz. of fluid during exercise, which is similar to research evaluating fluid-intake habits of recreational marathon runners (Passe et al., 2007). Passe et al. (2007) provided 18 recreational marathon runners ad libitum access to sports drinks at miles 2, 4, 6 and 8 during a 10 mile outdoor run (environmental temperature =  $20.5 \pm 0.7$  °C; relative humidity = 76.6%). The run lasted  $75.5 \pm 8.0$  min, resulting in a mean sweat loss of  $21.6 \pm 5.1$  mL·kg<sup>-1</sup>·h<sup>-1</sup> equating to an average dehydration level of  $1.9\% \pm 0.8\%$  of per-exercise body weight. On average, the runners only replaced  $30.5\% \pm 18.1\%$  of sweat loss ( $6.1 \pm 3.4$  mL·kg<sup>-1</sup>·h<sup>-1</sup>) during the run. Additionally, following the exercise bout, the runners were asked to estimate their sweat losses. The runners underestimated their sweat losses by  $42.5\% \pm 36.6\%$ . These results suggest that even under conditions where fluids are readily available, most runners will voluntarily dehydrate, and that runners are unable to estimate their sweat losses. These findings underscore the need for runners to determine fluid needs following exercise by measuring changes in pre to post-exercise body weight.



O'Neal et al. (2011) surveyed hydration practices and perceptions among half and full marathon runners. Runners were categorized based on running experience and placed into low, moderate, or high experience groups. Only 42% of runners reported always consuming fluids during outdoor runs in the heat and 6% reported never drinking during outdoor runs in the heat. Regarding monitoring of hydration status, 20% of the runners reported monitoring their hydration status through methods such as urine color (7%, 20 runners), frequency and volume of urination (3%, 9 runners) and changes in body weight (2%, 5 runners). Approximately 70% of runners reported experiencing decreased performance as result of dehydration and 44% reported experiencing multiple incidences of decreased performance as a result of dehydration. The high experience group reported more performance decrements than the low and moderate experience groups with 54% of the high experience group reporting they had experienced symptoms of heat-related illness as a result of dehydration. Further, compared to the low and moderate experience groups, the high experience group was more knowledgeable about the benefit and appropriate use of sports beverages. The high experience group reported greater consumption of sports beverages in exercise environments, believed more strongly that sports beverages were superior to water at meeting hydration needs, consuming sports beverages resulted in better recovery and improved subsequent exercise performance, and improved performance during exercise bouts lasting longer than 1 hour.

Overall, findings from Passe et al. (2007) and O'Neal et al. (2011) suggest that the majority of recreational runners do not consume adequate fluid during exercise in the heat, and few runners use urine color or acute body weight changes to assess hydration

status and fluid needs. This may help to explain why recreational runners commonly experience decreased performance and symptoms of heat illness (O'Neal et al., 2011). Hydration knowledge among recreational runners may be related to experience as more experienced recreational runners are more knowledgeable about the importance and appropriate use of sports drinks. Further research evaluating hydration knowledge and practices among recreational runners needs to be conducted to validate the findings of O'Neal et al. (2011) and to determine areas in which recreational runners need greater education. Better education may help to increase hydration knowledge and decrease the likelihood of runners experiencing heat illness.

The poor level of hydration knowledge exhibited by recreational athletes could be a result of acquiring hydration knowledge from questionable sources. O'Neal et al. (2011) reported that advice from other runners on beverage choices and hydration strategies had the greatest influence on development of recreational runners' personal hydration strategies. Similarly, Winger, Dugas, and Dugas (2010) reported that recreational runners attained the majority of information on hydration from running groups, trial/error, and advice from other runners. These findings suggest that recreational runners attain information on hydration practices from a number sources, some of which may be unconfirmed. Further, recreational runners typically do not train under the supervision of health professionals, such as coaches, athletic trainers, strength-conditioning specialists, or doctors, who have knowledge of hydration strategies for maintaining performance and safety. Thus, verifying the primary sources by which

recreational runners attain hydration information may help to determine the best avenue for disseminating accurate information to recreational runners.

### *Overall Summary*

In summary, recreational runners, especially those who commonly exercise in the heat, need to possess adequate levels of hydration knowledge to help prevent decreased performance and heat illness. Few studies have examined hydration knowledge in recreational runners, but the current literature suggests that the level of hydration knowledge among recreational runners is poor and behaviors such as inappropriately using sports drinks and failing to self-monitor hydration status are common amongst these runners. Additionally, the majority of hydration questions included in previous surveys have inquired mainly about pre-exercise hydration and hydration during training or competition. Little focus has been paid to assessing knowledge of post-exercise hydration practices. Team sport athletes, such as football, soccer, basketball, lacrosse, and rugby players, often have easily accessible fluids and multiple opportunities to drink during training and competition. Distance runners likely have limited access to water during training and, even when fluids are readily available, they are not shown to consume adequate volumes of fluid during exercise. This places emphasis on post-exercise rehydration for runners. Therefore, there is a need for research which closely examines the level of hydration knowledge among recreational runners. Such research may help to determine specific areas related to hydration in which recreational runners need more education. Additionally, research assessing the primary sources of hydration information used by recreational runners is warranted.

CHAPTER III  
ASSESSMENT OF HYDRATION KNOWLEDGE AND SOURCES OF  
INFORMATION AMONG RECREATIONAL RUNNERS AT VARYING LEVELS OF  
COMPETITION

*Introduction*

Currently, there are divided opinions in the scientific community on appropriate hydration practices for athletes; thus, the information that recreational runners encounter differs greatly depending on the source (Beltrami, Hew-Butler, & Noakes, 2008).

Organizations such as the American College of Sports Medicine (ACSM) and National Athletic Trainers Association (NATA), have published position stands on exercise and fluid replacement (Casa et al., 2000; McDermott et al., 2017; Sawka et al., 2007) intended to educate athletes, coaches, athletic trainers, and sport scientists on the deleterious effects of dehydration, and guide these groups in the development of individualized hydration strategies.

Several previous studies have assessed sports nutrition knowledge and practices among athletes (Nichols, Jonnalagadda, Rosenbloom, & Trinkaus, 2005; Shifflett, Timm, & Kahanov, 2002; Torres-McGehee et al., 2012; Zawilla, Steib, & Hoogenboom, 2003). However, these studies have only included collegiate athletes, and had little focus on assessing hydration knowledge. Previous survey research involving recreational runners has found that misconceptions and unscientific views about multiple hydration practices

are widespread in the running community (Winger, Dugas, & Dugas, 2010). Further, few recreational runners utilize methods for assessing hydration status or use pre to post-exercise changes in body mass to determine fluid needs following exercise as advocated by the ACSM and NATA guidelines (O'Neal et al., 2011). Consequently, the incidence of performance decrements and adverse health effects due to dehydration is high among recreational runners (O'Neal et al., 2011). These research findings suggest that recreational runners are unacquainted with the recommendations provided in the ACSM and NATA hydration guidelines; however, to our knowledge no study has utilized a survey instrument based on these guidelines to measure the level of hydration knowledge possessed by recreational runners.

Understanding the level of hydration knowledge possessed by recreation runners can help identify areas where further education is needed in the running community to improve performance and safety. Therefore, the primary purpose of this study was to evaluate the level of hydration knowledge possessed by recreational runners with varying training volumes, experience, and performance abilities. A secondary purpose of this study was to determine the primary information sources used by recreational runners to develop their hydration strategies.

### ***Methods***

#### *Participants*

Respondents included 161 individuals of whom 66% ( $n = 107$ ) were male and 34% ( $n = 54$ ) were female. Participant age ranged from 18 - 72 years: 32% ( $n = 51$ ) were 18 - 29 years old, 52% ( $n = 83$ ) were 30 – 49 years old, 15% ( $n = 25$ ) were 50 – 69

years old, and 1% ( $n = 2$ ) was 70 years old or older. Less than half ( $n = 65$  or 40%) of participants reported training in the heat 0 – 4 months of the year, 52% ( $n = 84$ ) reported training in the heat 5 – 8 months of the year, and 8% ( $n = 13$ ) reported training in the heat 9 or more months of the year. Participation in training under the supervision of a healthcare professional (e.g. coach, athletic trainer, strength and conditioning specialist, doctor, personal trainer, or another health professional) was reported by 27% ( $n = 43$ ) of the sample. Supervised training was defined as either exercising directly under the supervision of a healthcare professional or as participation in a training program designed by a healthcare professional. All participants completed an online informed consent form prior to data collection and were given the opportunity to decline to participate. The University Institutional Review Board approved this study (see Appendix A).

### *Questionnaire*

The lead investigator developed the questionnaire used in this study (see Appendix B). Questionnaire items were influenced by content from recent research articles assessing hydration knowledge among collegiate athletes (Rockwell, Nickols-Richardson, & Thye, 2001; Shifflett et al., 2002; Torres-McGehee et al., 2012) and recreational runners (O'Neal et al., 2011; Winger et al., 2010), review papers (Coyle, 2004; Maughan & Shirreffs, 2008), and position stands regarding fluid replacement, performance, and prevention of heat illness (Binkley, Beckett, Casa, Kleiner, & Plummer, 2002; Casa et al., 2000; Casa et al., 2015; McDermott et al., 2017; Sawka et al., 2007). The survey questions were reviewed for readability and content by the co-investigators, who included experienced researchers, experienced runners, and a certified

athletic trainer. Revisions were made and three female runners and three male runners evaluated a draft survey. After completing the survey, the runners provided feedback on items that were unclear and provided suggestions on content revisions.

The survey consisted of 3 sections: a demographic section, a hydration knowledge section, and a section on hydration information sources. In the demographics section, participants reported age, sex, training volume, race experience, race finishing times, and participation in supervised training. The section on hydration knowledge consisted of 13 multiple choice questions on topics such as: fluid accessibility, body weight reduction and distance running performance, signs of dehydration, methods of assessing hydration status, urinary markers of hydration status, determining post-exercise fluid needs, consumption of sports drinks during exercise, and inclusion of sodium in post-exercise beverages and meals. Runners were asked to select the best answer to each of the questions based on their knowledge of hydration practices. All questions were weighted equally. An overall score of 75% or more indicated *adequate hydration knowledge*, and a score less than 75% indicated *inadequate hydration knowledge* (Torres-McGehee et al., 2012).

In the section on hydration information sources, runners were asked to rate the importance of sources of hydration information used in developing their hydration strategies. A visual analog scale with anchors at 0 “*not at all important*” and 10 “*extremely important*” was used to rate the importance of each of the following information sources: Advertisements from magazines or commercials, peer-reviewed scientific research articles, articles from the internet, or in books, magazines, or

newspapers, advice from healthcare professionals (e.g. personal trainers, coaches, registered dietitians, doctors, or athletic trainers), advice from other distance runners, guidelines from organizations such as the NATA or ACSM. Directions specified that runners should score any sources that they do not use as 0 “*not at all important.*” If participants indicated other as a source of information, they were asked to describe the source.

### *Procedures*

Recruitment of runners was achieved by emailing runners through databases maintained by local running clubs and by posting web links on selected websites. Runners enrolled in local running clubs were contacted directly via email by their club president or organizer. The e-mail message contained a brief statement on the purpose and benefits of the study, and a link that directed participants to a professional, secure website (Qualtrics, Provo, Utah). Upon reaching the website, participants were provided with an overview of the questionnaire and the purpose of the study and provided the opportunity to consent to participate. Data collection lasted approximately 1 month.

### *Statistical Analysis*

International Business Machines Corporation Statistical Packages for the Social Sciences (version 19.0; SPSS Inc, Chicago, IL) software was used to conduct data analysis. The  $\alpha$  level was set at .05 for all analyses. Descriptive statistics were calculated as means and standard deviations, frequencies, and percentages. Participants were separated into groups based on methods described by O’Neal et al. (2011). Parameters used to categorize runners included running volume, performance based on expected race



completion time, and racing experience (VPE). The VPE was determined from a weighted z score based on expected finishing time of their best race (weighted 35%, expected finishing times were categorized, with 1 representing the slowest category and 6 representing the fastest category), average miles per week (weighted 35%), participation in organized running events over the last 24 months (weighted 15%), and number of aerobic exercise sessions per week (weighted 15%). Runners' z scores were ranked and separated into tertiles (low = Low; moderate = Mod; and high = High), based on the weighted z score.

A Welch analysis of variance (ANOVA) with Games-Howell pairwise comparisons was used to compare the overall hydration knowledge scores among runner VPE groups. A Chi-Square Test of independence was used to compare knowledge level (inadequate, adequate) among VPE groups. A two-way ANOVA was used to compare differences in importance ratings for hydration information, where runner VPE was a between-subjects variable and source of information was a within-subjects variable.

### ***Results***

A total of 227 runners completed the online survey. Due to missing data, 66 surveys were excluded resulting in a total of 161 surveys included in data analysis. The low, moderate, and high VPE groups consisted of 56, 52, and 53 runners, respectively. Descriptive and training history by VPE level are displayed in Table 1.

Hydration knowledge scores for low, moderate, and high VPE groups were  $40.9 \pm 18.2$ ,  $43.9 \pm 12.8$ , and  $32.6 \pm 21.2$ , respectively. The hydration knowledge scores

Table 1

## Participant Descriptive Statistics and Training Histories by VPE Group

Item	VPE Group			
	Low	Moderate	High	Full sample
Age	41.5 ± 12.2	37.3 ± 13.8	35.5 ± 15.5	38.2 ± 14.0
Males / females ( <i>n</i> )	27/29	34/18	46/7	
Training sessions/week	3.8 ± 2.0	5.2 ± 1.9	7.2 ± 1.9	5.4 ± 2.4
Training sessions/week >1 hour	1.9 ± 1.6	2.9 ± 1.8	4.7 ± 2.1	3.2 ± 1.6
Miles run/week	18.7 ± 6.8	35.3 ± 8.6	62.4 ± 15.6	38.6 ± 21.2
Months/year spent training in heat	5.5 ± 2.0	4.8 ± 1.6	4.9 ± 2.1	5.1 ± 1.9
Weekly two-a-day sessions or sessions separated by < 12 hours	0.7 ± 1.0	1.2 ± 1.5	1.8 ± 1.8	1.2 ± 1.5
Organized races past 24 months	7.9 ± 6.2	14.8 ± 13.4	13.9 ± 11.1	12.1 ± 11.0
% of training under supervision of health professional	14.8	34.6	31.5	26.9

*Note.* VPE = classifications of runners based on training volume, race performance, and race experience.

differed significantly among the VPE groups,  $F(2, 102.4) = 5.49, p = .005, \eta^2 = .067$ , with the moderate VPE group having greater knowledge than the high VPE group. The intended Chi-Square analysis to compare knowledge level (inadequate, adequate) among VPE groups could not be performed because only 1 out of 162 individuals was considered to have adequate hydration knowledge (i.e., hydration knowledge score of 75% or higher).

Descriptive statistics for ratings of importance for hydration information sources are presented in Table 2. The importance ratings differed by source of information,  $F(4.9, 704.4) = 87.83, MSE = 8.93, G-G p < .001, partial \eta^2 = .379$ , and by VPE group,  $F(2, 144) = 3.87, MSE = 19.37, p = .023, partial \eta^2 = .051$ . The interaction test was not significant,  $F(9.8, 704.4) = 1.71, MSE = 8.93, G-G p = .077, partial \eta^2 = .023$ . Sidak pairwise comparisons were conducted for source of information. Advice from distance runners was rated higher in importance than any other source of information (see Table 2). Peer-reviewed scientific research articles; articles from the internet, or in books, magazines, or newspapers; and advice from other healthcare professionals, such as registered dietitians, doctors, or athletic trainers were viewed as more important than advertising from magazines or commercials; guidance from organizations such as the NATA or ACSM, and 'Other' sources. Guidance from organizations such as the NATA or ACSM was rated as more important than information from advertising in magazines or commercials and 'Other' sources. The Games-Howell multiple comparisons indicated that low VPE runners consistently rated sources as more important than did high VPE runners.

Table 2

Ratings of Importance by Hydration Information Source ( $M \pm SD$ )

Source of Information	VPE Group <sup>1</sup>			Total <sup>2</sup>
	Low	Moderate	High	
Advertisements from magazines or commercials	1.5 ± 2.3	1.4 ± 1.9	0.7 ± 1.6	1.2 <sup>a</sup> ± 1.9
Peer-reviewed scientific research articles	5.8 ± 3.7	4.3 ± 3.5	5.0 ± 3.7	5.0 <sup>b,c</sup> ± 3.6
Articles from the internet, or in books, magazines, or newspapers	4.9 ± 3.0	4.4 ± 2.8	4.5 ± 2.9	4.6 <sup>b,c</sup> ± 2.9
Advice from other healthcare professionals, such as registered dietitians, doctors, or athletic trainers	6.6 ± 3.3	5.1 ± 3.5	4.8 ± 3.6	5.5 <sup>c</sup> ± 3.5
Advice from other distance runners	6.8 ± 2.5	6.6 ± 2.9	5.9 ± 3.1	6.5 ± 2.8
Guidelines from organizations such as the National Athletic Trainers' Association or American College of Sports Medicine	4.0 ± .7	2.7 ± 3.2	2.2 ± 3.2	3.0 ± 3.5
Other	0.9 ± 1.9	1.4 ± 2.8	1.2 ± 2.4	1.2 <sup>a</sup> ± 2.5

*Note.* <sup>1</sup> = Low, Moderate, and High are classifications based on training volume, race performance, and race experience. <sup>2</sup> = Source of information marginal total means with the same letter indicate no significant difference using a familywise alpha of .05. A digital analog scale with anchors at 0 (“not at all important”) and 10 (“extremely important”) was used to rate the importance of all information sources.

### *Discussion*

In this study, the level of hydration knowledge and sources of hydration information utilized among recreational runners at varying levels of competition and abilities were explored. The most significant finding of this investigation was that the full sample of runners exhibited inadequate overall levels of hydration knowledge. In the current sample, the majority of runners correctly identified times at which fluids should be readily accessible to distance runners, when consumption of sports drinks during exercise is recommended, foods and beverages that stimulate thirst and enhance fluid retention, signs of dehydration, and methods for assessing hydration status. However in contrast, the majority of runners incorrectly answered questions regarding body weight loss and distance running performance, urine color indicative of significant dehydration, pre-exercise urine specific gravity and urine osmolality values indicating euhydration, day-to-day body weight fluctuations in a euhydrated state, the use of body weight changes for determining post-exercise fluid needs, and the volume of fluid needed to achieve complete recovery from dehydration.

Findings of similar decrements in hydration knowledge have been documented in collegiate athletes and recreational runners. Torres-McGehee et al. (2012) reported collegiate athletes scored  $54.7\% \pm 24.2\%$  on the hydration knowledge portion of a nutrition survey, suggesting inadequate hydration knowledge. Winger et al. (2010) surveyed recreational runners on their beliefs regarding multiple hydration behaviors and the physiological effects of dehydration and overhydrating. Results indicated that 20% of recreational runners believed that dehydration and heat stroke were the result of “running

too fast,” and sodium sweat losses were the primary cause of hyponatremia. Based on a survey of 276 non-elite half and full marathon runners, O’Neal et al. (2011) reported only 20% of runners reported monitoring their hydration status, and only 2% of runners reported using changes in body mass to assess hydration status or determine fluid needs following exercise. The results of these studies, in conjunction with the current data, indicate that hydration knowledge in the running community is poor. This deficit in hydration knowledge promotes poor hydration practices, which can increase the risk of experiencing performance decrements and adverse health effects from both dehydration and overhydrating. Recreational runners commonly train and compete in hot and humid environments, where sweat losses of 1-2 L per hour are common (Sawka et al., 2007). Experiencing significant levels of dehydration during strenuous exercise in the heat increases the risk of muscle cramping and heat illness (e.g. heat exhaustion and heat stroke). Previous studies have also shown that levels of dehydration exceeding 2% body mass decrease running performance (Armstrong, Costill, & Fink, 1985; Casa et al., 2010; Davis et al., 2014; Fallowfield, Williams, Booth, Choo & Grows, 1996; McDermott et al., 2017). It is critical for recreational runners to employ proper hydration practices in order to prevent levels of dehydration resulting in performance decrements and increased risk of heat illness.

Although there is an abundance of literature providing information to runners on various hydration strategies (Cheuvront, Carter, & Sawka, 2003; Cheuvront, Montain, & Sawka, 2007; Maughan & Shirreffs, 2008; Shirreffs, Armstrong, & Cheuvront, 2004) recreational runners commonly report experiencing performance decrements and

symptoms of heat illness during and after exercise due to dehydration. Among the half and full-marathoners surveyed by O'Neal et al. (2011), nearly 70% reported experiencing performance decrements due to dehydration, and 45% reported experiencing symptoms of heat illness due to dehydration. Among runners in this study, those in the high VPE group had the lowest levels of hydration knowledge. This finding is striking because these runners likely experience higher levels of dehydration during exercise and are more likely to experience heat illness due to their more frequent completion of longer runs at higher intensities. This conclusion is supported by the findings of O'Neal et al. (2011) that the incidence of performance decrements and heat illness due to dehydration increased as VPE level increased, and that the incidence of performance decrements was highest among runners in the high VPE group. Together, these findings support the need for increasing hydration knowledge in the running community, particularly among high-level recreational runners. Providing hydration education to such runners would likely help to decrease the incidence of performance decrements and heat illness in the running community. Providing education and increasing knowledge regarding the benefits associated with a behavior change is pivotal in helping individuals adopt new behaviors (Brehm, 2004). Thus, further education is needed in the running community on the relationships among hydration practices, exercise performance, and health. Increasing hydration knowledge and awareness of the safety and performance benefits associated with employing appropriate hydration practices may encourage the adoption of said practices in the running community.

The top five sources of hydration information among runners in the current sample, in order of importance, were advice from other runners, advice from healthcare professionals, peer-reviewed research articles, articles from the internet, or in books, magazines, or newspapers, and fluid replacement guidelines. Information from advertisements in magazines and commercials, and “other” sources received the lowest ratings of importance from all runners. Winger et al. (2010) and O’Neal et al. (2011) concurrently reported that runners favored advice from other runners, rather than peer reviewed literature, professional position stands, and advertisements, when developing their hydration strategies. These previous findings, in conjunction with findings from this study, suggest that recreational runners place great importance on information obtained through interpersonal communication, particularly with other runners. However, as discussed above, many recreational runners possess inadequate levels of hydration knowledge, and therefore may be a poor source of information on dehydration and hydration practices. A heavy reliance on the advice of peer runners likely promotes the dissemination of inaccurate hydration information within the running community, and may help to explain why many recreational runners possess inadequate levels of hydration knowledge.

Previous researchers (Burns, Schiller, Merrick, & Wolf, 2004; Torres-McGehee et al., 2012) have reported that healthcare professionals, such as athletic trainers and strength conditioning specialists, were the top choices for sport-nutrition information among collegiate athletes. However, over 70% of the 161 runners in this study trained without the supervision of a healthcare professional. As such, most runners likely



develop their hydration strategies based on trial-and-error and the advice of other runners. This conclusion is supported by the decreasing importance placed on this information source as VPE level increased. Overall, the high importance that recreational runners place on the advice of healthcare professionals highlights the need for increasing personal interaction between healthcare professionals and the running community. Previous research found that a one-on-one training program increased hydration knowledge, attitudes, and practices of general practitioners working in clinical care settings (McCotter et al., 2016). Similar training programs in which healthcare professionals disseminate information about hydration, exercise performance, and safety to recreational runners in a conversational format may be successful at improving hydration knowledge and practices in the running community. Healthcare professionals might effectively provide such training to recreational runners by setting up information booths at race events and by conducting workshops for running clubs. Future research should evaluate the effectiveness of education interventions at improving the hydration knowledge and practices of recreational runners.

All runners in this study viewed information from sources such as peer-reviewed research articles, and articles from the internet, or in books, magazines, or newspapers as moderately important. While scientific research articles are likely reputable sources of information, without an understanding of current literature in the field, these articles can be hard to read and understand, and therefore, it can be difficult for lay runners to extrapolate research findings to real-world settings. Information on hydration practices conveyed on websites, or in books, fitness magazines, or newspapers may be particularly

alluring to recreational runners because these sources are easily accessible, and often the information presented in these sources is portrayed as “scientifically based” advice. However, a recent review of hydration advice from sources such as websites, textbooks, and fitness magazines indicated that much of the advice presented in these sources is obsolete or not evidence-based (Beltrami et al., 2008). Thus, recreational runners should scrutinize information from such sources before using this information in the development of their hydration practices.

Interestingly, despite the fact that ACSM and NATA fluid replacement guidelines are based upon current scientific literature, the ratings of importance for these guidelines were low among all runners. This finding mirrors that of Winger et al. (2010) who reported that few recreational runners pay heed to hydration guidelines published by national and international sport science organizations. A possible explanation for the low importance placed on information from such guidelines may be an increased message of drink-to-thirst in the running community. Drink-to-thirst has been demonstrated to be a safe method of fluid replacement during exercise (Dugas, Oosthuizen, Tucker, & Noakes, 2009), and is a practice advocated in scientific literature (Beltrami et al., 2008; Winger et al., 2010) and in hydration guidelines published by the International Medical Marathon Directors Association (Hew-Butler, Verbalis, & Noakes, 2006). Nonetheless, it is clear that recreational runners place little importance on the information presented in ACSM and NATA guidelines when developing their hydration strategies. This finding demonstrates that the methods used by the ACSM and NATA to disseminate hydration information to athletes are not sufficient to reach recreational runners. Given the high

incidence of dehydration-induced performance decrements and heat illness among recreational runners it is imperative that sport science organizations utilize websites and magazines that are popular amongst recreational runners to disseminate information and educate the recreational running community.

While this study primarily focused on assessing the influence of external information sources on the development of hydration practices, if runners indicated “other” as a source of information, they were asked to provide a description of the information source. An evaluation of these open-ended responses revealed that internal sources of information such as trial-and-error and personal experience were influential in the development of hydration practices. These open-ended responses mirror previous research findings (Winger et al. 2010) indicating that most recreational runners base their hydration practices on their personal experiences. It is also intriguing that low VPE runners rated all information sources as more important compared to runners in the moderate and high VPE groups. This finding suggests that runners who have less personal experience to base their hydration practices upon are more likely to seek information from a multitude of sources, both reputable and disreputable, to develop their hydration strategies upon, and that these runners are more easily influenced by the information presented in those sources. Running coaches, running clubs and healthcare professionals should make efforts to educate less experienced runners on hydration practices advocated by the ACSM and NATA, and on where to find reputable evidence-based hydration information. Doing so may help increase the importance that the running

community places on these resources, and encourage the adoption of evidence-based hydration practices to improve safety and performance.

In conclusion, a substantial deficit in hydration knowledge exists among recreational runners. This knowledge deficit is partly due to: 1) recreational runners obtaining hydration advice from disreputable or obsolete sources such as peer runners, websites, textbooks, and fitness magazines; 2) limited interaction between healthcare professionals and the running community; and 3) the low importance that recreational runners place on guidelines published by sport science organizations such as the ACSM and NATA. Limitations of this study include a low response rate, and the biases of self-reporting. Additionally, this study focused on assessing the level of hydration knowledge possessed by recreational runners; thus, readers should be cautious when extrapolating these results to more-elite distance runners.

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APPENDICES FOR STUDY I

## APPENDIX A

## IRB Approval Letter

**IRB****INSTITUTIONAL REVIEW BOARD**

Office of Research Compliance,  
010A Sam Ingram Building,  
2269 Middle Tennessee Blvd  
Murfreesboro, TN 37129

**IRBN001 - EXPEDITED PROTOCOL APPROVAL NOTICE**

Tuesday, July 05, 2016

Investigator(s): Brett Davis (PI), Jenn Caputo (FA), John Coons, Richard Farley and Dana Fuller  
 Investigator(s)' Email(s): *bad4e@mtmail.mtsu.edu; jenn.caputo@mtsu.edu*  
 Department: Health and Human Performance

Study Title: *Assessment of hydration knowledge and hydration strategies employed by distance runners at varying levels of competition*  
 Protocol ID: **16-2301**

Dear Investigator(s),

The above identified research proposal has been reviewed by the MTSU Institutional Review Board (IRB) through the **EXPEDITED** mechanism under 45 CFR 46.110 and 21 CFR 56.110 within the category (7) *Research on individual or group characteristics or behavior*. A summary of the IRB action and other particulars in regard to this protocol application is tabulated as shown below:

IRB Action	APPROVED for one year from the date of this notification
Date of expiration	<b>7/5/2016</b>
Sample Size	500 (FIVE HUNDRED)
Participant Pool	<b>Adult (18 years or older) who self-identify as recreational runners</b>
Exceptions	Collection of online consent is permitted
Restrictions	<b>Mandatory informed consent</b>

Comments	Quiz for the CITI's "Internet-Based Research" module for faculty co-investigators is waived for this study only.	
Amendments	<b>Date</b>	<b>Post-approval Amendments</b> NONE

This protocol can be continued for up to THREE years (**7/5/2019**) by obtaining a continuation approval prior to **7/5/2017**. Refer to the following schedule to plan your annual project reports and be aware that you may not receive a separate reminder to complete your continuing reviews. Failure in obtaining an approval for continuation will automatically result in cancellation of this protocol. Moreover, the completion of this study MUST be notified to the Office of Compliance by filing a final report in order to close-out the protocol.

Continuing Review Schedule:

Reporting Period	Requisition Deadline	IRB Comments
First year report	6/5/2017	INCOMPLETE
Second year report	6/5/2018	INCOMPLETE

IRBN001      Version 1.3  
Office of Compliance

Revision Date 03.06.2016 Institutional Review Board  
Middle Tennessee State University

Final report	6/5/2019	INCOMPLETE
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The investigator(s) indicated in this notification should read and abide by all of the post-approval conditions imposed with this approval. [Refer to the post-approval guidelines posted in the MTSU IRB's website](#). Any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918 within 48 hours of the incident. Amendments to this protocol must be approved by the IRB. Inclusion of new researchers must also be approved by the Office of Compliance before they begin to work on the project.

All of the research-related records, which include signed consent forms, investigator information and other documents related to the study, must be retained by the PI or the faculty advisor (if the PI is a student) at the secure location mentioned in the protocol application. The data storage must be maintained for at least three (3) years after study completion. Subsequently, the researcher may destroy the data in a manner that maintains confidentiality and anonymity. IRB reserves the right to modify, change or cancel the terms of this letter without prior notice. Be advised that IRB also reserves the right to inspect or audit your records if needed.

Sincerely,

Institutional Review Board  
Middle Tennessee State University

## APPENDIX B

## Hydration Knowledge Questionnaire

Demographics

1. What is your age?
2. What is your sex?
  - a. Male
  - b. Female
3. How many endurance training sessions do you complete during an average training week?
  - a. 1-2
  - b. 3-5
  - c. 6-7
  - d. > 7
4. How many endurance training sessions lasting longer than 1 hour do you complete in an average training week?
5. How many miles do you run during an average training week?
6. Do you frequently train and compete in warm or hot environments (> 85° F or > 30° C)?
  - a. Yes
  - b. No
7. How often do you complete two-a-day training bouts or training bouts separated by less than 12 hours (e.g. an evening run followed by a run the next morning)?
  - a. Never
  - b. 1-2 times per week
  - c. 3- 4 times per week
  - d. > 5 times per week
8. How many competitions of half-marathon distance or longer have you completed in the last 24 months?
9. What is your predicted finishing time for a half-marathon?
  - a. < 1.5 hour
  - b. 1.5 – 1.75 hours
  - c. 1.75 - 2.0 hours
  - d. 2.0 – 2.25 hours
  - e. 2.25 – 2.5 hours
  - f. > 2.5 hours

10. Do you regularly train under the supervision of a coach, athletic trainer, strength conditioning specialist, doctor, or any other healthcare professional?
  - a. Yes (If yes, please list what specialists you work with)
  - b. No
  
11. Please rank the importance of the following sources of hydration information in developing the hydration strategies you use. Mark sources that you do not use as 0 “not important at all”.
  - a. Advertisements from magazines or commercials
  - b. Peer-reviewed scientific research articles
  - c. Articles from the internet, or in books, magazines, or newspapers
  - d. Advice from other healthcare professionals, such as registered dietitians, doctors, or athletic trainers
  - e. Advice from other distance runners
  - f. Guidelines from organizations such as the National Athletic Trainers’ Association or American College of Sports Medicine
  - g. Other
  - h. Not applicable

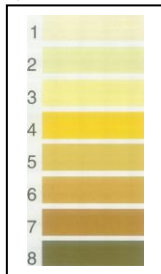
#### Hydration Knowledge

Please select the best answer for each of the following questions based on your knowledge of hydration practices for distance runners.

1. When should beverages be readily accessible to distance runners?
  - a. Before exercise
  - b. During exercise
  - c. After exercise
  - d. Before, during, and after exercise
  
2. Body weight reductions of greater than what percentage will decrease distance running performance?
  - a. 1%
  - b. 2%
  - c. 3%
  - d. 4%
  
3. Day-to-day, first-morning body mass for well hydrated distance runners should be stable and fluctuate by less than what percentage?
  - a. < 1%
  - b. < 2%
  - c. < 3%
  - d. < 4%
  - e. Other (e.g. stay within 2 pounds of baseline)

4. Based on the urine color chart, which urine colors represent significant dehydration?

- a. 1 or 2
- b. 3 or 4
- c. 5 or 6
- d. greater than 6



5. What value of pre-exercise urine specific gravity represents proper hydration status?

- a. Less than 1.010
- b. Less than 1.020
- c. Less than 1.025
- d. Less than 1.030

6. What value of pre-exercise urine osmolality represents proper hydration status?

- a. < 700 mOsmol
- b. < 800 mOsmol
- c. < 900 mOsmol
- d. < 1000 mOsmol

7. What is the best way to determine how much water or sports drink a distance runner should consume between exercise bouts?

- a. Assessing urine color immediately following a run
- b. Assessing urine osmolality immediately following a run
- c. Assessing urine specific gravity immediately following a run
- d. Measuring the change in pre- to post-run body mass
- e. Thirst sensation
- f. None of the above

8. Which of the following may indicate that a runner is dehydrated?

- a. Excessive thirst
- b. Delayed onset of sweating
- c. Muscle cramping
- d. Decreased heat tolerance
- e. Early onset of fatigue
- f. All of these are sign of dehydration

9. What is the goal of fluid replacement following exercise?

- a. Replace all fluid and electrolytes lost
- b. Satisfy thirst sensation
- c. Minimize further body water losses from bowel movements and respiration
- d. None of the above

10. Distance runners should consume a volume of fluid equivalent to what percent of sweat loss to achieve complete recovery from dehydration?
  - a. 100-125%
  - b. 125-150%
  - c. 150-175%
  - d. 175-200%
  
11. Consuming beverages which contain carbohydrates can help sustain exercise intensity during runs exceeding how many minutes?
  - a. 30 minutes
  - b. 60 minutes
  - c. 75 minutes
  - d. 90 minutes
  
12. Which method can be used to assess a runner's hydration status?
  - a. A series of nude first morning body weights (measured after urinating) can be used to establish a baseline body weight which is representative of being well hydrated
  - b. Assessment of pre-exercise urine color
  - c. Measurement of pre-exercise urine specific gravity
  - d. Measurement of pre-exercise urine osmolality
  - e. All of the above are methods of assessing hydration status
  
13. Consuming which of the following beverages and foods will help stimulate thirst and enhance fluid retention?
  - a. Sodium containing beverages such as sports drinks
  - b. Alcoholic beverages
  - c. Salted snacks and/or meals
  - d. Both a & b
  - e. Both b & c



CHAPTER IV  
ASSESSMENT OF HYDRATION PRACTICES EMPLOYED BY  
RECREATIONAL RUNNERS AT VARYING ABILITY LEVELS

*Introduction*

Every year millions of recreational runners train for and compete in organized races varying from 5 km to ultra-marathon distances in a wide range of environmental conditions. Proper hydration is an important nutrition practice for the maintenance of running performance and the prevention of heat illness and hyponatremia. However, the information that runners encounter with respect to hydration practices varies depending on the source of information. The American College of Sports Medicine (ACSM) and the National Athletic Trainers Association (NATA) have published hydration guidelines (Casa et al., 2000; McDermott et al., 2017; Sawka et al., 2007) promoting planned fluid intake strategies, based on sweat rate, which prevent body weight losses exceeding 2% during exercise. Conversely, the International Marathon Medical Directors Association (IMMDA) has published a consensus statement advocating thirst-driven fluid consumption during training and racing (Hew-Butler, Verbalis, & Noakes, 2006). The efficacy of these drinking strategies has been debated feverishly within the scientific community (Adolph & Dill, 1938; Armstrong, Johnson, & Bergeron, 2016; Bardis et al., 2017; Beltrami, Hew-Butler, & Noakes, 2008; Chevront, Kenefick, Montain, & Sawka, 2010; Chevront, Montain, & Sawka, 2007; Dill, Bock, & Edwards, 1933; Dion, Savoie,

Asselin, Gariépy, & Goulet, 2013; Dugas, Oosthuizen, Tucker, & Noakes, 2009; Greenleaf, Brock, Keil, & Morse, 1983; Greenleaf & Sargent, 1965; Kenefick, 2018; Noakes, 2010); however, few researchers have evaluated the utilization of these recommendations among recreational runners. Furthermore, limited research has been conducted to evaluate the use of the field techniques for assessing hydration status promoted by the ACSM and NATA, such as urine color, urine specific gravity (USG), and changes in body weight.

To date, Winger, Dugas and Dugas (2010) and O'Neal et al. (2011) have examined hydration practices among recreational runners. Winger et al. (2010) reported that among 197 recreational runners, 55.7% of runners drank only when thirsty, 36.9% utilized planned drinking schedules, and 8.9% drank as much as possible during racing and training. O'Neal et al. (2011) reported that among 276 recreational half and full marathoners, less than half of the runners (42%) reported always consuming fluids during outdoor runs in the heat, and 6% of the running sample reported never drinking during outdoor runs in the heat. However, there was no inquiry regarding barriers to fluid consumption while running. In addition, only 20% of the runners reported using any method to assess their hydration status, and urine color was the method most commonly used, but the authors did not inquire about the time and manner in which urine color was assessed. Furthermore, 70% and 45% of the runners reported experiencing performance decrements and symptoms of heat illness, respectively, as result of dehydration; yet, the factors that runners believed caused these events were not explored. Finally, fluid intake behaviors during races of various distance in cool and hot environments has not been

investigated, nor has the point at which runners begin to drink during races of half-marathon distance or longer. Thus, additional research evaluating hydration practices among recreational runners is warranted. Such research may shed light on areas where further education is needed in the running community, help decrease the incidence of performance decrements and heat illness among runners, help improve the use of the information in the guidelines of sport science organizations, and assist in the dissemination of those guidelines among recreational runners.

Therefore, the purpose of this study was to identify fluid intake behaviors of recreational runners during training, and during 5k, 10k, half-marathon, and full-marathon races in cool and hot environments. The barriers to fluid consumption while running were investigated, in addition to the incidence and causes of performance decrements and heat illness. Lastly, the hydration status monitoring techniques employed by recreational runners were examined. Differences in responses among areas were explored based on ability level.

### ***Methods***

#### *Participants*

Survey participants included 161 runners, of which 66% were male ( $n = 107$ ) and 34% were female ( $n = 54$ ). Participant age ranged from 18 to 72 years. A total of 52 runners (32%) were 18-29 years old, 83 runners (52%) were 30-49 years old, 25 runners (15%) were 50-69 years old, and 2 runners (1%) were 70 years old or older. Training in the heat 0 – 4 months of the year was reported by 40% ( $n = 65$ ) of runners. Training in the heat 5 – 8 months of the year was reported by 52% ( $n = 84$ ) of runners. Training in

the heat 9 or more months of the year was reported by 8% ( $n = 13$ ) of runners. Training under the supervision of a healthcare professional (e.g. a coach, athletic trainers, strength conditioning specialist, doctor, or fitness professional) was reported by 43 runners (27%). All participants completed an online consent form prior to data collection, and all participants were given the option to decline participation. The study methodology was approved by the University Institutional Review Board (see Appendix A).

### *Questionnaire*

The principal investigator developed the questionnaire used in this study (see Appendix B). Questionnaire items were influenced by content from recent research articles (O'Neal et al., 2011; Shifflett, Timm, & Kahanov, 2002; Winger et al., 2010), review papers (Coyle, 2004; Maughan & Shirreffs, 2008), and position stands regarding fluid replacement, performance, and prevention of heat illness (Binkley, Beckett, Casa, Kleiner, & Plummer, 2002; Casa et al., 2000; Casa et al., 2015; McDermott et al., 2017; Sawka et al., 2007). Experienced researchers, experienced runners, and a certified athletic trainer for readability and content reviewed all survey questions. Following revision by these individuals, three female runners and three male runners evaluated the survey and provided feedback on items that lacked clarity. The survey instrument was finalized after revisions were made to address feedback provided by these runners.

The survey consisted of a demographic section and sections on hydration behaviors during training and competition, performance decrements and symptoms of heat illness, and hydration monitoring techniques. The demographics section consisted of questions regarding age, sex, training volume, race experience, estimated race finishing times, and

participation in supervised training. The section on hydration behaviors consisted of questions regarding: fluid consumption during training in cold and hot environments, fluid consumption during organized races in cold and hot environments, barriers to fluid consumption during exercise, and consideration of water and sodium content of foods and beverages consumed during recovery. The section on performance decrements and symptoms of heat illness contained questions pertaining to the occurrence of these events, as well as, the perceived cause of these events. The section on hydration assessment techniques contained questions regarding the use of techniques including: urine color, frequency and volume of urination, occurrence of dehydration-induced symptoms, urine specific gravity, and fluctuations in body weight as markers of hydration status. Additionally, the last question in this section inquired about the use of pre to post-exercise body weight changes to assess post-exercise or between-bout fluid needs.

#### *Procedures*

Runners were recruited by posting web links on designated websites, and by emailing runners through databases maintained by local running clubs. The club president or organizer directly emailed runners enrolled in the club. The e-mail message indicated the study purpose and benefits of the study, and contained a web address leading participants to a professional, secure website (Qualtrics, Provo, Utah). Upon reaching the website, participants were presented with a description of the study purpose, a synopsis of the survey instrument, and provided the opportunity to consent to participate. Data collection lasted approximately 1 month.

### *Statistical Analysis*

Data analyses were conducted using International Business Machines Corporation Statistical Packages for the Social Sciences (version 19.0; SPSS Inc, Chicago, IL) software. The  $\alpha$  level was set at .05 for all analyses. Means and standard deviations, frequencies, and percentages were calculated for all descriptive statistics. Participants were separated into groups based on procedures described by O'Neal et al. (2011). Parameters used to categorize runners included running volume, performance based on expected race finishing time, and racing experience (VPE). The VPE was determined from a weighted z score based on expected finishing time of their best race (weighted 35%, expected finishing times were categorized, with 1 representing the slowest category and 6 representing the fastest category), average miles per week (weighted 35%), number of organized running events completed over the last 24 months (weighted 15%), and number of aerobic exercise sessions per week (weighted 15%). Runners' weighted z scores were ranked and separated into tertiles (low = Low; moderate = Mod; and high = High). Chi-Square Tests of Independence were then conducted among VPE groups to compare hydration behaviors, barriers to fluid consumption during training, the occurrence of decreases in running performance and symptoms of heat illness, the perceived cause of dehydration leading to performance decrements and symptoms of heat illness, and hydrations status monitoring techniques.

### ***Results***

The sample included 161 runners. Descriptive statistics and training histories by VPE level are displayed in Table 1.

Table 1

## Participant Descriptive Statistics and Training Histories by VPE Group

Item	VPE Group			Full sample
	Low	Moderate	High	
Age	41.5 ± 12.2	37.3 ± 13.8	35.5 ± 15.5	38.2 ± 14.0
Males / females ( <i>n</i> )	27/29	34/18	46/7	
Training sessions/week	3.8 ± 2.0	5.2 ± 1.9	7.2 ± 1.9	5.4 ± 2.4
Training sessions/week >1 hour	1.9 ± 1.6	2.9 ± 1.8	4.7 ± 2.1	3.2 ± 1.6
Miles run/week	18.7 ± 6.8	35.3 ± 8.6	62.4 ± 15.6	38.6 ± 21.2
Months/year spent training in heat	5.5 ± 2.0	4.8 ± 1.6	4.9 ± 2.1	5.1 ± 1.9
Weekly two-a-day sessions or sessions separated by < 12 hours	0.7 ± 1.0	1.2 ± 1.5	1.8 ± 1.8	1.2 ± 1.5
Organized races past 24 months	7.9 ± 6.2	14.8 ± 13.4	13.9 ± 11.1	12.1 ± 11.0
% of training under supervision of health professional	14.8	34.6	31.5	26.9

*Note.* VPE = classifications of runners based on training volume, race performance, and race experience. Unless indicated, values presented as  $M \pm SD$ .

VPE level are displayed in Table 1.

### *Hydration Behaviors*

Frequencies and test results for hydration behavior items with statistically significant test results are presented in Table 2. The low, moderate, and high VPE groups contained 55, 52, and 54 runners, respectively. A greater percentage of moderate VPE ( $n = 39$ ) runners (80%) consumed fluids during runs in the heat than did high VPE ( $n = 20$ ) runners (54%),  $\chi^2(2, 134) = 7.27, p = .026$ . A greater percentage of low VPE runners (38%) made plans to consume fluids during runs lasting longer than 30 minutes than did high VPE runners (13%),  $\chi^2(8, 134) = 17.25, p = .028$ . A greater percentage of low VPE runners (23%) consumed fluids during 5k races in cool or cold weather than did high VPE runners (3%),  $\chi^2(2, 133) = 8.42, p = .015$ . A greater percentage of low VPE runners (51%) consumed fluids during 10k races in cool or cold weather than did high VPE runners (14%),  $\chi^2(2, 133) = 14.43, p = .001$ . A greater percentage of high VPE runners (84%) consumed fluids during marathon races in cool or cold weather than did low VPE runners (55%),  $\chi^2(2, 133) = 8.36, p = .015$ . A greater percentage of low VPE runners (54%) consumed fluids during 5k races in hot weather than did high VPE runners (11%),  $\chi^2(2, 133) = 17.39, p < .001$ . A greater percentage of high VPE runners (89%) consumed fluids during marathon races in hot weather than did low VPE runners (46%),  $\chi^2(2, 133) = 16.70, p < .001$ .

For non-significant hydration behavior items, only the overall percentages are reported because there were no differences among VPE groups. Making plans to consume fluids during training runs based on the environmental temperature did not differ among VPE groups,  $\chi^2(6, 95) = 5.01, p = .542$ . In the sample, 24% of the runners



Table 2

## Frequencies and Chi-Square Tests for Hydration Behavior Items

Hydration behavior item	Response	VPE Group <sup>1</sup>		
		Low	Moderate	High
Do you regularly consume fluids during runs in hot weather? (> 85°F or > 30°C)	Yes	36 <sub>a,b</sub>	39 <sub>b</sub>	20 <sub>a</sub>
	No	12 <sub>a,b</sub>	10 <sub>b</sub>	17 <sub>a</sub>
$\chi^2(2, 134) = 7.27, p = .026$				
How long does a training run have to be before you make plans to consume fluid during the run?	> 30 min	18 <sub>a</sub>	14 <sub>a,b</sub>	4 <sub>b</sub>
	> 45 min	10 <sub>a</sub>	11 <sub>a</sub>	4 <sub>a</sub>
	> 60 min	13 <sub>a</sub>	14 <sub>a</sub>	12 <sub>a</sub>
	> 75 min	1 <sub>a</sub>	2 <sub>a</sub>	5 <sub>a</sub>
	> 90 min	6 <sub>a</sub>	8 <sub>a</sub>	12 <sub>a</sub>
$\chi^2(8, 134) = 17.25, p = .028$				
In cool or cold weather (< 60°F or < 15.5°C), do you drink during a 5k competitive race?	Yes	11 <sub>a</sub>	5 <sub>a,b</sub>	1 <sub>b</sub>
	No	36 <sub>a</sub>	44 <sub>a,b</sub>	36 <sub>b</sub>
$\chi^2(2, 133) = 8.42, p = .015$				
In cool or cold weather (<60°F or < 15.5°C), do you drink during a 10k competitive race?	Yes	24 <sub>a</sub>	13 <sub>b</sub>	5 <sub>b</sub>
	No	23 <sub>a</sub>	36 <sub>b</sub>	32 <sub>b</sub>
$\chi^2(2, 133) = 14.43, p = .001$				
In cool or cold weather (<60°F or < 15.5°C), do you drink during a marathon competitive race?	Yes	26 <sub>a</sub>	29 <sub>a</sub>	31 <sub>b</sub>
	No	21 <sub>a</sub>	20 <sub>a</sub>	6 <sub>b</sub>
$\chi^2(2, 133) = 8.36, p = .015$				
In hot weather (>85°F or >30°C), do you drink during a 5k competitive race?	Yes	26 <sub>a</sub>	15 <sub>a,b</sub>	4 <sub>b</sub>
	No	22 <sub>a</sub>	34 <sub>a,b</sub>	32 <sub>b</sub>
$\chi^2(2, 133) = 17.39, p < .001$				
In hot weather (>85°F or >30°C), do you drink during a marathon competitive race?	Yes	22 <sub>a</sub>	32 <sub>a</sub>	32 <sub>b</sub>
	No	26 <sub>a</sub>	17 <sub>a</sub>	4 <sub>b</sub>
$\chi^2(2, 133) = 16.70, p < .001$				

Note. <sup>1</sup> = Low, Moderate, and High are classifications based on training volume, race performance, and race experience. VPE groups with the same subscript (e.g., a) are not significantly different based on a familywise alpha = .05.

( $n = 23$ ) made plans to consume fluids during training when the temperature was greater than 60° F; 31% ( $n = 29$ ) made plans when the temperature was greater than 70° F; 27% of runners ( $n = 26$ ) made plans when the temperature was greater than 80° F; 17% of runners ( $n = 18$ ) made plans when the temperature was greater than 90° F. The percentage of runners reporting a barrier to consuming fluids while training was: 22% ( $n = 29$ ) for indigestion or stomach discomfort,  $\chi^2(2, 134) = 2.17, p = .338$ ; 60% ( $n = 80$ ) for carrying bottles or other hydration systems,  $\chi^2(2, 134) = 2.61, p = .271$ ; 50% ( $n = 67$ ) for the inconvenience of placing fluids along the route prior to training runs and/or inconvenience of scheduling fluid delivery during training runs,  $\chi^2(2, 134) = 5.74, p = .057$ . Increasing the volume of fluid consumed after training in hot environments was reported by 90% of runners ( $n = 121$ ),  $\chi^2(2, 133) = 3.23, p = .199$ . Consumption of fluids during 10k competitive races in hot weather was reported by 66% of runners ( $n = 88$ ),  $\chi^2(2, 133) = 2.51, p = .286$ . Consumption of fluids during half marathon competitive races was reported by 74% of runners ( $n = 98$ ) in cool or cold weather,  $\chi^2(2, 133) = 3.86, p = .145$ , and reported by 88% of runners ( $n = 117$ ) in hot weather,  $\chi^2(2, 133) = 1.77, p = .413$ .

During half-marathon or longer competitive races, the point at which runners begin drinking did not differ among VPE groups,  $\chi^2(4, 113) = 1.07, p = .899$ . Greater than one-fourth (29%) of runners ( $n = 33$ ) reported beginning to drink early in the race, 3% of runners ( $n = 3$ ) reported beginning to drink at mid-race, and 27% of runners ( $n = 30$ ) reported beginning to drink late in the race. The impetus for fluid consumption during half-marathon or longer races did not differ among VPE groups,  $\chi^2(6, 113) = 3.60,$

$p = .730$ . During half-marathon or longer races, drinking only when thirsty was reported by 27% of runners ( $n = 30$ ), 51% of runners ( $n = 58$ ) reported utilizing a drinking schedule, 12% of runners ( $n = 13$ ) reported drinking as much as possible, and 9% of runners ( $n = 12$ ) reported “other.” Less than one-third (30%) of runners ( $n = 39$ ) reported considering the water content of food consumed during recovery when developing hydration strategies,  $\chi^2(2, 132) = 5.28, p = .071$ . Nearly half (47%) of runners ( $n = 61$ ) reported considering the sodium content of food consumed during recovery when developing hydration strategies,  $\chi^2(2, 131) = 0.61, p = .736$ .

#### *Performance Decrements and Symptoms of Heat Illness*

The VPE groups had similar responses for each performance decrement and symptom of heat illness item. The chi-square test results to compare the VPE groups and overall percentages are reported for each item in the text below because there were no group differences. Over 80% of runners ( $n = 109$ ) reported experiencing decreases in running performance believed to be the result of dehydration,  $\chi^2(2, 132) = 0.05, p = .975$ . No differences existed among VPE groups regarding the believed cause of dehydration resulting in decreased running performance,  $\chi^2(6, 109) = 6.23, p = .398$ . The believed cause of the dehydration identified by runners was: inadequate fluid intake before or during exercise (54%,  $n = 59$ ), lack of fluid availability (10%,  $n = 11$ ), inadequate pre-run hydration strategy to compensate for actual fluid deficit (27%,  $n = 29$ ), and unexpected change in the weather (9%,  $n = 10$ ). Experiencing symptoms of heat illness believed to be the result of dehydration was reported by 58% of runners ( $n = 75$ ) during or after training,

$\chi^2(2, 132) = 0.96, p = .618$ , and reported by 57% of runners ( $n = 75$ ) during or after competition,  $\chi^2(2, 132) = 4.53, p = .104$ .

#### *Hydration Status Monitoring Techniques*

Monitoring of hydration status was reported by 68% of runners ( $n = 89$ ), and the percentage differed among VPE groups,  $\chi^2(2, 132) = 6.38, p = .041$ . A greater percentage of high VPE runners (83%) monitored hydration status compared to low VPE runners (57%). Chi-square analyses of all other hydration status monitoring techniques were non-significant which indicates that the VPE groups used similar techniques to monitor their hydration status. For these items, only the overall percentages are reported in the text below. Some items could not be analyzed because of low response numbers. For such items, the frequencies are reported but test results are not.

The method most commonly used to assess hydration status was urine color (92%,  $n = 82$ ),  $\chi^2(2, 89) = 1.57, p = .455$ . Assessment of urine color before running was reported by 70% of runners ( $n = 57$ ),  $\chi^2(2, 81) = 1.44, p = .488$ , and reported by 77% of runners ( $n = 62$ ) after running,  $\chi^2(2, 81) = 2.47, p = .290$ . Making a color judgement based on the color of one's urine stream was reported by 20 runners, and 54 runners reported basing color judgements on the color of urine in the toilet. Only 1 runner reported collecting urine in a clear container before making a color judgement. Assessing frequency or volume of urination as a marker of hydration status was reported by 58% of runners ( $n = 52$ ),  $\chi^2(2, 89) = 1.38, p = .501$ . Using the occurrence of dehydration-induced symptoms as a marker of hydration status was reported by 52% of runners ( $n = 46$ ),  $\chi^2(2, 89) = 3.20, p = .202$ . Using changes in body weight as a method of assessing

hydration status was reported by 38% of runners ( $n = 34$ ),  $\chi^2(2, 89) = 2.71, p = .257$ . The use of bioelectrical impedance for hydration status assessment was reported by 3 runners, and 1 runner reported using urine specific gravity measurements to monitor hydration status. Only 22% of runners ( $n = 29$ ) reported weighing immediately before and after exercise to calculate sweat losses and determine fluid needs,  $\chi^2(2, 131) = 0.96, p = .620$ .

### *Discussion*

The purposes of this study were to evaluate fluid intake among recreational runners during training, and during races of various distances in cool and hot environments, identify barriers to fluid consumption while running, evaluate the incidence and causes of performance decrements and heat illness among recreational runners, and evaluate the hydration status monitoring techniques employed by recreational runners. The most significant findings of this study are that 80% of runners reported having experienced performance decrements during running, 58% reported experiencing symptoms of heat illness during training, and 57% reported experiencing symptoms of heat illness during racing as result of dehydration. These findings are similar to those of O'Neal et al. (2011) who reported that 70% and 45% of 276 recreational runners reported experiencing decreases in running performance and symptoms of heat illness, respectively, as result of dehydration. The findings from this study also indicate that most recreational runners believed the primary causes of dehydration, performance decrements, and heat illness were inadequate fluid intake before or during exercise and an inadequate pre-run hydration strategy to compensate for actual fluid deficit. No matter the cause, it is clear that recreational runners are at risk of

performance decrements and heat illness as result of dehydration. Education is needed within the running community regarding the association among hydration practices, running performance, and heat-related injuries in order to decrease negative consequences.

Fluid needs during competitive races vary greatly depending on environmental temperature, intensity and duration of exercise, body size, and heat acclimatization state. In the days prior to an organized race, runners are likely to have a heightened focus on hydration. This results in many runners beginning races in a euhydrated or hyperhydrated state; thus, fluid intake during 5k and 10k races, regardless of the factors mentioned above, is negligible due to the short race duration. In the current sample, low VPE runners were more likely to consume fluids during 5k races and during 10k races in temperate or cooler environments, and the consumption of fluids during these events decreased as VPE level increased. This suggests that as runners gain training and racing experience, they place less importance on fluid consumption during these events. It is speculated that this behavior is likely the result of experiences during training runs of similar distances, rather than increased knowledge of fluid needs. This conclusion is supported by previous research (Winger et al., 2010) reporting that, due to a lack of knowledge regarding basic exercise physiology and appropriate hydration behaviors, recreational runners develop their fluid intake strategies based upon trial-and-error. In addition, Winger et al. (2010) reported that gastrointestinal distress was the primary reason runners reported avoiding over hydrating while running. This may help explain why fluid consumption during these events decreased as VPE level increased. As

running ability increases, runners' complete short duration runs at higher intensities. Therefore, to eliminate discomfort associated with fluid jostling in the stomach during high intensity running, runners may avoid consuming fluids.

In contrast, 66% of runners, across all VPE categories, in this sample report consuming fluids during 10k races in the heat. During these events, runners are unlikely to experience levels of dehydration and elevations in core temperature that put them at risk of heat illness. Dugas et al. (2009) evaluated the effects of various levels of fluid replacement on physiological responses and performance among six well-trained cyclists performing 80 km time-trials in hot and humid conditions. When fluid intake was restricted below ad libitum levels, cyclists maintained core temperatures below critical levels by decreasing power output. This decrease in power output was evident within the first 10 km of the time-trial, persisted throughout the duration of the event, and resulted in decreased performance time. Dugas et al. (2009) concluded that this decrease in power output was the result of cyclists subconsciously deciding to decrease pace in anticipation of the amount of fluid they would receive during the time-trial in order to prevent critical elevations in core temperature. Similarly, during 10k races in the heat, recreational runners may anticipate experiencing decreases in performance or symptoms of heat illness without the consumption of fluids; thus, they have a drive to consume fluids in order to maintain pace. These expectations of performance decrements or heat illness may stem from previously experiencing negative performance or health effects during training and racing.

Fluid intake is important during half and full-marathon races due to the longer duration of these events, especially for those competing at higher intensities or those who have higher sweat rates due to larger body size or lack of heat acclimation. In an attempt to mitigate body weight losses and the occurrence of heat injuries, the majority of races that are half-marathon distance or longer are scheduled during cooler months of the year and have multiple fluid stations along race courses. However, depending on the month of the year and geographic region in which these races occur, there can be a large increase in environmental temperature from the beginning to the end of a race. The majority of runners in this study reported consuming fluids during half and full-marathon races, regardless of the environmental temperature. Furthermore, during races of half-marathon distance or longer, 27% of runners reported only drinking when thirsty (i.e. ad libitum), 51% of runners reported utilizing a planned drinking schedule, and 12% of runners reported drinking as much as possible. Our finding that a majority of recreational runners utilize planned drinking schedules and only slightly more than one-quarter of runners drink only when thirsty while racing contradicts previous findings that most recreational runners consume fluids only when thirsty, and only one-third of recreational runners utilize planned drinking strategies (Winger et al., 2010). In a recent review, Kenefick (2018) noted the efficacy of planned drinking strategies varies depending on the duration of exercise, environmental temperature, and sweat rate. Kenefick (2018) reported that ad libitum fluid consumption is sufficient to prevent body mass losses of > 2% and increased risk of heat illness when exercise duration is less than 90 minutes, when performing exercise in cooler environments, or when exercise intensity is low. In



contrast, planned drinking schedules are beneficial when exercise duration exceeds 90 minutes (particularly in hot environments), during higher intensity exercise with high sweat rates, and when performance outcome is a concern.

In addition, Chevront et al. (2007) examined data from 14 marathon studies, including runners with a wide range of abilities (completion times ranging from 2 hours 10 minutes to 4 hours), conducted in a wide range of environmental temperatures (10–28° C), and concluded that ad libitum fluid consumption commonly resulted in levels of dehydration exceeding 2% body weight loss. These studies demonstrate that recreational runners competing in half and full-marathon races will receive the greatest performance and safety benefits by utilizing planned drinking schedules. It is recommended that planned drinking strategies be developed by calculating sweat rate from changes in pre to post-exercise body weight (Casa et al., 2000; Chevront et al., 2007; Kenefick, 2018; Maughan & Shirreffs, 2008; McDermott et al., 2017; Sawka et al., 2007). Although the majority of runners in this study reported utilizing a drinking schedule during half and full-marathons, it is unclear what these drinking schedules are based upon as only 22% of runners in this sample reported weighing immediately before and after exercise to determine sweat rate. This suggests that further education is needed in the running community on appropriate methods for developing planned drinking schedules.

It is also important to note that a large percentage of runners (12%) in this study reported drinking as much as possible during half and full-marathons. This finding is similar to that of previous research (Winger et al., 2010) reporting that among 197 recreational runners, 8.9% of runners reported drinking as much as possible during racing

and training. This practice is contraindicated because it can lead to exercise-associated hyponatremia, a condition that can result in seizures, respiratory arrest, or death. It is estimated that 1% - 13% of runners finish marathon races with evidence of exercise-associated hyponatremia (Almond et al., 2005; Kipps, Sharma, & Pedoe, 2011; Mettler et al., 2008) and the worldwide incidence of this condition continues to rise (Hew-Butler et al., 2008). It is important for future research to evaluate why runners who drink as much as possible do so, and to develop and evaluate the effectiveness of educational interventions to decrease the incidence of exercise-associated hyponatremia.

To our knowledge, no study has evaluated the point at which recreation runners begin to drink during races of half-marathon distance or longer. Current data indicate that, during such races, 27%, 3%, and 22% of runners begin drinking at the beginning of the race, at mid-race, and late in the race, respectively. Previous studies evaluating the fluid intake of recreational runners during 1 hour of self-paced outdoor running in hot (O'Neal et al., 2012) and temperate (O'Neal et al., 2013) environments have reported that, in both environments, runners approached or surpassed body weight losses of 2% in spite of fluids being readily available during the run. During competitive races of half-marathon distance or longer recreational runners are more likely to experience body mass losses exceeding 2% due to the longer duration of these events. Thus, runners competing at these distances should be encouraged to begin drinking early in the race in order to prevent significant levels of dehydration that can result in performance decrements and increased risk of heat illness.

Recreational runners in this study reported completing an average of five or more training sessions per week, with three or more of these sessions lasting longer than one hour. The majority of runners in this study (52%) also reported training in the heat 5 - 8 months of the year. These statistics illustrate that recreational runners spend a significant amount of time training in hot environments. During runs in the heat, fluid needs are greater because sweat rates are higher, especially for those who are larger, those who are acclimated to the heat, and those training for longer durations or at higher intensities. Unlike during competitive races where runners are supervised, and fluids are readily available, the majority of recreational runners serve as their own supervision during training and are responsible for providing their own fluids. As a result, opportunities for fluid consumption during training may be limited. Among the recreational runners surveyed by O'Neal et al. (2011), 11% reported participating in supervised training, and only 42% reported always-consuming fluids during runs in the heat. Similarly, only 27% of runners in the current sample reported participating in supervised training; however, 71% of the runners in this study reported regularly consuming fluids during runs in the heat. Runners reported carrying bottles or other hydration systems, and placing fluids along the training route or scheduling delivery of fluids as the most common barriers to consuming fluids during training. Less than one-fourth of runners reported gastrointestinal distress as a barrier to consuming fluids during training. Although the majority of runners in the current sample reported consuming fluids during runs in the heat, the volume of fluid that these runners consumed during these runs is unclear.

However, previous research has evaluated fluid intake behaviors among recreational runners while exercising in the heat.

O'Neal et al. (2012) documented the volume of fluid consumed by 20 female and 19 male recreational runners while completing 1 hour of self-paced running in the heat with access to chilled water. During the run, male runners lost  $1,797 \pm 449$  ml of sweat ( $2.3\% \pm 0.6\%$  body weight loss), but consumed only  $272 \pm 196$  ml of water, and female runners lost  $1,155 \pm 258$  ml of sweat ( $1.9\% \pm 0.4\%$  body weight loss), but consumed only  $177 \pm 161$  ml of water. This study demonstrates that fluid consumption among recreational runners is minimal during exercise in the heat, even when fluids are readily available and, as a result, recreational runners are likely to experience reductions in body weight of 2% or more. Thus, even though the majority of runners in this study reported consuming fluids during runs, many likely consume a minimal volume of fluid. This places greater emphasis on fluid replacement between exercise bouts.

In order to determine fluids needs following exercise, recreational runners must measure changes in pre and post-exercise body weight, with consideration for voids and fluids consumed during exercise. However, only 22% of runners in this study reported weighing immediately before and after exercise to determine fluid needs. It is likely that recreational runners who do not employ this practice, simply estimate their fluid needs. This is a poor strategy because previous research has shown that runners greatly underestimate their sweat losses (O'Neal et al., 2012, O'Neal et al., 2013; Passe, Horn, Stofan, Horswill, & Murray, 2007). For runners who experience large sweat losses on consecutive days, this practice can eventually lead to a significant body water deficit.

Another key aspect of hydration is pre-exercise hydration status. Pre-exercise hydration status is particularly important in situations, such as during training, where fluids may not be readily available. In this study, 68% of runners reported monitoring their hydration status. This is a larger percentage than that reported by O'Neal et al. (2011), who found that only 20% of recreational runners monitored their hydration status. However, similar to runners surveyed by O'Neal et al. (2011), the majority of runners in this study report using urine color to monitor hydration status. When questioned about the time at which color judgements were made, 70% of runners reported making a color judgement before exercise and 77% of runners reported making a color judgement following exercise. Furthermore, the majority of runners reported making color judgements based on the color of urine in the toilet, 20 runners reported looking at the color of their urine stream, and only one runner reported collecting urine in a clear container before making a color judgment. The assessment of urine color is an effective technique for monitoring hydration status in athletic settings where a high degree of accuracy is not required (Armstrong, 2005). Although the results of this study indicate that recreational runners are aware of the utility of urine color in assessing hydration status, it appears that many recreational runners are unaware of the appropriate time and manner in which urine color should be assessed.

The use of urine specific gravity to monitor hydration status was only reported by one runner. Although the measurement of urine specific gravity requires a handheld or digital refractometer, this technique is quick, easy, portable, and provides greater accuracy than urine color (Armstrong, 2005). Yet, it appears that recreational runners are

either unaware of this technique, intimidated due to the need to use a refractometer, or are discouraged about using this technique due to the cost of a refractometer. A shortcoming of this study is the failure to inquire about the use of day-to-day changes in body mass to assess hydration status; however, previous research reported that only 7 of 39 recreational runners reported using this technique to monitor hydration status (O'Neal et al., 2012). Measurement of changes in body mass is the quickest, easiest, and most reliable method for assessing changes in hydration status (Armstrong, 2007). Our findings emphasize that recreational runners need further education on how to appropriately use urine color to monitor hydration status, and that techniques such as urine specific gravity and day-to-day changes in body mass should be advocated in the running community.

In conclusion, the findings of this study indicate that low ability runners place greater emphasis on fluid consumption during 5k races, regardless of environmental conditions, and during 10k races in temperate or cooler environments; however, as ability level increases, less emphasis is placed on fluid consumption during these races, possibly in an attempt to prevent gastrointestinal distress during high-intensity running. During 10k races in the heat, most runners consume fluids, likely due to previously experiencing negative effects resulting from dehydration. During races of half-marathon distance or longer, the majority of recreational runners consume fluids and report using planned drinking strategies; yet, these planned drinking strategies do not appear to be based upon sweat rate. The majority of recreational runners consume fluids during training runs in the heat; however, the amount of fluid consumed is likely minimal due to a lack of supervision, the inconvenience of carrying fluids while running, and the inconvenience of

scheduling fluid delivery or placement of fluids along the route before the run. In addition, most recreational runners monitor their hydration status, but this practice is most prominent among runners with the highest ability level. Furthermore, urine color is the most common method used by recreational runners to assess hydration status; however, the time and manner in which this assessment is performed may lead to inaccurate conclusions regarding hydration status. Finally, the incidence of performance decrements and heat illness among recreational runners is high, regardless of ability level. The most common causes of dehydration resulting in negative performance and health effects are thought to be inadequate fluid consumption and inadequate strategies to compensate for actual fluid losses.

Overall, these conclusions suggest that further education is needed in the running community regarding the development of planned drinking schedules, the use of hydration status monitoring techniques, and the use of acute changes in body mass to determine sweat rate and fluid needs. Limitations to this study included a small sample size and biases associated with self-reporting. Furthermore, practitioners should be cautious when extrapolating findings from this study to more elite level runners such as collegiate and professional distance runners.

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APPENDICES FOR STUDY II

## APPENDIX A

## IRB Approval Letter

**IRB****INSTITUTIONAL REVIEW BOARD**

Office of Research Compliance,  
010A Sam Ingram Building,  
2269 Middle Tennessee Blvd  
Murfreesboro, TN 37129

**IRBN001 - EXPEDITED PROTOCOL APPROVAL NOTICE**

Tuesday, July 05, 2016

Investigator(s): Brett Davis (PI), Jenn Caputo (FA), John Coons, Richard Farley and Dana Fuller  
 Investigator(s)' Email(s): *bad4e@mtmail.mtsu.edu; jenn.caputo@mtsu.edu*  
 Department: Health and Human Performance

Study Title: *Assessment of hydration knowledge and hydration strategies employed by distance runners at varying levels of competition*  
 Protocol ID: **16-2301**

Dear Investigator(s),

The above identified research proposal has been reviewed by the MTSU Institutional Review Board (IRB) through the **EXPEDITED** mechanism under 45 CFR 46.110 and 21 CFR 56.110 within the category (7) *Research on individual or group characteristics or behavior*. A summary of the IRB action and other particulars in regard to this protocol application is tabulated as shown below:

IRB Action	APPROVED for one year from the date of this notification
Date of expiration	<b>7/5/2016</b>
Sample Size	500 (FIVE HUNDRED)
Participant Pool	<b>Adult (18 years or older) who self-identify as recreational runners</b>
Exceptions	Collection of online consent is permitted
Restrictions	<b>Mandatory informed consent</b>

Comments	Quiz for the CITI's "Internet-Based Research" module for faculty co-investigators is waived for this study only.	
Amendments	<b>Date</b>	<b>Post-approval Amendments</b> NONE

This protocol can be continued for up to THREE years (**7/5/2019**) by obtaining a continuation approval prior to **7/5/2017**. Refer to the following schedule to plan your annual project reports and be aware that you may not receive a separate reminder to complete your continuing reviews. Failure in obtaining an approval for continuation will automatically result in cancellation of this protocol. Moreover, the completion of this study MUST be notified to the Office of Compliance by filing a final report in order to close-out the protocol.

Continuing Review Schedule:

Reporting Period	Requisition Deadline	IRB Comments
First year report	6/5/2017	INCOMPLETE
Second year report	6/5/2018	INCOMPLETE

IRBN001      Version 1.3  
Office of Compliance

Revision Date 03.06.2016 Institutional Review Board  
Middle Tennessee State University

Final report	6/5/2019	INCOMPLETE
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The investigator(s) indicated in this notification should read and abide by all of the post-approval conditions imposed with this approval. [Refer to the post-approval guidelines posted in the MTSU IRB's website.](#) Any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918 within 48 hours of the incident. Amendments to this protocol must be approved by the IRB. Inclusion of new researchers must also be approved by the Office of Compliance before they begin to work on the project.

All of the research-related records, which include signed consent forms, investigator information and other documents related to the study, must be retained by the PI or the faculty advisor (if the PI is a student) at the secure location mentioned in the protocol application. The data storage must be maintained for at least three (3) years after study completion. Subsequently, the researcher may destroy the data in a manner that maintains confidentiality and anonymity. IRB reserves the right to modify, change or cancel the terms of this letter without prior notice. Be advised that IRB also reserves the right to inspect or audit your records if needed.

Sincerely,

Institutional Review Board  
Middle Tennessee State University

## APPENDIX B

## Hydration Practices Questionnaire

Demographics

1. What is your age?
2. What is your sex?
  - c. Male
  - d. Female
3. How many endurance training sessions do you complete during an average training week?
  - a. 1-2
  - b. 3-5
  - c. 6-7
  - d. > 7
4. How many endurance training sessions lasting longer than 1 hour do you complete in an average training week?
5. How many miles do you run during an average training week?
6. Do you frequently train and compete in warm or hot environments (> 85° F or > 30° C)?
  - a. Yes
  - b. No
7. How often do you complete two-a-day training bouts or training bouts separated by less than 12 hours (e.g. an evening run followed by a run the next morning)?
  - a. Never
  - b. 1-2 times per week
  - c. 3- 4 times per week
  - d. > 5 times per week
8. How many competitions of half-marathon distance or longer have you completed in the last 24 months?
9. What is your predicted finishing time for a half-marathon?
  - a. < 1.5 hour
  - b. 1.5 – 1.75 hours
  - c. 1.75 - 2.0 hours
  - d. 2.0 – 2.25 hours
  - e. 2.25 – 2.5 hours
  - f. > 2.5 hours



10. Do you regularly train under the supervision of a coach, athletic trainer, strength conditioning specialist, doctor, or any other healthcare professional?
  - a. Yes (If yes, please list what specialists you work with)
  - b. No

#### Hydration Behaviors

Please select the best answer for each of the following questions based on your hydration practices.

1. Do you regularly consume fluids during runs in warm or hot environments (> 85° F or > 30° C)?
  - a. Yes
  - b. No (Proceed to question 3)
2. How hot does it have to be before you make a plan to consume fluid during a training run?
  - a. > 60° F
  - b. > 70° F
  - c. > 80° F
  - d. > 90° F
  - e. Other (Please describe)
3. How long does a training run have to be before you make plans to consume fluid during the run?
  - a. Longer than 30 min
  - b. Longer than 45 min
  - c. Longer than 60 min
  - d. Longer than 75 min
  - e. Longer than 90 min
4. Please indicate which item(s) in the following list is/are barrier(s) to you consuming a beverage while training:
  - a. Indigestion or stomach discomfort
  - b. Carrying bottles or other hydration systems is uncomfortable
  - c. Inconvenience of placing fluids along route prior to training runs and/or inconvenience of scheduling fluid delivery during training runs
  - d. Other (Please describe)
  - e. None of these items
5. Do you increase the volume of fluid you consume after training in warm or hot environments (>85° F or > 30° C)?
  - a. Yes
  - b. No

6. In cool or cold weather (< 60° F or < 15.5° C), do you drink during any of the following competitive race distances? (Please mark all that apply)
  - a. 5 km
  - b. 10 km
  - c. Half-marathon
  - d. Marathon or longer
  - e. None of the above
  
7. In hot weather (>85° F or > 30° C), do you drink during any of the following competitive race distances? (Please mark all that apply)
  - a. 5 km
  - b. 10 km
  - c. Half-marathon
  - d. Marathon or longer
  - e. None of the above (Please proceed to question 10)
  
8. If you consume fluids during half marathon or longer races, please indicate the point at which you begin to consume fluids:
  - a. I begin drinking early in the race
  - b. I begin drinking mid race
  - c. I begin drinking later in the race
  - d. I do not run half- or full-marathon (Proceed to question 10)
  
9. If you consume fluids during half marathon or longer races, do you...
  - a. only drink when you are thirsty
  - b. utilize a drinking schedule (e.g. drink every 5 minutes) please describe
  - c. Try to drink as much as possible
  - d. Other
  
10. Do you consider the water content of food consumed during recovery when developing hydration strategies?
  - a. Yes
  - b. No
  
11. Do you consider the sodium content of foods or beverages consumed during recovery when developing hydration strategies?
  - a. Yes
  - b. No
  
12. Have you experienced a decrease in running performance which you believe was the result of being dehydrated?
  - a. Yes
  - b. No (Proceed to question 14)

13. If yes, what do you believe caused you to reach a level of dehydration which resulted in decreased performance?
- Inadequate fluid intake before or during exercise
  - Lack of fluid availability
  - Inadequate pre-run hydration strategy to compensate for actual fluid deficit
  - Unexpected change in the weather
14. Have you experienced symptoms of heat illness during or after training (severe muscle or stomach cramps, lightheadedness, dizziness, nausea, confusion) which you believe to be the result of dehydration?
- Yes
  - No
15. Have you experienced symptoms of heat illness during or after competition (severe muscle or stomach cramps, lightheadedness, dizziness, nausea, confusion) which you believe to be the result of dehydration?
- Yes
  - No
16. Do you monitor your hydration status?
- Yes
  - No (Proceed to question # X)
17. If you answered “yes” to the previous question, what method(s) do you use to monitor your hydration status? (Please mark all that apply)
- Urine color
  - Urine specific gravity
  - Frequency or volume of urination
  - Dehydration-induced symptoms (eg, lack of sweating, cramps, dry skin, chapped lips)
  - Change in body weight
  - Bioelectrical impedance (i.e. hydration estimation scale such as a Tanita®)
  - Other
18. If you indicated that you use urine color to monitor your hydration status, when do you look at urine color? (Please mark all that apply)
- Before running
  - After running
  - Other (Please indicate)

19. If you indicated that you use urine color to monitor your hydration status, In which way do your runners evaluate their urine color?
- a. By looking at urine stream
  - b. By looking at urine color in the toilet
  - c. By collecting urine in a clear container before making a color judgement
  - d. Other (Please describe)
  - e. Not applicable
20. Do you weigh immediately before and after exercise to calculate sweat losses and determine your fluid needs?
- a. Yes
  - b. No

## CHAPTER V

### OVERALL CONCLUSIONS

This dissertation centered on identifying an effective method to disseminate accurate hydration information among recreational runners to increase knowledge and implementation of evidence-based hydration practices. The first study in this dissertation was designed to assess hydration knowledge and sources of information among recreational runners of varying ability. In the second study, the hydration practices of this same populations were assessed.

Hydration knowledge was assessed via a survey instrument designed to reflect hydration information provided in position stands published by the ACSM and the NATA. In addition, the importance runners placed on sources of hydration information was assessed. Among the entire sample of recreational runners, the level of hydration knowledge was inadequate, with higher ability (high VPE) runners having the lowest level of knowledge. Advice of other runners and advice from healthcare providers was rated as having the highest level of importance in the participants for this study. In contrast, recreational runners placed little importance on guidelines published by the ACSM or the NATA and information conveyed in commercial and magazine advertisements. These findings suggest that runners place greater importance on information conveyed in conversational format, and that the current methods used by sport science organizations to disseminate hydration information are insufficient in

reaching the recreational running community. In light of the large number of US adults participating in the sport of endurance running, and the high incidence of performance decrements and heat illness among recreational runners, this study provides valuable information that can be used to improve hydration knowledge among recreational runners. Further, it can help decrease the occurrence of performance decrements and adverse health effects resulting from dehydration and overhydrating.

Increasing personal interaction between healthcare providers and the recreational running community can assist in the dissemination of accurate hydration information and encourage the adoption of evidence-based hydration practices. Conducting workshops for running clubs and setting up information booths at organized races are potential platforms for healthcare professionals to disseminate hydration information to recreational runners in a conversational format. In addition, sport science organizations might effectively reach a larger audience by utilizing popular running websites and magazines and platforms to disseminate scientifically-based hydration information to recreational runners.

Data from the second study illustrated the high incidence of dehydration-induced performance decrements and heat illness among this sample of recreational runners, their fluid intake behaviors during training and common competitive race distances, and their implementation of hydration status monitoring techniques. Over 75% of the runners in the study reported experiencing performance decrements as a result of dehydration, and nearly 60% of the runners reported experiencing symptoms of heat illness as result of dehydration. The recreational runners in this sample reported minimal consumption of

fluids during 5k races, regardless of environmental temperature, and during 10k races in cool environments. In contrast, the runners reported consuming fluids during 10k races in the heat, and during races of half-marathon distances or longer, regardless of the environmental temperature. In addition, the majority of the runners reported utilizing planned drinking strategies during races of half-marathon distance or longer; however, these strategies were not based upon calculations of sweat rate. Similarly, the majority of runners reported consuming fluids during training runs; however, due to a lack of supervision and the inconvenience of carrying fluids or ensuring access to fluids prior to training, opportunities for fluid replacement during training were likely limited. This places greater emphasis on assessing fluid needs following exercise; yet, less than 25% of runners report weighing immediately before and after exercise to determine fluid needs.

The majority of the sample reported monitoring hydration status by urine color, and this practice was most common among the runners with the highest ability level. However, current data do not allow determination of whether the timing or manner in which urine color was evaluated resulted in accurate assessments of hydration status. The poor fluid intake behaviors during and after exercise, as well as the poor implementation of hydration status monitoring techniques, help explain the high incidence of dehydration-induced performance decrements and heat-illness among these runners. It is important to educate recreational runners on the utility of body weight changes for developing fluid replacement strategies during and between exercise bouts. Recreational runners should be encouraged to regularly weigh immediately before and after exercise to determine fluid needs and calculate sweat rate. During exercise,

recreational runners should utilize drinking schedules, based on sweat rate, that prevent body water losses exceeding 2% of body weight, predominantly when exercising for longer than 90 minutes (particularly in the heat), during high intensity exercise with high sweat rates, or when performance is a concern.

In scenarios such as training when fluid intake opportunities are limited, runners should consume a volume of fluid equivalent to 125% - 150% of calculated sweat losses between exercise bouts, especially when recovery is short or substantial body water losses are incurred. Regular monitoring of hydration status should be encouraged as well. Urine color is an appropriate method to assess hydration status; however, color judgments should be made with a urine color chart and urine collected in a clear container. In addition, to most effectively monitor hydration status, assessment techniques such as urine color should be used in conjunction with other monitoring techniques such as urine specific gravity and day-to-day fluctuations in body weight. Education on and implementation of these simple hydration practices can help decrease the incidence of negative performance and health effects associated with inadequate or excessive fluid replacement.

In conclusion, results from these studies indicate that in order to educate recreational runners about the relationship among hydration, running performance, and safety it is vital that professional organizations utilize sources which recreational runners view as important to disseminate best-practices within the recreational running community. Increasing personal interaction between health professionals who have adequate knowledge regarding the fluid needs and appropriate hydration practices for



distance runners and the running community, through platforms such as workshops and information booths, is also critical in educating recreational runners. Educating recreational runners about the potential performance and safety benefits of proper hydration may encourage the adoption of evidence-based hydration behaviors and practices within the running community. Future research should evaluate the effectiveness of educational interventions at improving hydration knowledge, behaviors, and practices among recreational runners.

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